Bovine Medicine

Diseases and Husbandry of Cattle

Second edition

Edited by

A.H. Andrews

with

R.W. Blowey

H. Boyd

R.G. Eddy

Blackwell

Science

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Preface

It is now about ten years since the first edition of *Bovine* vertent omissions will be rectified in any future reprint

Medicine was published. While it was originally antici-or edition of this work.

pated that it would be used mainly in Britain and

I hope that everyone reading the new edition will find

Europe, it is pleasing to note that a good proportion of

it to be an interesting source of information.

the sales have been in other parts of the world. In

recognition of this, more emphasis has been placed on

Readers' note

conditions and their treatment in areas other than

temperate regions. Additionally, a new section gives an

Inevitably, when it comes to therapies, medicines and

insight to the differences in bovine medicine as prac-

vaccines, each country has different needs and require-

tised in various parts of the world.

ments. The laws concerning the use of particular thera-

Almost all parts of the book have been updated or

peutic and preventative agents may vary and the reader completely rewritten. There are some new chapters, is reminded that it is his or her duty to ensure that any including one which integrates the various problems preparation prescribed conforms with all relevant which occur in cattle, another on basic surgical tech- national legislation where the preparation is to be used. niques and others on artificial insemination and embryo It is also essential to ensure that dosages and routes transfer. An effort has been made to encompass all the of administration are determined according to any main subjects which occur in the husbandry and dis- national or local directions and other product informa- eases of cattle.

tion which has been provided with the medicine. While I wish to thank all the authors and co-editors for their every effort has been made to ensure that the uses sug- hard work. Roger Blowey, Hugh Boyd and Roger Eddy gested and doses recommended are correct they should have provided advice and assistance despite their many always be checked with currently available information. commitments. I would also like to thank John Sproat

It must also be remembered that any meat withdrawal

for supplying the photographs of cattle used on the end

time or milk witholding time for drugs should follow the

papers.

guidelines of the country in which a drug is used.

Every effort has been made to identify copyright

holders of material reproduced in this book. Any inad-

A.H. Andrews

Preface to the First Edition

Bovine Medicine aims to provide, within the covers of would be pleased to receive comments from readers on

one book, much of the practical information available

any deficiencies or difficulties encountered in presenta-

on cattle disease and production. Such an objective is

tion or content.

admirable in sentiment but very difficult to achieve in

It has taken approximately 2 years to complete a

practice. It involves the concentration of effort by a

work of this magnitude. The continual expansion in

large number of different, and often very busy, experts

veterinary knowledge and expertise may well mean that
into one volume. For the present part it is hoped that
in certain areas some recent developments have been
what we have produced will not only be a source of
omitted. Again, we would be pleased for any such defi-
information but, in many areas, it will be an enjoyable,
ciencies to be pointed out to us.
educational read. It is hoped that it will be used as a
There has been considerable recent interest in alter-
working guide rather than a reference book and that it
native medicine for animals. Mindful of this, a section
will be of particular help to those at the 'sharp end' of
is included on the subject to help readers make up their
the veterinary profession, i.e. in practice. Bearing this
own minds on its relevance to cattle therapy.
in mind, this work does not contain every detail con-
I must thank Blackwell Science, and particularly
cerning each disease, organism or clinical entity.
Peter Saugman for his patience during the production
Inevitably there are some areas of subject overlap
of this book. Much work has also fallen on my coedi-

as might be expected with skin conditions and ecto-

tors Hugh Boyd, Roger Blowey and Roger Eddy.

parasites and 'downer cow', etc. Where possible each

However, the book would not have been completed but

author has provided his or her own perspective on the

for the dedicated secretarial and managerial help of

subject.

Mrs Rosemary Forster.

In addition, references have been kept to a minimum

to ensure a less disjointed read. In consequence, we

A.H. Andrews

Part 1

MANAGEMENT

Chapter 1

Calf Rearing

D.M. Allen

Introduction

calves with signs of lice should be treated with an

Calf reception

3

approved ectoparasite product. A multivitamin injec-

Rearing systems

3

tion containing vitamins A, D and E is good value for

Early weaning: bucket feeding

4

money.

Early weaning: machine feeding

5

The calves should be housed in pens bedded liberally

Follow-on rearing

5

with dry straw and clean, fresh water should be made

Performance targets

5

available. Milk is best withheld for a few hours after

Veal production

5

Calf identification

6

arrival but any calves that appear stressed may be given

a warm drink of 1 litre of a proprietary electrolyte

solution.

If calves are housed individually, which is permissible

Introduction

up to eight weeks of age, pens should be at least 1.8 ¥

1.0 metres and should permit visual and physical

Whether calves from the dairy herd are being reared as

contact with at least one other calf. Group-housed

dairy herd replacements or for beef production, a good

calves up to 150 kg liveweight need a minimum space

start in life is essential. Calves of subnormal weight at

allowance of 1.5 m2, rising to 2.0 m2 at 150–200 kg. Pen

three months of age tend to lag behind throughout the

floors should have a slope from back to front of at least

growing period.

1 in 20 to permit good drainage.

The starting point for good calf rearing is the con-

Calves do not mind cold weather but need good ven-

sumption of at least 2 litres of colostrum by suckling or

tilation without drafts. The modern trend in temperate bucket feeding within the first six hours of life and a

climates is to erect simple monopitch buildings in which

further 2 litres within 12 hours. The passive immunity

calves can be housed until they are 12 weeks or older.

conferred on the calves by the immune lactoglobulin in

In the coldest weather straw bales or wooden sheets can

colostrum is vital to disease resistance, especially if

be placed above the rear half of pens to provide more

calves are transferred to another farm for rearing, prob-

insulation. Where calves are single-penned, the pens are

ably via a collection centre or auction. Mortality among

dismantled at weaning and the calves left where they

calves deprived of colostrum is high. Therefore, it is

are as a rearing group. If buildings and pens are used

advisable to keep some colostrum in a freezer in case

continuously for calf rearing, after each batch they

of emergencies.

should be power washed or steam cleaned, disinfected

Colostrum is a rich feed and a good source of the fat

and left empty for at least two weeks before restocking.

soluble vitamins A, D and E. Therefore it is sensible to feed all available colostrum even to calves that are

beyond the stage when they can gain passive immunity.

Rearing systems

In high yielding dairy herds, calves are weaned off their

Calf reception

dams as soon as possible after they have received

colostrum and are reared by the early weaning system

Dairy-bred calves for beef rearing are usually pur-

pioneered in the UK but also applicable worldwide.

chased at about two weeks of age, often from a calf

Calves can be weaned off milk replacer after five to

group or dealer. When they arrive at the farm, calves

seven weeks, which makes the system convenient and

should be inspected individually and any showing signs

saves money compared to weaning at an older age. The

of ill health returned to the supplier or isolated. Navels

secret of success is to ensure that individual calves are

should be dipped in a concentrated iodine or phenol

eating at least 1 kg per day of a palatable early weaning

solution to guard against navel ill and joint ill. Any

concentrate before they are weaned.

The commonest rearing system is a twice daily bucket
calves are moved at this time. Frequent observation is
feed of milk replacer, but some rearers use computer-
needed to identify the early symptoms of pneumonia –
controlled machines that mix milk replacer and provide
listlessness, holding back at feeding time, a runny nose,
it to the calves via teats from which they suckle.
rapid breathing or coughing. Veterinary advice should
In the EU, where milk production is subject to milk
be sought straight away. Not only is pneumonia a major
quotas, milk produced over the quota has no market
cause of calf mortality but also infected calves that
value so it is sensible to feed it to calves rather than pur-
recover often fail to thrive due to lung damage.
chase a milk replacer. However, if milk production is at
Dehorning and castration are stressful and so should
or under quota, a milk replacer should be used. Feeding
not be done together, nor should they coincide with the
whole milk needs just the same attention to tempera-

stress of weaning. Healthy calves can be dehorned three

ture and feeding level as milk replacer.

weeks into the rearing period using a hot air or hot iron

The high cost of dried skimmed milk on which milk

disbudder, with castration at four weeks.

replacers used to be based has led to the development

of so-called ‘zero’ milk replacers. These are based on

Early weaning: bucket feeding

dried whey supplemented with fats and lactose to

equate as closely as possible to cow’s milk. Whey-based

The commonest early weaning rearing method is twice

replacers are up to 25 per cent cheaper than skimmed

daily bucket feeding with weaning at five to seven

milk products but can give equally good results.

weeks. With milk replacer mixed at 125 g/l, the first full

For bucket feeding, replacers are mixed at 125–

feed for a purchased calf is 1 litre. Home-bred calves

150 g/l, according to the manufacturer’s recommenda-

are fed this level twice daily until they are about five

tion. The mix is made up with water at 45–50°C so that

days old, then the feeding level per feed is increased by

the temperature at feeding is 42°C. Automatic feeding
0.25 litres every other day up to a maximum of 2 litres
machines mix replacer at 100–125 g/l but can be set
per feed, that is 4 litres per day.
to vary reconstitution rates according to the stage of
Some expert calf rearers have found a useful saving
rearing. It is essential to keep all feeding equipment
in labour, without detriment to calf performance, by
scrupulously clean.
feeding the calves milk replacer once daily after the first
Scouring and pneumonia are the twin scourges of calf
seven to ten days. In this case the feeding level is built
rearing. Typically, calf mortality is 5 per cent, mainly due
up gradually to 3 litres per day. However, the saving in
to these two causes, but it can rise to 10 per cent. The
labour should not compromise calf inspection, which
target in a well-managed calf rearing unit should be to
should continue frequently to detect health problems.
keep mortality below 3 per cent.
From the start calves are fed an early weaning con-
Scouring is most likely in the first two weeks follow-

centrate containing 18 per cent crude protein and with

ing removal from the dam and may be simply because

a good amino acid profile, since the calf needs some of

the calf has been overfed or the milk replacer is at the

its protein intake to escape fermentation and degrada-

wrong temperature. However, it may also be caused by

tion in the forestomachs. The energy value should be at

pathogenic organisms. *E. coli* is the classic cause but a least 12.5 MJ ME/kg DM.

survey of calf units by practising veterinarians identi-

Even the youngest calves crave some roughage in

fied a number of other pathogens responsible for scour-

their diet and, rather than letting them pick up straw

ing. The immediate reaction to scouring is to take the

from the bedding, it is better to feed hay or straw from

calf off milk and feed a warm electrolyte solution. If the

a rack. Hay is rarely of good enough quality for calves

scouring does not start to clear up within 24 hours vet-

and, even if it is, they eat too much of it at the expense

erinary advice should be sought. Antibiotics should

of concentrates and become pot-bellied. Instead, feed only be used on veterinary prescription.

bright, dry barley or oat straw.

If salmonella infection is suspected, veterinary advice

As previously mentioned, calves must be eating at

should be sought straight away and rectal swabs taken

least 1 kg concentrate per day before they can be

for laboratory analysis so that the appropriate anti-

weaned. Weaning may be abrupt after about 35 days, or

biotic can be prescribed. Infected calves should be iso-

a gradual weaning procedure may be used in which the

lated. Many *Salmonella* species are transmissible to

level of milk replacer is reduced gradually over an addi-

humans so during an outbreak special attention needs

tional 5–10 days to encourage concentrate consump-

to be paid to personal hygiene. Salmonellosis usually

tion. Gradual weaning avoids the check to growth that

occurs in the first two or three weeks of life but can

accompanies abrupt weaning.

occur later, even beyond the milk feeding period

The early weaning concentrate should be fed *ad*

(Chapter 15).

libitum until it is replaced by a cheaper follow-on

Pneumonia can occur at any time but is most preva-

concentrate, or until it is rationed as forage feeds are

lent in still, damp winter weather and is exacerbated if

introduced (p. 5).

The consumption of milk powder is 15–20 kg and the

Consumption of milk replacer powder is 25–30 kg

target daily gain to weaning is 0.5–0.6 kg/day, depend-

and the target daily gain to weaning is 0.6–0.7 kg/day,

ing on breed type and sex.

depending on breed type and sex.

Early weaning: machine feeding

Follow-on rearing

Feeding milk *ad libitum* to group-housed calves can be the preferred choice where the buildings used for calf

When calves are weaned at five to seven weeks the early

rearing do not lend themselves to the erection of indi-

weaning concentrate must continue to be fed *ad*

vidual pens or, as in dairy herds, where calves are born

libitum. In the case of calves going into intensive beef over a long period.

systems, concentrate feeding continues to appetite
The saving in labour is not as great as might be
through to 12 weeks, although the finishing diet is intro-
supposed because, although mixing is automatic and
duced gradually from eight to ten weeks.
cleaning is quicker, handling the calves is more time
Where calves are designated for forage-based beef
consuming, especially teaching them to suckle.
systems, forage is introduced by the tenth week and the
The most sophisticated machines are computer con-
early weaning concentrate is replaced by a cheaper mix.
trolled and recognize individual calves fitted with an
When calves reared through the winter are to be grazed
electronic tag. So mixing rates and feeding levels can be
in the next summer, it is important to hold gains at
varied from calf to calf, including a gradual weaning
0.6–0.8 kg/day until turnout in the spring or the ability
procedure. Some machines can feed whole milk as well
of the calves to exhibit extra rapid compensatory
as milk replacer and even dispense a small quantity of
growth on high quality grazed grass will be inhibited.

concentrates to encourage calves to eat dry feed imme-

To achieve this the follow-on concentrate needs to be

diately after suckling. Of course these machines are

rationed at about 21/2 kg/day with forage fed to appetite.

expensive but the cost is spread over up to 80 calves

that can be reared at a time, so the annual depreciation

per calf may be reasonable.

Performance targets

A cheaper approach to *ad libitum* feeding held

sway for a time but is little used now. This was to feed

Performance targets for early weaned bull calves fed

cold acidified milk which stays fresh for two to three

concentrates *ad libitum* to three months are shown in

days stored in a simple plastic bin and is led to a teat

Table 1.1.

through a tube fitted with a non-return valve. The

equipment is cheap but lacks the sophisticated control

of individual calves achieved by computer-controlled

Veal production

feeders.

Calves are trained to suckle about 1 litre of milk

Veal production is a specialized system of calf rearing

replacer and then the milk supply is removed until the

designed to produce a white meat that is especially

next feed. The procedure is repeated twice in the next

popular in Italy and Germany. Traditionally, calves were

24 hours and then calves are allowed to suckle *ad*

housed in narrow crates and fed milk only until slaugh-

libitum, with not more than six calves per teat. Intake ter at 14–16 weeks, producing a carcass of 100–110 kg.

may be depressed in the coldest winter weather and

Subsequently the feeding period was extended to 22

then it is advisable to use an immersion heater to take

weeks or more to produce a carcass of 160+ kg.

the chill off the milk replacer. The feeding equipment

Consumer revulsion at the unnatural production

should be cleaned thoroughly between mixes.

method has brought about considerable changes in the

A trough containing early weaning concentrates

way veal is produced, sanctioned by EU and national

should be placed near the teats, but far enough away to

legislation. For example, veal crates have been banned avoid spoilage by saliva or spilt milk.

in Britain since 1990, although EU legislation does not

Calves fed *ad libitum* consume more milk replacer

ban existing crated housing in continental Europe until

than restricted bucket-fed calves. This manifests itself

2006. Similarly, legislation stipulates a minimum iron

as rather loose faeces that must be differentiated from

content for calf milks and insists that calves over two

scouring. The high replacer intake inhibits early con-

weeks of age have access to digestible solid food. The

centrate consumption and may delay weaning. There-

effect has been to promote the production of veal that

fore, it is important to employ a gradual weaning

is pink in colour rather than white.

programme to allow weaning at five to seven weeks.

A welfare-friendly veal production system has been

Even at these high intakes of milk replacer, it is essen-

demonstrated experimentally in Britain with group-

tial that fresh water should always be available.

housed calves fed milk replacer from a machine and

Table 1.1

Calf rearing targets to three months of age for bull calves fed concentrates *ad libitum.* Source: Meat and Livestock Commission (MLC).

Bucket feeding

Machine feeding

Holstein–Friesian

Charolais ¥ F

Holstein–Friesian

Charolais ¥ F

Hereford ¥ F

Simmental ¥ F

Hereford ¥ F

Simmental ¥ F

Feeds (kg)

Milk powder

15–20

15–20

25–30

25–30

Concentrates

170

185

160

180

Liveweight (kg)

Purchase

50

55

50

55

Weaning

68

76

71

80

3 months

110

120

115

130

Daily gain (kg)

Preweaning

0.5

0.6

0.6

0.7

Post weaning

0.9

1.0

0.9

1.0

F = Holstein–Friesian.

supplemented with barley straw as a source of roughage.

that being able to trace the whereabouts of cattle

Carcasses were acceptable to the veal trade but vari-

throughout their lives is an essential requirement of

ability of performance was an unsolved problem.

food safety for people and disease control in cattle.

In the Netherlands, the main EU veal producer, there

Traceability is subject to EU legislation. The British

are now two approaches to veal production. First there

Cattle Tracing System (CTS) is administered by the

is a white veal system in which group-housed calves are

British Cattle Movement Service (BCMS) that com-

fed largely on milk replacer but with limited access to

menced operations in September 1998. This fully com-

maize silage (which does not affect meat colour). The

puterized system was preceded by a paper passport

calves are slaughtered at about six months of age at

system that started in July 1996. A one-off survey was

around 285 kg liveweight. A pink veal system is also

undertaken of all cattle in 2000, including older cows

employed by some producers in which calves are fed

and bulls which did not have passports, so that all cattle

about 40 kg milk replacer powder plus 500 kg concen-

could be included in the BCMS database.

trates and 500 kg maize silage. The calves are slaugh-

Calves must be double tagged within 36 hours of

tered at about 32 weeks at a weight of around 320 kg.

birth unless they are being sent for immediate slaugh-

ter. An application for a passport must normally be

made within seven days of tagging but calves can be

Calf identification

moved twice during the first 28 days of life, using the reverse of the cattle passport application form as a tem-

A beneficial consequence of the BSE crisis and subse-

porary passport. An all-numeric numbering system has

quent foot-and-mouth disease epidemic is a realization

replaced the former alpha numeric identity.

Chapter 2

Suckler Herds

D.M. Allen

Introduction

7

ment. Can the herd be integrated with a sheep flock?

Planning the suckler herd

7

Are there arable crop residues that can be used to

Choice of bull

7

cheapen cow feeding? Are buildings and feeds available

Choice of cow breed type

8

to add value to calves by feeding them beyond weaning?

Rearing replacement heifers

9

The answers to these and other relevant questions

Suckler herd management

10

provide the framework on which a profitable enterprise

Suckled calf management

11

can be built.

Grassland management

12

Targets of performance

13

Particularly important is the choice of season of

calving. Most herds calve in the spring or at the start of

the rainy season because this minimizes cow feeding

costs. The cow is working hardest suckling her calf on

Introduction

low cost, high quality grazed forage. On productive

grassland autumn calving is an option, the extra cost of

The key indicator of profitability and technical effi-

winter feeding cows suckling calves being offset by

ciency in suckler herds is the calf output produced
greater calf weaning weight. Autumn calving usually
annually from each cow that is bulled. The most prof-
achieves the highest financial gross margin per cow,
itable herds owe their success to producing a large
but spring calving rivals its gross margin per hectare.
number of live calves per 100 cows bulled, with low calf
The need to reduce production costs has forced many
mortality, rapid growth to weaning and a high sale value
former autumn-calving herds to change to spring
per kg for well-reared calves. This is as true under
calving.
dry range conditions as it is on productive temperate
The decision on calving season may be forced by the
grassland.
availability of housing and labour, regardless of feed
Suckler herd management is not the simple matter
availability. Housing allows a choice of calving season
it may seem at first sight, with a cow suckling a single
and avoids poaching of land by outwintered stock.
calf. The linked components are reproductive efficiency,

However, the provision of housing increases fixed costs

milk production and growth. However, in practice the

on the farm.

body condition of cows is a simple and sensitive barom-

eter of their nutritional status and potential perform-

ance. Controlling body condition through the year is

Choice of bull

the key to high herd output at low cost.

Most beef suckler cows are kept on marginal land in

The bull contributes half the genes of all the calves sired

upland or range areas where winter (or dry season)

by him and so choice of breed and individual bull are

feeds are scarce. So it is common for calves to be sold

both critical to herd performance. Even at weaning,

at weaning, or after a period of further feeding, to fin-

when maternal effects are expressed at their maximum,

ishers on better land. However, increasingly in UK

sire breed has a greater effect on weaning weight than

upland herds where suitable buildings are available,

dam type.

male calves are finished as bull beef on purchased

Heavy breeds such as Charolais and Simmental are

concentrates.

generally used as terminal sires, that is to produce the

slaughter generation. They sire calves with the highest

weaning weights (Table 2.1) and the rapid gains are

carried through into the post-weaning period. However,

the cost of this extra growth performance is a higher

Fitting a suckler enterprise into farm resources is as

proportion of assisted calvings and greater neonatal calf

important to profitable production as herd manage-

mortality (Table 2.2). Overall, nevertheless, calves sired

by heavier breeds produce the greatest annual output of

also be affected if herd replacements are home bred.

weaning weight per cow.

Then easy calving breeds with good maternal abilities

It is several years since these survey data were col-

would be preferred (see p. 9).

lected and there may have been subsequent changes in

The selection of an individual bull within a breed is
the relative performance of breeds. Also, breeds such as
just as important as breed choice. In recent years
the double-muscled Belgian Blue are now available to
bull selection has been transformed by the develop-
commercial producers in the UK. This breed is just
ment of a sophisticated statistical method of analys-
below the Charolais in growth performance but has
ing breeding records from pedigree herds, known by
greater dystokia. Belgian Blue crosses have exceptional
its acronym BLUP (best linear unbiased predictor).
carcass characteristics with high killing out and meat
The analysis of records from all related cattle, whatever
yield percentages. Limousin crosses are also outstand-
herd they are in, effectively disentangles management
ing for these characteristics.
and genetic effects on performance to calculate esti-
Most commercial suckler herds in Britain have opted
mated breeding values (EBVs) that can be used with
for continental terminal sire breeds, especially Charo-
confidence to select bulls of above average genetic

lais, Limousin and Simmental. However, some produc-

merit.

ers prefer local breeds or use Angus bulls to gain quality

In Britain the recording agency Signet combines

premiums that offset poorer growth performance. Easy

EBVs for selected performance characters into selec-

care Angus and Herefords are often selected in pastoral

tion indices of overall genetic merit. There are two such

and range countries where large numbers of cattle are

indices. The calving value is used where ease of calving

managed by a single stockworker. Breed choice would

is paramount, for example for heifer matings and in the

selection of bulls to breed female replacements. The

beef index is used for bull selection when growth rate

Table 2.1

Effects of sire breed on calf 200-day weights.

and carcass quality are the objectives, for example for

Source: Meat and Livestock Commission (MLC).

terminal sires in suckler herds. Signet publishes EBVs

and selection indices for participating breeds. A

Sire breed

Type of farm

maternal index is under development.

Lowland

Upland

Hill

Choice of cow breed type

Hereford

208

194

184

200-day weight (kg)

Difference from

In range countries the tradition was to keep purebred

Hereford (+ /- kg)

herds of Angus, Hereford, Shorthorn or local breed

Charolais

+32

+33

+21

cattle. To some extent that tradition still exists. For

Simmental

+24

+28

+14

example, French suckler cows are still largely purebred.

South Devon

+23

+27

+16

However, crossbred cows have a considerable advan-

(North) Devon

+17

+21

+7

tage over purebreds due to hybrid vigour (or heterosis),

Lincoln Red

+14

+20

+5

which is most pronounced for improved reproductive

Sussex

+7

+13

+2

efficiency. The outcome is that the weaning weight of

Limousin

+7

+10

+2

calves from crossbred cows is 15–25 per cent above

Aberdeen Angus

-14

-12

-8

the average of the parent breeds. Add to this an

Table 2.2

Effects of sire breed on calving ease and annual productivity. Source: Meat and Livestock Commission (MLC).

Sire breed

Assisted

Calf mortality

Calving interval

Calf weaning weight

calvings (%)

(%)

(days)

per cow per year (kg)

Charolais

9.0

4.8

374

208

Simmental

8.9

4.2

374

203

South Devon

8.7

4.0

375

203

(North) Devon

6.4

2.6

373

200

Limousin

7.4

3.8

375

199

Lincoln Red

6.7

2.0

373

198

Sussex

4.5

1.5

372

196

Hereford

4.0

1.6

372

189

Aberdeen Angus

2.4

1.3

370

179

improvement in longevity and the lifetime advantage to

score and gestation length) and a high EBV for 200-day

crossbreds is considerable.

milk (an estimate of the genetic merit for milk produc-

Recognition of the benefits of crossbreeding in

tion that the sire passes to his female offspring).

Britain is as old as the development of breeds them-

In some parts of the world, notably the US, sophisti-

selves. Traditional crossbreds include the celebrated

cated breeding programmes have been used to create

Blue Grey (White Shorthorn bull ¥ Galloway cow),

composite breeds combining the best features of three

Shorthorn ¥ Highland and Irish-bred Blue Grey

or four foundation breeds. A composite may be bred to
(Angus ¥ Dairy Shorthorn). As supplies of these tradi-
feature maternal qualities, terminal sire qualities, heat
tional crosses started to become scarce some 30 years
tolerance and so on. A four-breed composite is effec-
ago, beef breed ¥ dairy cows started to be used as
tively a purpose-bred pure breeding population that
suckler cows, notably Hereford ¥ Friesian and Angus ¥
retains up to 75 per cent of the hybrid vigour of the
Friesian. It was later still that US ranchers discovered
initial first (F1) crosses between the original four
the heterosis advantage of Hereford ¥ Angus and the
breeds.
reciprocal cross over either of the pure breeds.
The creation of composite breeds needs very large
The Hereford ¥ Friesian was, and still is, widely used
numbers of cattle. However, commercial suckled calf
as a suckler cow. It produces more milk than the Blue
producers with relatively small herds will have access
Grey and weans a heavier calf; however, the Blue Grey
to composites from international genetics companies

has better reproductive efficiency and, overall, per-
with large-scale breeding operations involving thou-
formance of the two crosses is similar. Both crosses
sands of cattle. The main demand will be for purpose-
share the advantage of medium body size. Heavy cows
bred suckler herd replacements of good maternal
such as Charolais ¥ Friesian need more feed but are
ability.
unable to translate enough of their greater weight into
heavier calf weaning weight to rival the efficiency of a
lighter breed type. Nonetheless, many British suckled

Rearing replacement heifers

calf producers use these heavier cows and are prepared
to trade a theoretical reduction in efficiency (that may
The replacement policy in a suckler herd should involve
not be apparent at farm level) for the improved con-
culling cows that are persistently barren, calve unac-
formation of calves which commands a premium at the
ceptably late or are on the verge of the emaciation com-
calf sales and later in carcass value.
monly associated with old age. A typical replacement

The penetration of the Friesian breed by extreme

rate is 16 per cent which indicates an average herd life

dairy Holstein genes from North America has caused

of seven years.

such a deterioration in beef breed ¥ Friesian cow

In the UK, culling policies have been disrupted in

conformation that it shows through in the calf. This

the wake of the BSE crisis by the Over Thirty Month

has sparked off a search for alternative suckler herd

Scheme (OTMS) in which the carcasses of cattle over

replacements that are crossbred with good maternal

30 months old are removed from human consumption.

qualities and have acceptable conformation. Moreover,

Compensation payments for culls are much lower than

in the wake of the BSE crisis many herd owners wish

cull cow values before the BSE crisis and this will

to breed their own replacements so that they can

continue to inhibit planned culling until the scheme is

maintain a closed cow herd.

eventually wound down.

Merely saving heifer calves from terminal sire breeds

Replacements may be purchased as calves from dairy
such as Charolais increases cow size progressively and
herds, as bulling heifers or, less frequently nowadays, as
reduces maternal performance – the worst of all worlds.
heifers on the point of calving. With calves and bulling
The simplest planned approach to breeding replace-
heifers it is prudent to purchase a surplus of 15–20 per
ments is to breed about half the herd to a sire breed of
cent to allow selection. Heifers that prove unsuitable as
medium size with good maternal qualities, for example
replacements are slaughtered for beef.
Angus or Salers. In smaller herds this is best done by
In most situations heifers should be calved for the
artificial insemination (AI). In the next generation,
first time at two years of age to optimise lifetime per-
Angus cross females, for example, might be mated to
formance. However, autumn-born calves from the dairy
Salers whose female progeny are in turn mated back to
herd would usually be calved at 21/2 years in a spring-
Angus. This two-breed rotation is known as criss-
calving suckler herd. In either case, good management

crossing. The other half of the herd would usually be

is necessary to achieve target mating and post calving

mated to terminal sire breeds.

weights (Table 2.3).

Bulls for breeding herd replacements should be

Heifers are best calved at the start of the herd calving

selected to have a good calving value index (which

period to allow for an almost inevitable slippage in time

incorporates EBVs for calf birth weight, ease of calving

to the second calving. Also, since dystokia is worst in

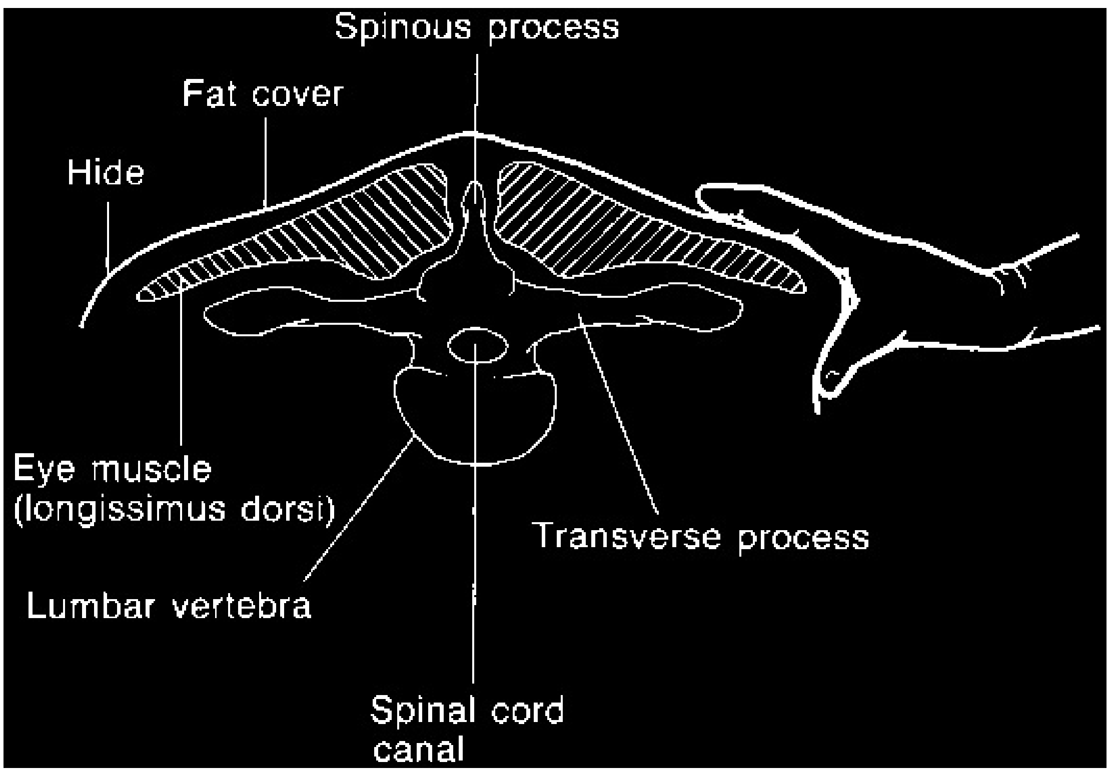


Table 2.3

Rearing targets for replacement heifers.

Mating Post

calving

weight (kg)

weight (kg)

Two-year calving

British breed crosses

325

510

Continental breed crosses

350

550

Calving at 21/2 years

British breed crosses

400

540

Continental breed crosses

435

575

Fig. 2.1

Technique for condition scoring.

heifers, it is desirable to mate them to an easy calving

breed such as Angus or Hereford. Difficult calving is a

cause of delayed rebreeding.

side of the cow. The thumb curls over the ledge formed

by the transverse processes of the spine to feel the over-

lying fat cover. It is best to handle cows until experi-

Suckler herd management

ence of the technique has been gained but, thereafter,

a skilled stockworker can use close visual inspection to

Suckler herd management aims for a high proportion

obtain a working guide to condition.

of cows producing live calves in a calving period of 12

Descriptions of condition score classes are presented

weeks or less. The advantages of a compact calving

in Table 2.4. One possible confusion is with continental

period are, firstly, that herd rationing matches closely

crosses of good conformation. Their thick muscling may

the nutritional needs of individual cows, saving feed

overhang the transverse processes of the spine and

costs. Secondly, calvings can be supervised closely to

confuse handling or visual assessments. If this is the
provide assistance when needed, reducing calf mortal-
case, condition should also be assessed by handling the
ity. Finally, calf performance is uniform with few of the
ribs with the flat of the hand. If the score is above 3 in
late-born calves that are so difficult to utilize profitably.
the autumn, autumn-calving cows are put at the risk of
Generally, a long drawn out calving period is a sure
a difficult calving. If spring calvers score less than 3 in
sign of low herd conception rate. Late calvers have too
the autumn, the permissible winter weight loss is
little time to rebreed by the end of the mating season
reduced and feed costs increase.
and get later and later, eventually failing to get in calf
Feeding spring-calving cows through the winter that
altogether. The only solutions to an over-long calving
are at target condition score 3 in the autumn allows the
period are to cull late calvers or switch them between
loss of one unit of condition score, which equates to
spring- and autumn-calving herds so that they calve on
about 100 kg liveweight or 0.5 kg daily. Autumn calvers,

time. The danger of the latter strategy is that cows
on the other hand, must be fed through the winter for
shuttle from one herd to the other without the under-
the additional strain of lactation and must be at condi-
lying causes of low conception rate being tackled.
tion score 21/2 when mated in mid-winter. Therefore, in
The main reason why cows fail to conceive is that
cows at condition score 3 in the autumn a weight loss
they are too thin. Under UK conditions, body condition
of only 0.25 kg/day is permissible until they are safely in
at mating, scored on a scale from 0 (emaciated) to 5
calf. If there is a time to feed suckler cows generously,
(grossly overfat), needs to be 21/2 in winter but can be
this is it. Thereafter, the rate of weight loss can increase
as low as 2 if cows are grazing high quality forage and
to 0.5 kg/day. Autumn-calved heifers are still growing as
current nutrient intake is high. The key targets that
well as milking and should not be allowed to lose weight
achieve the necessary body condition at mating are a
through the winter.
score of 3 in the autumn and 2 at turnout to grazing in

These guidelines are translated into daily metaboliz-

the spring. The time to carry out condition scoring is in

able energy (ME) allowances expressed as megajoules

mid pregnancy, while there is still time to adjust feeding

(MJ) for cows fed a typical moderate quality ration in

management before calving.

Table 2.5.

The method of condition scoring (Fig. 2.1) is to grip

It is all too easy during the grazing season to con-

the loin between the thumb and forefinger mid-way

centrate on calf performance and forget that cows at

between the hip (hook) bone and the last rib on the left

target condition score 2 in the spring need to gain

Table 2.4

Condition scoring of suckler cows.

Condition score	Description
0	Spine very prominent with no detectable fat cover over the sharp transverse processes of the spine 1

Spine still prominent but transverse processes no longer sharp 2

Transverse processes can still be felt, but now rounded with a thin covering of fat 3

Individual transverse processes can now only be felt with firm pressure by the thumb 4

Transverse processes can hardly be felt, even with firm pressure 5

Transverse processes completely obscured with a thick layer of soft fat and puffy fat deposits around the tail head

Table 2.5

Metabolizable energy (ME) allowances for winter

after itself. Nevertheless, a compact calving means

feeding suckler cows. Reproduced from Allen (2001) with per-

fewer of the late-born calves have subnormal weaning

mission of Chalcombe Publications.

weights. In addition, achieving target body condition

scores in cows is conducive to high milk yield.

Liveweight

Daily weight

Milk yield

ME

In most situations the cow is capable of producing as

(kg)

loss (kg)

(kg)

(MJ/ day)

much milk as the calf can suckle. This can lead to prob-

lems early in the suckling period, especially with spring-

Spring calver

calving beef ¥ dairy cows of high milk potential, when

(a) Precalvinga

500

-0.5

0

55

calves consume too much milk and scour. If the cause

600

62

of scouring is viral or bacterial it is worth considering

700

69

an appropriate scour vaccine.

(b) Post calvinga

Milk consumption increases quickly during the first

500

-0.5

10

89

month of suckling and, although calves pick at solid

600

97

food early in life, milk intake dominates calf perform-

700

105

ance in the first three months. With a cow type of mod-

Autumn calver

erate yield potential, milk still accounts for half the calf

(a) Prematingb

gain in the third month and in higher yielding beef

500

-0.25

10

99

breed ¥ Friesians this balance is not reached until the

600

107

fourth month. Nevertheless, by this time the intake of

700

115

(b) Post matingb

solid food by the calf is increasing rapidly.

500

-0.5

7

74

Milk intake is especially important to the spring-born

600

81

calf that has a relatively short suckling period of six to

700

88

seven months. The nutritional requirements of the calf

and seasonal grass growth are well matched, although

a If no weight loss is permissible add 20 MJ ME per day.

supplementary feeding helps to sustain daily gain from

b If no weight loss is permissible add 10 MJ ME per day.

late summer onwards as grass growth and quality

decline.

100 kg liveweight by the autumn. If by mid-season there

Management of the autumn-born calf is more com-

is any doubt that the whole herd or individual cows may

plicated because the suckling period is longer and peak

not attain the required total gain, action must be taken

milk yield must be supported on winter rations. The

to rectify the situation. The provision of more selective

most cost-effective approach over the winter is to feed

grazing of fresh pasture may suffice. Alternatively, it

the cow well in the early months until she is safely in

may be necessary to take more drastic action with

calf and then to rely increasingly on creep feeding

autumn calvers and wean calves early to remove the

calves concentrates and the highest quality conserved

strain of lactation.

forage available. It is energetically much more efficient

to feed the calf directly than to increase cow feeding to

stimulate milk yield.

Suckled calf management

When autumn-calved cows are turned out to grass in

the spring there is a boost to milk yield, but by late

If cow performance is good, calf performance is usually

summer calves require creep feeding to sustain daily

also good. This is not to say that calf performance looks

gains. It is wise to wean the calves sooner rather than

Table 2.6

Performance targets for lowland and upland suckler herds.

Continental breed sirea

British breed sirea

Autumn

Spring (silage)

Spring (straw)

Autumn

Spring (silage)

Spring (straw)

Calves reared/cow

0.92

0.92

0.92

0.95

0.95

0.95

Calf gain (kg/day)

1.0

1.1

1.1

0.9

1.0

1.0

Weaning (months)

10

7

7

10

7

7

Calf autumn weight (kg)

350

280

280

320

260

260

Cow concentrate (tonnes)

0.25

0.12

0.3

0.25

0.12

0.3

Calf concentrate (tonnes)

0.25

0.08

0.08

0.1

0.05

0.05

Silage (tonnes @ 22% DM)

6.5

5.0

—

6.5

5.0

—

Feeding straw (tonnes)

0.5

1.0

2.5

0.5

1.0

2.5

a Mated to suckler cows of average weight 550–600 kg.

later so that they can be managed separately and the

Grassland management for suckler herds does not

cows left to gain condition before housing. The least

necessarily mean using the levels of nitrogen fertilizer

stressful way of breaking the bond between calf and

employed by dairy farmers, although this may be the

dam at weaning is to house the calves. An alterna-

right policy on some productive lowland farms. In prac-

tive approach is to put the cows and calves in well-

tice, especially on the upland farms where most suckler

fenced adjacent fields within sight and sound of each
cows are kept in the UK, farmers use only moderate
other.
levels of nitrogen fertilizer and rely more on clover to
In most ranching and pastoral countries bull calves
increase sward productivity. Moreover, extensive
are castrated for the convenience of herd management
grassland management is encouraged in the EU by
and a preference for steer beef over bull beef. However,
the payment of extensification premiums for stocking
in France, Italy and Spain it has become the custom to
lightly.
rear male calves entire because they grow faster and
Whatever the type of sward, grazing management
leaner than steers and are more profitable. In the UK,
should aim to control the average sward height of
suckler bull beef is increasing and finds a ready market.
grazed and ungrazed areas. Cows gain most weight early
The most common approach is to wean spring-born
in the grazing season when average sward height is
bulls in late summer and transfer them gradually over

maintained at 8–10 cm. However, they graze selectively
a period of about three weeks to an all-concentrate diet
leaving patches that go to seed and are of poor nutri-
(Chapter 3).
tional quality when they have to be grazed later on. So
For the system to be successful it is a considerable
until mid season it is necessary to graze swards more
advantage to have a compact calving period so that
tightly at an average sward height of 6–8 cm to inhibit
older bull calves do not pester late-calving cows when
seed heading. Thereafter, when the risk of seed heading
they are in oestrus. In any case, cows with bull calves
is less and there is an inevitable build-up of dead
need to be separated from those with heifers by six
herbage in the base of the sward, average sward height
months of age or there is a risk of premature pregnancy
can be relaxed to 8–10 cm to allow selective grazing.
in the heifer calves. For this reason the system works
In the period of peak grass growth in early summer,
best in spring-calving herds because there is no need to
high stocking rates of three autumn calving cows per

split the herd.

hectare or four spring calvers are needed to exert the

necessary control of sward height. At these relatively

high stocking rates it is important to have a reserve

Grassland management

grazing buffer in case of reduced grass growth in dry

weather. This can be achieved by setting aside an addi-

Grazed grass is the cheapest and one of the most nutri-

tional 25 per cent of grassland that is conserved as silage

tious feeds available on the farm. With financial

if possible, but grazed if necessary.

margins under pressure, the key to profitable produc-

As the season progresses beyond mid season the

tion is to utilize grazing to the full. This involves good

grazing area needs to increase and this is achieved by

grazing management and extending the grazing season

grazing aftermaths on fields cut previously for silage or

where practicable.

hay.

Parasitic worms causing gastroenteritis and bronchi-

targets appropriate to lowland and upland herds in the
tis are less of a problem in suckled calves than in young
UK and other European countries with similar climatic
dairy-bred calves in their first grazing season. Never-
conditions (Table 2.6). For the predominant spring-
theless, it is advisable to treat autumn-born calves at
calving herds targets are shown for herds both on grass
weaning. In any case, both autumn- and spring-born
farms, where silage is the basic winter feed, and on
calves should be treated at yarding to guard against
arable farms, where winter diets are based on straw
winter scour (Chapter 19).
and concentrates. Achieving the physical targets is a
With silage making the priority is a feed with high
prerequisite of profitable production.
intake characteristics rather than the highest possible
ME per kg dry matter (DM). Cutting can be delayed
for a week or so to await dry sunny weather that allows

Reference

an effective 24-hour wilt for clamp silage, longer for big
bales, and produces silage with the best fermentation

Allen, D. (2001) *Rationing Beef Cattle*, 2nd edn. Chalcombe quality.

Publications, Lincoln.

Targets of performance

The objectives of suckler herd management outlined in

this chapter have been compiled into suckler herd

Chapter 3

Beef Finishing Systems

D.M. Allen

Introduction

14

ishers in the autumn may be finished through the

Planning and budgeting

14

ensuing winter for sale at 16–18 months old. Heifers

Finishing suckled calves and stores

15

and lighter steer calves are fed a store ration over the

Winter finishing

15

winter in preparation for grazing the following summer.

Grass finishing

17

Any that fail to finish off grass are yarded for a further

Dairy beef systems

18

winter finishing period.

Cereal (barley) beef

19

Still, all too many cattle are managed aimlessly with

Grass and maize silage beef

19

Eighteen-month beef

20

no particular finishing system in mind and are sold

Grass beef

20

finished or in store condition when prices seem

favourable. This approach leads to a good deal of

trading in suckled calves and stores, some of which may

change ownership three or four times in their lifetime.

Introduction

Farm assurance schemes now limit the number of times an animal can be traded within the scheme.

A whole range of overlapping beef finishing systems is

Under range conditions in the USA, the growth rate

applicable to cattle bred in suckler and dairy herds. The

of suckled calves is poorer than on European grass

higher the lifetime daily gain of the beef system, the

farms. However, feed grains are cheap and a special

younger is the slaughter age and the lighter the slaugh-

approach to finishing has been adopted in beef feed

ter weight at a stated carcass fat cover. Also, within a

lots. Weaned calves from range herds are sold to ‘back

given beef system, bulls grow faster and are leaner than

grounding’ farms where they are grown on forage at

steers which, in turn, grow faster and are leaner than

moderate store rates of gain as feeder cattle. They then

heifers.

enter feed lots at 12–18 months of age for rapid finish-

These characteristics of beef systems make it possi-

ing over a five-month period on a ‘hot’ high-grain ration.

ble to chart average relationships between slaughter

In the case of dairy-bred calves, several distinctive age and slaughter weight, illustrated in Fig. 3.1 for

beef systems have been developed. At one extreme

Charolais crosses. It is possible to construct similar

is cereal (barley) beef in which bulls fed an all-

graphs for other breed types and to predict the likely

concentrate diet grow rapidly to slaughter at 11–13

slaughter weight of cattle slaughtered at a particular

months of age. At the other extreme are forage-based

age and vice versa. Note that as long as the Over Thirty

systems in which steers and heifers are either winter fin-

Month Scheme (OTMS) is in place as a BSE control

ished off silage supplemented with concentrates for

measure in the UK, beef from cattle over 30 months old

slaughter at 16–20 months of age or grass finished in

at slaughter is destroyed, although this will change from

summer at 20–24 months old.

2004 onwards.

In reality, cattle passport statistics indicate that more

Cattle remain in an EU fat class for several weeks.

than a third of steers do not follow any of the produc-

The main EU fat class for bull carcasses is 3 on a tion systems described here and are slaughtered at

five-point scale from 1 (ultra lean) to 5 (grossly overfat)

24–30 months of age. The reason is thought to be that

and 4L for steers and heifers, which is the average fat

farmers delay slaughter until after they have obtained

class for all carcasses in Britain.

the second beef subsidy (p. 15), paid from 22 months of

Calves from beef suckler herds on marginal land

age. It demonstrates how subsidy rules manipulate pro-

usually have to be sold in the autumn for finishing on

duction and marketing decisions.

farms with more productive land. However, spring-

born calves may be overwintered for sale in spring, if

buildings and feed are available, and bull calves may

Planning and budgeting

be finished on purchased concentrates as suckler bull

beef.

The fall in market prices for beef cattle in the aftermath

The heaviest yearling steer calves purchased by fin-

of the BSE crisis has focused attention on beef system

700

If production is based on borrowed capital, it is

important to calculate the interest on working capital

650

that must be paid. The conventional method of calcu-

600

lation is the cost of the calf or store plus half the vari-

550

able costs multiplied by the monthly bank interest rate

for the number of months cattle are fed.

500

Sale returns are highly dependent on the quality of

450

cattle produced, especially their conformation. Figure

3.3 illustrates differentials for steer carcasses classified

Slaughter liveweight (kg)

400

by the EU method, in a conformation range from E

350

(excellent), U+, -U, R (average), O+, -O and P (very

12

14

16

18

20

22

24

28

poor). Note the severe discount for poor -O confor-

Slaughter age (months)

mation, especially for carcasses that stray into what is

Fig. 3.1

Average relationships between slaughter age and

regarded by most buyers as overfat class 4H. Hol-

slaughter weight for Charolais cross cattle. (Bulls were slaugh-stein–Friesian carcasses fall into the poorest conforma-

tered at EU fat class 3, steers and heifers at EU fat class 4L.) tion classes -O and P and a high proportion of the beef

粽 = Bulls; 糉 = steers; 簵 = heifers.

is used for manufacturing. Good conformation classes

-U and better contain mainly continental breed crosses.

plans and budgets. Formerly, too many beef farmers

Generally, young bulls sell for the same price per kg

were preoccupied by the margin between buying and

carcass or slightly less than steers in deadweight sales,

selling prices, or even just the sale price achieved

but command a premium at selected live auction

regardless of cost. Now controlling costs, whilst achiev-

markets. Heifers usually sell at a small discount. There

ing performance targets, is very important. Also essen-

is a steady move towards deadweight selling under

tial is maximizing eligibility for EU subsidies, without

pressure from supermarket buying specifications.

which profitable production is difficult.

The EU beef regime that came into effect in January

Finishing suckled calves and stores

2000 is more complex than previous schemes. As

before, bulls may qualify for a single Bull Premium and

At the start of a winter feeding period there are two

steers for one or both Beef Special Premiums (BSP),

options for steers and heifers. Either the cattle are fed

the first of which is paid at 9–20 months of age and the

to gain at least 0.9 kg/day, often higher, for finishing second at over 22 months. There is no upper limit on

that winter. Or they are fed a store ration to gain 0.6–

the number of claims provided the stocking rate does

0.8 kg/day in preparation for grazing the following

not exceed 1.8 Livestock Units (LU) per forage hectare,

summer.

otherwise claims are scaled back. If a national ceiling

It is generally held that the profitability of finishing

of claims is exceeded, payments are also scaled back.

depends mainly on buying and selling skills. It is per-

Cattle must be retained for at least 2 months after the

fectly true that the feeder's margin – the difference

claim is made. All slaughter cattle, including cull cows,

between the purchase and sale price – determines the

qualify for a slaughter premium provided they have

average gross margin. However, finishers with the best

been on the farm for at least two months. Suckler Cow

margins owe much of their success to achieving high

Premiums are paid up to a farm quota and a minimum

standards of cattle performance.

of 5 per cent and maximum of 40 per cent of claims can be made on heifers over 8 months of age. Complex rules

Winter finishing

apply to Extensification Premiums paid on farms prac-

tising extensive production methods. Detailed rules and

Winter finishing has a feeding period of four to eight

rates of payment can be found in official publications.

months, depending on breed, sex category and individ-

In 2003 discussions were in progress to alter funda-

ual performance. At the start of the winter the cattle

mentally the basis of subsidy payments with headage

may be yearling suckled calves or older store cattle.

subsidies replaced by area payments.

Commonly, they are fed rationed concentrates with

The starting point for planning is a decision on which

silage to appetite, but on arable farms arable byprod-

beef system fits farm resources best, setting perfor-

ucts may partly or wholly replace grass silage.

mance targets and drawing up a budget to evaluate

Steers of all breed types are well suited to winter fin-

margin potential. Figure 3.2 presents a budget format

ishing. Early maturing heifers are less suitable because that can be used to evaluate finishing systems and

they finish too quickly at light weights. Nevertheless,

shows as an example cereal bull beef from purebred

continental cross heifers can be winter finished at

Holstein–Friesian bulls.

around 0.9 kg/day on a high forage diet.

Budget

Example: cereal beefa

(£/head)

(£/head @ 2003 prices)

A Calf or store cost

40

B Calf rearing to 3 months: dairy-bred calf

58

C Forage costs . . . cattle/ha @ . . . £/hab

0

D Concentrate costs *1.9* tonnes @ £ *100*/t 190

E Other feeds: straw *0.3* tonnes @ £ *30*/t 9

straights . . . tonnes @ . . . /t

by-products . . . tonnes @ . . . /t

F Other variable costs: veterinary

10

bedding

20

marketing

8

Miscellaneous

10

Total

48

G Total calf + **variable costs**

(**A** + **B** + **C** + **D** + **E** + **F**) **345**

H Sale weight (kg liveweight or carcass)

475 kg

I Forecast sale price (£/kg)

0.8 £/kg

J Returns: weight **H** ¥ sale price **I**

380

K Gross margin (excluding premiums)

35

L Premiums: 1st beef special premium

0

2nd beef special premium

0

bull premium

130

slaughter premium

50

extensification premium

0

Total

180

Overall gross margin (including premiums) **K** + **L**

215

a Holstein–Friesian bull beef.

b Guidelines on forage costs at 2003 prices:

intensive (350 kg N fertilizer/ha) £210/ha

semi-intensive (250 kg N/ha) £150/ha

extensive (75 kg N or less/ha) £70/ha.

Fig. 3.2

Budget format for beef finishing systems.

Standards for winter finishing suckled calves and stores are shown in Table 3.1. Continental cross steers

185

slaughtered at two years old or more may be too heavy

180

for some buyers.

175

Suckler bull beef is still relatively new to the UK, but

has been commonplace in France for many years. Pro-

170

duction is expanding in the UK but demand is limited

165

and it is important to secure a market before com-

160

mencing production. The system is simplest for spring-

Carcass p/kg

155

born calves which are weaned in the autumn and

–U

150

R

transferred gradually over about three weeks to an all-

145

concentrate diet containing 16 per cent crude protein.

O+

140

However, autumn-born calves weaned in the spring can

3

–O

4L

also be used. The British safety code for bull beef pro-

4H

Better conformation

duction recommends no more than 20 bulls to a pen but

Fatter

much larger groups are housed in continental Europe.

Maize silage is short of protein but has good feed

Fig. 3.3

Price differentials for steer carcasses of different EU

conformation and fat classes. Source: Meat and Livestock

intake characteristics and is an excellent source of

Commission price report 1999.

energy. In continental Europe maize silage is widely

Table 3.1

Standards for winter finishing.

Yearling suckled calf

18-month store

British

Continental

British

Continental

Steer

Steer

Heifer

Steer

Steer

Heifer

Feeding period (months)

5

6

5

5

5

5

Start weight (kg)

320

350

310

420

475

400

Daily gain (kg)

0.9

1.0

0.8

0.8

0.9

0.8

Silage (tonnes, 22% DM)

3.6

3.6

4

5.7

5.9

5.5

Concentrates (kg)

300

450

220

135

265

200

Slaughter weight (kg)

455

525

430

540

610

525

Carcass (kg)

250

295

235

300

340

290

Table 3.2

Standards for suckler bull beef using continental crosses.

Spring-born

Autumn-born

Concentrates

Maize silage

Concentrates

Maize silage

Start age (months)

6

6

6

6

Feeding period (months)

6

7

6

7

Start weight (kg)

245

245

230

230

Daily gain (kg)

1.4

1.3

1.4

1.3

Concentrates (tonnes)

1.4

1.0

1.4

1.0

Maize silage (tonnes)a

—

3.3

—

3.1

Slaughter weight (kg)

500

525

485

510

Carcass (kg)

280

295

270

285

a Maize silage at 30% DM.

used as the forage base for intensive bull beef produc-

value of daily gain and carcasses being too heavy for

tion. The medium-sized feed lots of the Po valley in

buyers.

northern Italy with a few hundred to a few thousand

cattle are a good example. In these maize silage com-

Grass finishing

prises 30–50 per cent of ration DM.

Maize silage has not been used much for bull beef

Grazed grass is the cheapest and potentially the highest

production in Britain but there is potential for systems

quality home grown feed. There is a growing realization

in which maize silage forms up to 30 per cent of the dry of the need to exploit grass better by managing swards

matter of the diet, producing daily gains not far short

to maximize daily gains and, where practicable, to

of all-concentrate diets. Where suckled calf producers

extend the grazing season.

on marginal land have suitable buildings available, bull

In grass finishing systems, achieving high daily gains

beef fed purchased concentrates can be a useful way of

is especially important so that marketing begins in mid-

adding value to herd output.

season and reduces cattle numbers in step with declin-

Standards for suckler bull beef are shown in Table

ing grass production and quality.

3.2. Achieving the target daily gains is a prerequisite

Two aspects of management are crucial. Firstly, in the

of profitable production. In practice many producers

winter preceding grass finishing, gains are held down at

extend the feeding period and take bulls to slaughter

a store level so that cattle exhibit rapid compensatory

weights in excess of 600 kg. At these high slaughter

growth when they are turned out onto spring grass.

weights there is a danger of feed cost exceeding the

Secondly, grazing should be managed to get the best

Table 3.3

Specimen winter store rations.

Weight

British cross steer/heifer @ 0.6 kg/day

Continental cross steer @ 0.8 kg/day

(kg)

Silage

Straw + **concentrate**

Silage + **concentrate**

Straw + **concentrate**

(kg/day)

(kg/day)

(kg/day)

(kg/day)

200

18

3.5 + 2.0

16 + 1

3.5 + 3.0

250

21

4.0 + 2.5

19 + 1

4.5 + 3.0

300

23

4.5 + 3.0

22 + 1

4.5 + 3.5

350

26

5.0 + 3.5

20 + 2

5.0 + 4.0

400

28

5.0 + 4.0

23 + 2

5.0 + 4.5

combination of daily gains in cattle and regrowth of

Table 3.4

Standards for overwintering and grass finishing

high quality grass.

suckler-bred steers and heifers.

Grass finishing may commence with stores purchased

in the spring or with suckled calves or stores purchased

Continental

British cross

cross

in the autumn that are overwintered before grass fin-

ishing. Specimen low cost rations for overwintering

Steer

Heifer

Steer

Heifer

cattle are shown in Table 3.3. The lower gain of 0.6 kg/

day is optimum for British cross steers and heifers of all

Winter store period

breed types. The higher gain of 0.8 kg/day is suitable for

Feeding period (months)

6

6

6

6

continental cross steers.

Start weight (kg)

270

235

300

260

During the grazing season on set stocked pastures,

Daily gain (kg)

0.6

0.6

0.8

0.6

the provision of a continuous supply of nutritious grass

Concentrates (kg)

90

90

500

90

is achieved by controlling sward height (the average of

Silage (tonnes)

4.5

4.3

5.2

4.5

grazed and ungrazed grass). In the first half of the

Grass finishing

season sward height is controlled at 6–8 cm to inhibit

Turnout weight (kg)

375

345

445

370

seed heading. Then in the second half of the season,

Feeding period (months)

5

5

6

5

when there is less risk of seed heading and dead

Daily gain (kg)

0.8

0.7

0.9

0.8

herbage begins to accumulate in the base of the sward,

Concentrates (kg)

50

0

150

50

grazing height is relaxed to 8–10 cm to allow more selec-

Slaughter weight (kg)

500

450

600

490

tive grazing.

Carcass (kg)

275

245

335

270

The confidence to manage cattle at the high early

summer stocking rates needed to achieve this degree of

control is helped by adding 25 per cent to the main

BSP is paid from 22 months of age, steers that are close

grazing area as a buffer that can be grazed if grass runs

to this age at the end of the grazing season are often

short but is conserved if not needed. From mid-season

yarded for winter finishing just to claim the subsidy. It

grazing needs to expand onto aftermath regrowths on

is a strategy that needs to be costed carefully.

areas previously cut for silage or hay.

Grazing performance is undermined if cattle, espe-

cially those in their first season of independent grazing,

Dairy beef systems

become infected with parasitic worms that cause gastro-

enteritis and bronchitis. Effective control programmes

In the UK the main dairy herd calving season is in late

include early season treatment to inhibit the build-up summer and autumn, which contrasts with many other

of infective larvae on the sward, mid-season treatment

countries where cows calve in the spring. It reflects the

accompanied by a move to fresh aftermaths on fields

high proportion of milk produced used for year-round

previously conserved or mid-season treatment with a

liquid consumption.

long-acting bolus to control infection even though pas-

Intensive indoor dairy beef systems can utilize calves

tures carry infective larvae. The choice depends on farm

born at any time of year. However, grass-based systems

circumstances (Chapter 19).

work best utilizing calves from the main calving season.

Standards for an overwintering and grass finishing

At turn-out in the spring these calves are old enough to

system are presented in Table 3.4. Because the second

make effective use of grazed grass.

Cereal (barley) beef

Grass and maize silage beef

Cereal beef is a housed bull beef system feeding an

Grass silage bull beef was popular in the 1980s as a beef
all-concentrate diet to slaughter at 11–13 months of
system that made very intensive use of grass, all of
age. Carcasses have a creamy white fat which is popular
which was made into silage. Its flaw was that it was a
with some supermarkets and independent butchers.
system designed for its production capabilities rather
However, it is advisable to secure market outlets before
than market demand. In the original system bulls were
commencing production, especially if poor conforma-
16–18 months old at slaughter, by which time the car-
tion Holstein–Friesians are reared. The system is at its
casses were too heavy for many buyers and the fat was
most profitable when it adds value to home-grown grain
coloured by carotene. There are also question marks
or home-bred calves.
over the eating quality of beef from bulls over 14
Profitable production is heavily dependent on achiev-
months of age.
ing high target daily gains. The protein content of the
There is still a place for grass silage bull beef up to

diet is reduced progressively from 18 per cent crude

14 months of age and the standards in Table 3.6 are for

protein in the calf ration to 14 per cent in the final fin-

slaughter at this age. The system could also be used for

ishing ration. From six months of age part of the protein

steers and heifers but, for reasons that have been

can be supplied by urea. Rumen enhancers such as

enumerated already, grass-based systems now place

monensin sodium improve feed conversion efficiency

emphasis on the utilization of grazed grass.

by about 10 per cent, but their continued use in the EU

The section on winter finishing (see p. 15) has already

is controversial.

discussed the potential for maize silage in beef produc-

Standards for cereal beef are shown in Table 3.5.

tion. With up to 30 per cent of the ration DM as maize

Table 3.5

Standards for cereal bull beef.

Breed type

Holstein–Friesian

Limousin ¥ Friesian

Belgian Blue ¥ Friesian

Charolais ¥ Friesian/

Simmental ¥ Friesian

Slaughter age (months)

11.5

12.5

12.5

12.5

Daily gain (kg)a

1.3

1.3

1.35

1.4

Concentrates (tonnes)a

1.8

1.9

1.9

2.0

Slaughter weight (kg)

460

500

510

530

Carcass (kg)

250

285

290

295

a From 3 months of age.

Table 3.6

Standards for grass silage bull beef.

Breed type

Holstein–

Hereford ¥

Limousin ¥

Belgian Blue ¥

Charolais ¥ Friesian/

Friesian

Friesian

Friesian

Friesian

Simmental ¥ Friesian

Daily gain (kg)a

1.15

1.05

1.3

1.25

1.3

Slaughter age (months)

14

14

14

14

14

Concentrates (tonnes)a

1.1

0.63

0.63

0.94

1.3

Silage (tonnes @ 22% DM)a

5.7

6.8

6.7

6.1

5.4

Cattle/ha

7.9

6.6

6.7

7.4

8.3

Slaughter weight (kg)

495

465

513

535

555

Carcass (kg)

270

255

290

300

305

a From 3 months of age.

Table 3.7

Standards for maize silage bull beef production.

Breed type

Holstein–

Hereford ¥

Limousin ¥

Belgian Blue ¥

Charolais ¥ Friesian/

Friesian

Friesian

Friesian

Friesian

Simmental ¥ Friesian

Daily gain (kg)a

1.25

1.2

1.25

1.3

1.3

Slaughter age (months)

13

12.5

13.5

13.5

13.5

Protein concentrate (tonnes)a

0.50

0.47

0.52

0.52

0.52

Cereal (tonnes)a

1.0

0.7

0.7

0.7

0.75

Silage (tonnes @ 30% DM)a

3.8

4.0

4.4

4.4

4.4

Cattle/hectare

8.7

8.3

7.5

7.5

7.5

Slaughter weight (kg)

490

455

510

530

535

Carcass (kg)

265

245

285

300

300

a From 3 months of age.

silage there is little decline in daily gain from cereal

production and quality decline. In addition, there is a

beef levels. Experience of the system is limited and so

strong case for supplementing calves with about 1 kg

the bull beef system presented in Table 3.7 is somewhat

concentrate daily for two or three weeks after turn-out

speculative. It is based on 25 per cent of the ration DM

in the spring until they become accustomed to grazing.

as maize silage supplemented with a protein con-

Also, supplementation should be reintroduced in late

centrate and cereal. Profitable production is heavily

summer to counter rapidly declining grass quality, start-

dependent on a high yield of good quality maize silage

ing at 1 kg daily and building up to 2 kg daily for a

and achieving target daily gains. Continental ¥ Friesian

month before housing.

heifers may be suitable for maize silage beef fed to

Standards for the system are shown in Table 3.8. The

gain about 1.0 kg/day and slaughtered at 435–450 kg

overall daily gain of 0.9 kg for Limousin ¥ Friesian liveweight.

steers is made up of 0.8 kg/day through the rearing

winter, 0.8 kg/day during grazing and 1.1 kg/day in the

finishing winter. The finishing gain would be achieved

Eighteen-month beef

at an average concentrate consumption of about 2.5 kg

Eighteen-month beef is a grass-based system that uti-

cereal or concentrate with good quality grass silage

lizes dairy-bred steers born in the autumn. It is the

to appetite. Limousin ¥ Friesian heifers would be

original planned system of production in the UK.

managed at an overall daily gain of 0.8 kg/day to a

Calves are reared through their first winter, grazed from

slaughter weight of 450 kg.

six to twelve months of age and then finished in their

second winter on rationed concentrates with silage to

Grass beef

appetite. Heifers may be used for eighteen-month beef,

but are better suited to grass finishing.

Grass beef is the most extensive of the planned dairy

Profitability depends heavily on achieving good

beef systems. Farmers see it as a low cost system that
grazing performance. In farm practice this has taken
maximizes subsidy income. At best, steers qualify for
second priority to making a large tonnage of first-cut
both BSP payments, an extensification premium and
silage. This partly explains the poor financial margins
the slaughter premium. Carcasses from continental
achieved in recent years. In addition, the system has a
cross steers may be too heavy for some buyers. Heifers
relatively high concentrate requirement, a high silage
are well suited to the system and can be more profitable
requirement and, at best, steers only qualify for a single
than unsubsidized steers.
BSP payment.
Good grazing gains are essential for profitable
The principles of good grazing management
production. If first season gains are below target,
described for grass finishing (see p. 17) apply equally to
winter store feeding costs are increased to catch up
eighteen-month beef. The cattle graze for the full
lost ground. Ideally, winter gains should be 0.5–

season and so, from mid-season, there is a need to

0.6 kg/day for heifers and early maturing Hereford ¥

expand onto fresh aftermath grazing on areas previ-

Friesian steers and 0.7–0.8 kg/day for continental cross

ously cut for silage as the cattle grow heavier, but grass

steers.

Table 3.8

Standards for steers in eighteen-month beef.

Breed type

Holstein–

Hereford ¥

Limousin ¥

Belgian Blue

Charolais ¥ Friesian/

Friesian

Friesian

Friesian

¥ Friesian

Simmental ¥ Friesian

Daily gain (kg)

0.85

0.85

0.9

0.95

0.95

Slaughter age (months)

18

17

18

18

18

Concentrates (tonnes)a

1.3

0.9

1.0

1.1

1.2

Silage (tonnes @ 22% DM)a

5.8

5.1

6.0

5.7

5.5

Cattle/hectare

3.4

3.9

3.3

3.5

3.6

Slaughter weight (kg)

500

460

520

525

540

Carcass (kg)

270

250

290

295

300

a From 3 months.

Table 3.9

Standards for steers in grass beef production.

Breed type

Holstein–

Hereford ¥

Limousin ¥

Belgian Blue

Charolais ¥ Friesian/

Friesian

Friesian

Friesian

¥ Friesian

Simmental ¥ Friesian

Daily gain (kg)

0.73

0.68

0.75

0.80

0.83

Slaughter age (months)

22+

22+

22+

22+

22+

Concentrates (tonnes)a

0.4

0.3

0.5

0.5

0.6

Silage (tonnes @ 22% DM)a

7.0

5.7

6.7

6.7

6.7

Cattle/ha

1.6

1.7

1.6

1.6

1.6

Slaughter weight (kg)

555

515

585

595

610

Carcass (kg)

300

280

330

335

340

a From 3 months of age.

In the second grazing season steers need to be mar-

complex leader–follower grazing system was developed

keted as soon as possible after they qualify for the

in which the younger cattle graze selectively ahead of

second BSP to reduce stocking rate as the season pro-

the older age group. Despite its merits, it is rarely

gresses. Marketing of heifers should start in mid-season.

adopted by farmers who prefer to keep the two age

This need to reduce stock numbers from mid-season

groups separate.

in step with declining grass production favours early

The principles of good grazing management

maturing types of cattle. So early maturing Hereford ¥

described for grass finishing (see p. 17) are applicable

Friesian steers fit the system better than late maturing

to grass beef. As with eighteen-month beef there is a

Holstein–Friesians or Charolais ¥ Friesians that may

strong case for supplementing calves with about 1 kg

fail to finish off grass and have to be housed for a period

concentrate daily for two or three weeks after turn-out

of winter finishing. Similarly, early maturing heifers

in the spring and reintroducing supplementation in late

have advantages over later maturing steers. None-

summer to counter declining grass production and

theless, all the breed types, steers and heifers can be

quality.

utilized in the system provided their perfor-

Standards for steers in the system are presented in mance characteristics are understood and managed

Table 3.9. As an example of standards for heifers,

accordingly.

Limousin ¥ Friesians would have a lifetime gain of

Grazing management is complicated by the fact that

around 0.6 kg/day to slaughter at 20 months of age

there are two age groups of cattle on the farm. A

weighing 500 kg.

Chapter 4

Dairy Farming

A.H. Andrews and A. Poole

Structure in Europe and the world

22

herds consist of a single cow, often with a calf at foot,

Trends of structure in the United Kingdom

24

or very small numbers of low-yielding cows. This occurs

Milk utilization

26

in many parts of Africa and Asia, and in Europe

Dairy breeds

27

smallish herds are seen in countries such as Greece,

Feeding dairy cows

30

Portugal, Spain and Italy. While there have been very

Dry matter intake

30

gradual changes in the last half-century in Europe and

Energy

31

the United Kingdom, the introduction of milk quotas in

Protein

31

Feeding strategies

32

1984 accelerated these. In the last decade since the first

Minerals and vitamins

33

edition of *Bovine Medicine* was published the changes

Grassland farming

33

have been faster and at the start of the new twenty-first

Grassland production

33

century they have become very rapid indeed. There are

Grassland utilization

35

increasing trends towards a so-called ‘global market’

Winter feeding systems

37

with a lowering of tariff barriers. If this continues this

Dairy farm buildings

38

will mean that many areas where milk price is directly or

Parlour and dairy

39

indirectly subsidized will have to deal with lowered

Cow housing and feeding barn

40

price for the product. Many areas with low labour costs

Feed storage area

41

and good weather to grow crops are starting to gear

Calving and isolation boxes

42

themselves up to the challenge of producing low cost

Slurry

42

Herd records

44

milk for export to other parts of the world. This is at

Physical records

44

present particularly occurring in North and South

Breeding records

45

America.

Milk records

45

Over the past few years much thought has been

Financial records

47

invested by the World Trade Organization, among

Management

47

others, about increasing the flow of milk and dairy prod-

Labour

47

ucts across the globe. However, the dairy markets are

Breeding

47

some of the most protected of agricultural products

Culling

47

and the Organization for Economic Co-operation and

Age at first calving

48

Development estimated in the late 1990s that member

Breed of sire used

48

states producer support arrangements were, in absolute

Genetic worth of the sire

48

Health

49

terms, higher than for all other commodities. It is this

Economics of dairy farming

50

background which is causing international trade organ-

Measures of efficiency

50

izations to find ways to reduce export subsidies paid

Farm assurance and herd health schemes

52

by countries and to alter tariff quotas for imported

Organic farming

52

products.

The future

52

The introduction of milk production quotas had a

very profound effect on the European milk industry. Its

aim was to reduce overall European milk production

Structure in Europe and the world

and the changes undertaken by producers to accommodate this altered many milk parameters. The struc-

Dairy farming in Europe and elsewhere is a very diverse

ture in 1983 prior to the change is given in Table 4.1a

industry and ranges from high-yielding cows in Israel,

and the present situation within the enlarged EU is

the USA and Canada as well as within European coun-

shown in Table 4.1b. The position presented in Table

tries such as the Netherlands, Denmark and the UK

4.1a was reached over the previous 23 years by each

to the small, low-yielding herds of Greece, Portugal,

country expanding its milk production through an

Spain and Italy. In many parts of the world milking

expanded herd size and increased yield per cow. Total

Table 4.1a

EEC dairy structure (pre milk quotas).

Cows

Herds

Average herd

Yield

Total

Self-sufficiency

('000)

('000)

size

(l/cow)

production

('000 t)

BF

SNF

(%)

(%)

Germany

5451

363

15.3

4650

26 007

116

136

France

6506

367

19.8

3950

33 337

122

128

Italy

3120

424

7.3

3540

11 030

66

63

Netherlands

2333

58

40.8

5330

12 550

256

116

Belgium

946

45

21.7

3930

4145

104

116

}

Luxembourg

70

2

29.7

4274

320

UK

3257

54

58.2

4906

17 680

86

104

Irish Republic

1528

77

19.9

3910

6 480

298

175

Denmark

913

35

28.2

5585

5 205

212

142

Greece

219

77

3.1

3200

770

–

–

Portugal

369

115

3.2

3021

1 115

–

–

Spain

1885

–

–

3382

6 375

–

–

Source: Milk Marketing Board (1986).

Table 4.1b

EU dairy structure in 2000 (post milk quotas).

Country

Cows

Herds (1997)

Average herd

Yield

Total

Butterfat

Protein

(2000)

('000)

size (1997)

(2000)

production

content

content

('000)

(kg/cow)

(2000)

(2000)

(2000)

(’000 t)

(% by weight)

(% by weight)

Germany

4 539

186

27.9

6157

28 332

4.22

3.41

France

4 413

146

30.7

5844

24 775

4.08

3.19

Italy

2 172

102

20.5

5113

10 774

3.66

3.26

Netherlands

1 532

37

44.0

7302

11 155

4.40

3.46

Belgium

629

20

32.3

5420

3 383

4.09

3.34

Luxembourg

44

1

36.5

6030

265

4.19

3.34

United

2 339

36

68.8

6133

14 489

4.01

3.30

Kingdom

Irish

1 238

39

32.4

4191

5 280

3.70

3.23

Republic

Denmark

644

13

50.8

7272

4 720

4.28

3.44

Greece

173

24

7.7

4756

805

3.67

3.22

Spain

1 141

106

11.9

5007

5 900

3.75

3.09

Portugal

355

70

5.2

5819

2 057

3.84

3.19

Austria

621

86

8.4

4977

3 340

4.13

3.33

Finland

358

29

13.3

6916

2 524

4.22

3.29

Sweden

426

16

29.6

7748

3 348

4.18

3.31

EU Fifteen

20 624

911

24.0

5885

121 146

4.07

3.31

Sources: various including mainly National Dairy Council (2001).

cow population did not increase to the same extent as

The Common Agricultural Policy (CAP) set out to

the number of dairy producers gradually declined. The

increase food production, maintain farm incomes and

reasons for this were due to both individual national

prevent rural depopulation. This encouraged the very

policies and the then EC requirements.

small farms of much of Europe to survive and expand,

Table 4.2

Production and milk quota ('000 tonnes) for EU

quota producers at a rate of 100 per cent of the target

Member States.

price for milk. On an on-farm basis, provided national

production exceeded quota, each farm paid super-levy

Production

Milk quota

on excess production above its individual quota at

a rate of 75 per cent of the target price for milk. In

1983

1983–84

1991–92

2000–2001

1987–88 further changes to the means of determining

super-levy liability were made so that those producers

Germany

26 429

23 792

22 927

27 865

most over quota paid the highest proportion of the levy,

France

33 230

26 768

24 613

24 236

Italy

11 310

9 914

9 221

10 314

again provided the national quota was exceeded.

Netherlands

12 782

12 197

11 213

11 075

Quota has been transferable between individual

Belgium

4 149

3 643

3 364

3 310

farmers within a member state, either on a sale

Luxembourg

319

294

272

269

(attached to land or without, but both are complex) or

UK

17 878

15 950

14 789

14 602

lease basis (a much simpler procedure) or else on an

Irish Republic

6 380

5 599

5 301

5 342

administratively based system where unused quota

Denmark

5 361

4 933

4 525

4 455

reverts to an authority and is re-allocated. Further reg-

Greece

765

588

581

675

ulation in 1987 imposed a butterfat ceiling on quotas,

Spain

5 917

thereby giving a reduction in national quota if the

Portugal

1 872

average butterfat of 1985–86 was exceeded. Also in

Austria

2 749

1987 further quota cuts were announced, resulting in a

Finland

2 407

Sweden

3 303

further fall by 1989 of 8 per cent. The calculation of any

EU Fifteen

118 391

liability for excess production for a farmer is extremely

complex. It depends on the amount of milk over quota

Sources: Milk Marketing Board (1990); National Dairy Council (2001).

and on the average butterfat content of the milk. Each

producer has a butterfat reference figure. If a levy is to

be charged then the farmer's production volume will be

adjusted up or down by the amount that the butterfat

while for the larger producers, financial help made dairy

average differs from his/her reference figure. Again

farming relatively profitable compared with other

levies only arise when national production is too

sectors of agriculture. Thus total milk production for

high.

the 10 members of the EC at that time rose from 87.5

The objective of reducing milk production has been
million tonnes in 1965 to 120.7 million tonnes in 1983.
achieved. Initially it was envisaged that milk quotas
The success of the EU milk quota in controlling
would be phased out in the early 2000s. However, this
production is demonstrated by the fact that even in
has not been the case and the CAP reform has extended
the expanded Union total milk production was 120.9
milk quota until 2006. Special increases in quota were
million tonnes in 1998.

allocated to Italy, Spain, Greece, Ireland and Northern
While the CAP was proving very satisfactory for
Ireland in 2000 and 2001 in addition to the increase of
dairy farmers, the financial support they were receiving
1.5 per cent given to all countries in three stages from
was increasingly threatening the whole EU budget.
2005. The intervention price will be gradually cut from
Most of this aid was provided through intervention
2005 and it is expected that the system will have been
buying of surplus products. In fact, sale into interven-
re-examined in detail by then.

tion became the accepted market rather than the

market of last resort. Thus by 1983, self-sufficiency

Trends of structure in the United Kingdom

levels rose within the EC to 125 per cent for butterfat

(BF) and 166 per cent for solids-not-fats (SNF) (Table

Changes to the structure in dairy farming in the United

4.1a) and the cost of dairy support made up one quarter

Kingdom have mirrored the trends over the last 25

of the whole EC agricultural budget. Thus at this stage,

years in Europe. Thus there are fewer producers and

milk quotas were imposed to control milk production

slightly fewer cows, but in larger herds and with a higher

and each member country had to take a cut of varying

yield per cow (Table 4.3). This has been brought about

proportions (Table 4.2).

by the virtual elimination of the small herd. In 1972, 20

If national production exceeded the allocated quota

per cent of cows were in herds of less than 30 cows, but

then a super-levy was imposed. This super-levy was to

by 1997 it was about 5 per cent. This acceleration has

be calculated either on a dairy basis or on an on-farm increased at the beginning of the new century as milk

basis. On a dairy basis, if national production and the

prices dropped, causing most farms either just to break

supplying dairy were over quota, then levy was imposed

even or to lose money. The foot and mouth disease out-

on the dairy and hence back to the individual over-

break of 2001 has caused more producers to cease milk

production, and present numbers of herds are likely to

Herringbone parlours accounted for only 11 per cent of

decrease sharply.

milking installations in 1972, but made up over 45

The December 2001 census showed UK dairy cows per cent in 1990 (Fig. 4.1), and are the main system

down to 2.203 million with in-calf heifers down to 0.442

today.

million. While beef cows were down to 1.673 million, in-

The increased yields have been realized by improved

calf beef heifer numbers rose.

feeding (see Chapter 9), breeding and management

The changes to larger herds have been facilitated by

techniques. The breed of cow in the UK has altered, 64

new technology and mechanization and a consequent

per cent Friesian in 1965 moving to over 91 per cent

loss of labour. In 1972, 67 per cent of farms milked

Holstein–Friesian by 1990, which has also made a major

through a cowshed, with only 28 per cent in 1990.

contribution.

Milk purchase has also undergone some very funda-

mental changes in the last century. Initially farmers

sold direct to dairy companies. However, as the latter

Table 4.3

The structure of dairying in England and Wales, 1965

became larger the individual farmer had problems in to 2001.

obtaining a fair price. This resulted in Agricultural Mar-

keting Acts in 1931 and 1933, which set up a framework

Year

Producers

Cows

Average

Yield

whereby all the milk produced was taken by the Milk

('000)

(millions)

herd size

(l/cow)

Marketing Boards who then had to sell it on the pro-

ducer's behalf. The Agricultural Act of 1993 allowed the

1965

100.5

2.65

26

3545

1970

80.3

2.71

33

3755

abolition of the Milk Marketing Boards in Great

1975

60.3

2.70

46

4070

Britain and from 1 November 1994 the Milk Marketing

1980

43.4

2.67

58

4715

Scheme was revoked (Northern Ireland from 1 March

1984

39.3

2.70

67

4950

1995). In the deregulated market, producers are free to

1988

31.7

2.38

69

4870

sell their milk wherever they choose including direct

1990

31.5

2.33

70

5020

to dairy companies, or via intermediary organizations

1995

28.1

2.10

74

5380a

managed jointly by the dairy company and producers,

1998

24.7

1.92

77

5770a

or independent producer groups, usually co-operatives,

1999

23.3

1.94

82

5955a

who either then sell to the dairy companies or process

2000

21.8

1.84

85

5940a

the milk themselves. Many sold milk via Milk Marque,

2001

20.2

1.76

which was considered in 1999 to be a monopoly, result-a

ing in its division into three new regionally based co-

United Kingdom figures.

Source: Milk Marketing Board, 1990; National Dairy Council, 2001.

operatives, namely Axis, Milklink and Zenith, which

Fig. 4.1

Milking in the herringbone

parlour.

Table 4.4

Utilization of milk in England and Wales (%) to 1989–90 and in the United Kingdom (%) to 2000.

Liquid

Butter

Cheese

Condensed

Cream

Others

milk

milk

1964–65

73

3

11

5

5

3

1969–70

66

10

10

4

7

3

1974–75

62

8

16

4

8

2

1979–80

50

23

15

3

7

2

1982–83

45

31

14

2

6

2

1983–84

45

30

14

2

6

3

1984–85

48

27

15

2

5

3

1987–88

49

23

19

2

3

4

1989–90

51

20

18

2

4

4

1993–94a

86

2

4

2

3

3

2000a

50

2

22

4

2

20

Source: Milk Marketing Board (1986); National Dairy Council (2001).

a Figures on a different basis to previously.

began to operate as fully independent businesses from 1 April 2000. There has since been more rationalization and mergers, with one group involved in milk purchase in Scotland, England and Wales becoming known as British Milk. Some milk purchasers now have their headquarters outside the UK.

The last few years have seen many milk purchasers buying milk from individual farmers or small groups or farmer clubs. In the early part of the twenty-first century the number of purchasers has been reducing and farmers are starting to combine in co-operatives to provide more negotiating power with the purchasers. Milk is now purchased in varying ways, but is usually paid for according to its composition, cell count and bacterial count (undertaken in the UK by a Bactoscan, see Chapter 25). There are also seasonality payments.

Milk utilization

Fig. 4.2

A modern butter-making creamery produces and packs 5 tonnes of butter an hour.

While milk production has increased over the last 25
years, milk consumption has slightly reduced. The
amount used as liquid milk has declined from 73 to 45
per cent. However, because of quotas this percentage
This changed with increasing amounts of milk being
has increased again (Table 4.4). Self-sufficiency in 1999
used for manufacturing. At one stage (Table 4.4) butter
compared with 1996 in the UK was 74 per cent (68 per
manufacture increased (Fig. 4.2) with much interven-
cent) for butter, 64 per cent (69 per cent) for cheese,
tion producing the so-called 'butter mountain'. With
128 per cent (129 per cent) for condensed milk, 147 per
liquid milk sales realizing the highest return to the pro-
cent (147 per cent) for cream and 187 per cent (112 per
ducer, the producers in England and Wales should be
cent) for skim milk powder.
in a more favourable position than the rest of the EU,
Prior to the EU, the UK was mainly concerned with
as shown in Table 4.5. The large quantities of other uses
supplying the liquid market, with Commonwealth
constitute mainly milk powder and milk fed to live-

countries supplying butter and cheese requirements.

stock, which is common practice in some countries.

Table 4.5

Utilization of whole milk, 1984–1989 (%).

Liquid

Butter

Cheese

Condensed Cream

Others

Milk

milk

’84

’89

’84

’89

’84

’89

’84

’89

’84

’89

’84

’89

Germany

13

14

46

34

13

17

4

3

9

13

15

19

France

9

17

38

36

22

28

1

1

4

5

26

13

Italy

29

28

14

14

44

43

–

–

4

5

9

10

Netherlands

6

6

42

36

27

32

8

6

3

4

14

16

Belgium

15

16

55

51

5

7

–

1

5

8

20

17

Luxembourg

11

13

56

53

3

4

–

–

9

13

21

17

UK

41

48

26

20

14

19

2

3

4

3

13

7

Irish Republic

10

11

62

58

9

13

2

2

3

4

14

12

Denmark

8

6

38

37

30

32

–

–

5

8

19

17

Greece

29

30

3

2

47

53

–

–

2

3

19

12

Source: Milk Marketing Board (1986, 1990).

Table 4.6

Dairy herd breed distribution.

Approximate

Yield

Butterfat

Protein

percentage of

(kg/cow)

(%)

(%)

national herd

Ayrshire

2.0

5887

4.04

3.34

Holstein/Friesian

90.0

6960

3.98

3.27

Guernsey

1.8

4899

4.76

3.58

Jersey

1.6

4708

5.40

3.29

Dairy Shorthorn

0.3

5589

3.88

3.30

Others and crosses

4.3

–

–

–

Sources: various, including National Dairy Council (2001).

While this table relates to the 1980s, proportions are rel-

are now becoming very similar in many other parts of

atively similar today. The surplus situation in Europe

the world. While every breed has its enthusiasts, the vast

was at one time exacerbated by much of the liquid milk

majority of herds are mainly Holstein–Friesian type

consumed being skimmed milk, or semi-skimmed milk,

(Fig. 4.3). These black and white cows are renowned for

allowing the release of milk for butter production. The

their high yields of average quality milk. As they

last 20 years have also seen a similar trend in the UK,

become more extreme, the surplus males are of less use

with about 20 per cent of liquid milk consumed as skim for beef. Recently the input costs have been examined

or semi-skim in the 1980s, 55 per cent in 1994 and 62

by some farmers and there is a slight tendency for those

per cent in 1998. The further quota restrictions have

who wish low input production to favour animals of a

taken this into account.

less extreme Holstein type. These animals are also often

favoured by the organic milk producers. However,

those aiming at the very high yielding herd are still pur-

suing a Holstein type of animal. The main drawback of

Dairy breeds

such animals is that any surplus calves produced are of

limited use in beef production. Such problems in the

The principal dairy breeds of the United Kingdom are

future may be overcome by the use of sexed semen and

given in Table 4.6. These breeds or their local variations

then possibly by the one of embryo transfer in those

Fig. 4.3

(a) A Friesian cow, (b) a Guernsey cow, (c) a Jersey cow, (d) an Ayrshire cow.

cows not required to produce dairy herd replacements.

decreased, the breed has currently been given a boost

The increased interest in organic farming and sustain-

as its milk is being specifically retailed by some chain

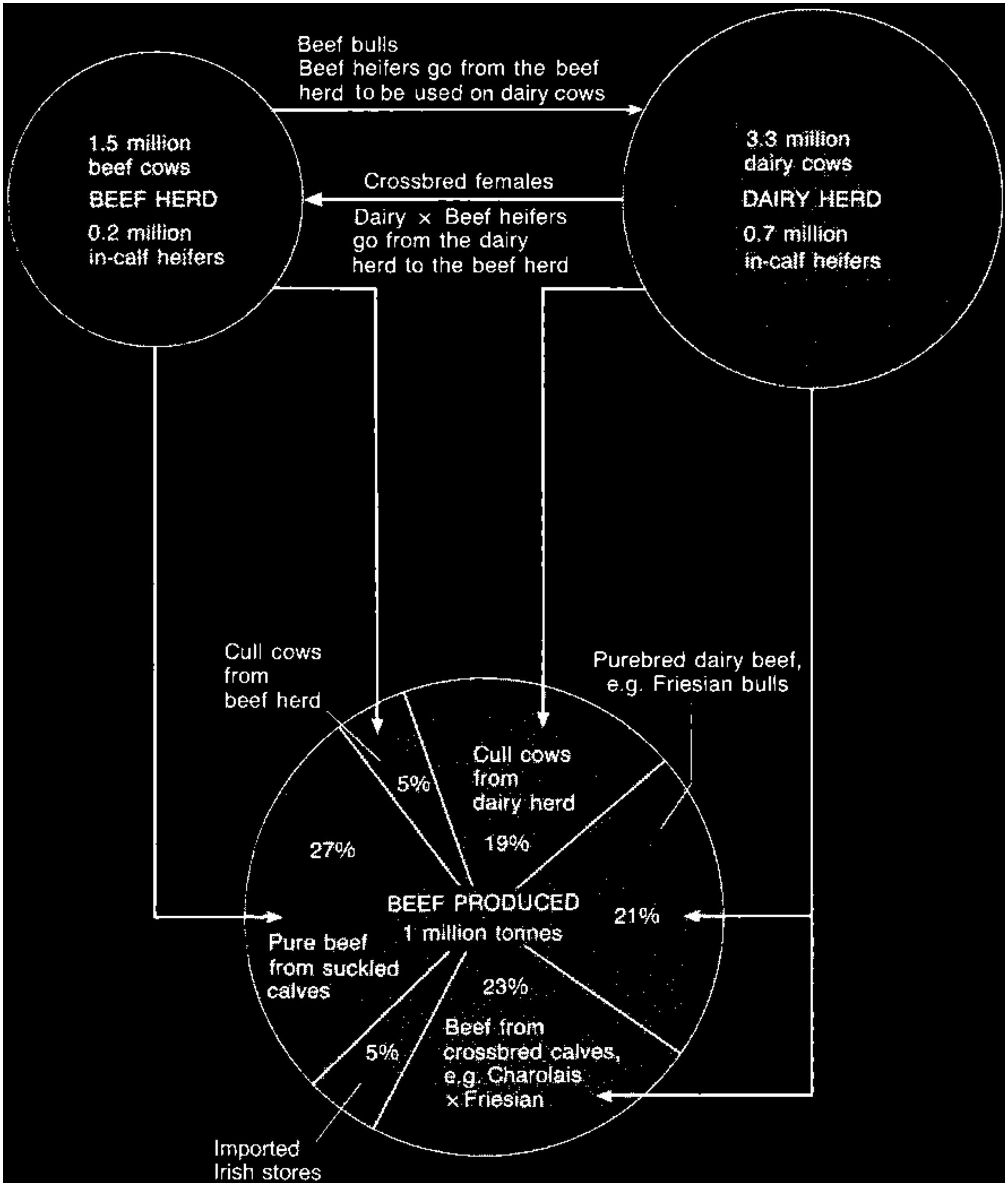
able agriculture is likely to be reflected in an increase

food stores. A smaller cow than the Friesian, it produces

in usage of Friesian-type animals, which are more

lower milk yields but of higher quality. It is a breed
adjusted to such production systems than the Holstein.
renowned for the dairy type and so is not very suitable
The Channel Island breeds, Guernseys and Jerseys,
for beef.
are still popular with a minority of breeders. They are
The Dairy Shorthorn has suffered from the demise of
docile cows producing lower yields of very high quality
being the major breed pre World War II, now slipping
‘gold top’ milk. This sells at a premium to the liquid
to almost insignificance. With good beefing qualities, it
milk or cream markets. The milk is now often sold
tended to fall between two stools, with neither the milk
homogenized. The breed does produce very efficiently
quantity of the Friesian nor the quality of the Channel
on the basis of weight of milk constituents produced.
Island breeds. Types of the breed are used in some
The beefing qualities are low and the fat tends to
countries. Its use may also increase on farms practising
be yellow, but the meat can be acceptable when
sustainable or organic agriculture.

crossed with one of the continental beef breeds such as
The beefing characteristics of the dairy breeds are of
Charolais, Limousin, Simmental or Belgian Blue. Dys-
importance in England and Wales as the majority of the
tokia problems in the Channel Island breeds are few
beef produced originates from the dairy herd. Until
because of a broad and pliable pelvis that allows deliv-
March 1996, the origin of British beef was as in Fig. 4.4.
ery of viable live calves when crossed with the large
The Over Thirty Month Scheme (OTMS), which pre-
beef breeds.
vented the sale of older animals for human consump-
The Ayrshire is still regionally very popular in a few
tion, plus the Calf Processing Aid Scheme (CPAS),
parts of its native Scotland. While its numbers have
which paid a premium for calves slaughtered before 20



Dairy Farming • 29

Fig. 4.4

Sources of beef in the UK.

Source: Meat and Livestock Commission.

Table 4.7

Sources of home-produced beef. Reproduced with

derived from the dairy herd. Recent BSE problems in

permission from Meat and Livestock Commission (1999).

other parts of Europe are also altering the types of

animal which are entering the meat industry for use

1993

1995

1996

1998

both directly and in manufacturing. In Britain, should

(%)

(%)

(%)

(%)

the OTMS be removed, it will cause another alteration

in the constituents of beef which is consumed. At

UK-bred steers,

78

76

92

100

present, increased proportions of total beef production

heifers and

are being used for manufacturing and catering and so

young bulls

beef herd

34

35

43

52

if human consumption of over thirty-month-old beef

dairy herd

44

41

49

48

is again allowed, there should be a market for the

product.

Cull cows

19

22

8

0

The Friesian breed has played an important part in

beef herd

8

6

3

0

beef production with most farmers producing sufficient

dairy herd

11

16

5

0

of their cows pure to provide the heifer replacements

Adult bulls

1

1

0

0

for the dairy herd, with the remainder being bred to a

Irish cattle

1

1

0

0

beef bull to maximize calf returns. Figure 4.5 shows

that, in most years, 60–70 per cent of inseminations have

been to a dairy bull, with the remainder to beef breeds.

days of age, payable from May 1996 until 31 July 1999,

These data cannot at present be updated, but the most

altered these proportions so that in the early twenty-

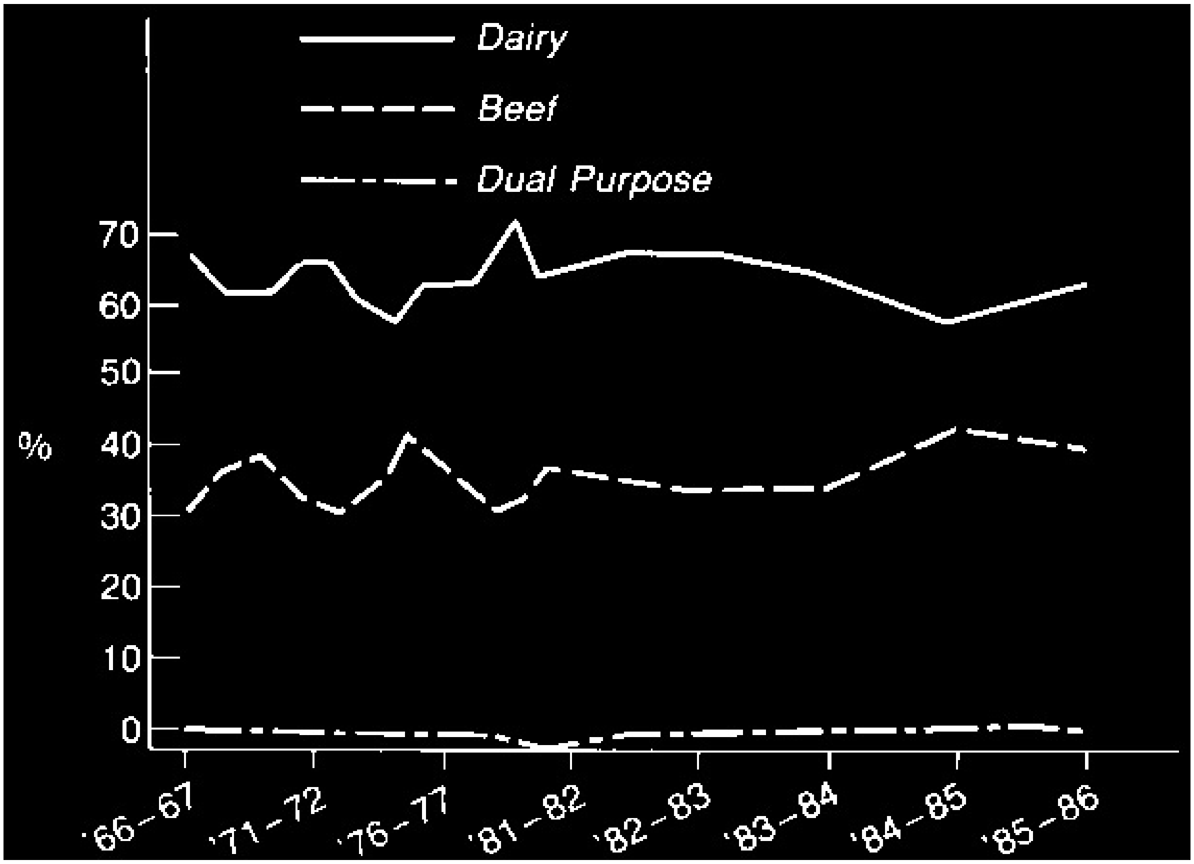
numerous breeds of bull used for artificial insemination

first century the origins are as in Table 4.7. These are

(AI) in 1986 are shown in Table 4.8. While the dairy

likely to alter with an increase in the amount of beef

inseminations follow the pattern of breed distribution,



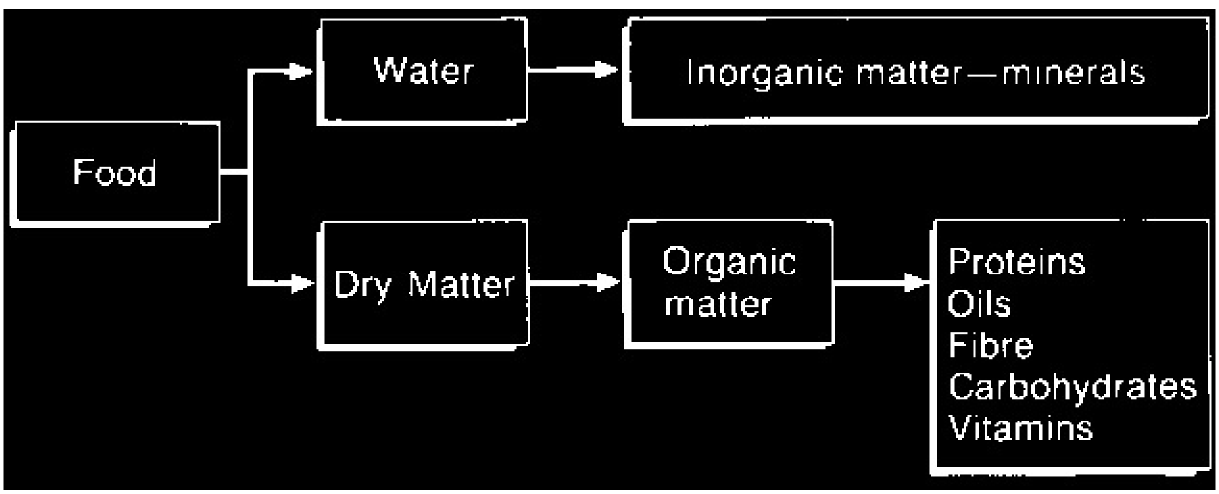


Fig. 4.6

Food components.

dependent on the price and the quality of the bulls offered.

Fig. 4.5

Dairy, dual purpose and beef inseminations as per-

centages of total inseminations. Source: *Report of Breeding and Production Organization*, MMB (1986).

Feeding dairy cows (see also Chapter 9)

A vital feature of dairy cow management is correct

feeding. Food, either purchased or home produced,

Table 4.8

AI breed demand in MMB areas, 1986 (%).

amounts to 60 per cent of the variable costs of produc-

tion so the efficiency of feed use is extremely im-

Ayrshire

0.7

portant. In the past, most high-energy feeds were

Friesian/Holstein

57.8

purchased as concentrates from feed manufacturing

Guernsey

0.8

companies. The onset of bigger herds, access to machin-

Jersey

1.2

ery to mix up feeds and the ability to buy feed con-

Shorthorn

0.2

Total dairy breeds

60.7

stituents at competitive prices have meant that many

Aberdeen Angus

2.8

dairy and beef farmers now produce their own rations,

Belgian Blue

1.1

often feeding them as complete feeds or total mixed

Charolais

7.4

rations (TMR).

Hereford

12.0

The main components of feed are shown in Fig. 4.6.

Limousin

12.7

All feeds contain water in varying amounts. Dry feeds

Simmental

1.7

such as cereals will only have about 14 per cent water,

Others

1.6

while other feeds such as mangels and other root crops

Total beef breeds

39.3

will be up to 90 per cent water. While all cows require

water it is the dry matter proportion of the total food

Source: *Report of the Breeding and Production Organization*, MMB

(1986).

that supplies the nutrients for maintenance and pro-

duction. In general, the higher the dry matter of the

overall diet, the higher will be the dry matter intake

(DMI). Apart from the need for minerals and vitamins,

the main aspects to consider in dairy cow feeding are

with beef the continental breeds are replacing the tra-

DMI and energy and protein levels.

ditional British beef breeds, especially the Hereford.

The Belgian Blue is more widely used in the UK than

shown in Table 4.8, but again recent figures are unob-

Dry matter intake

tainable. The Aberdeen Angus continues to enjoy some

support because of the ease of calving, particularly

Dry matter intake (DMI) is affected by the liveweight

when used on maiden heifers or small cows. It also has

of the cow, stage of lactation, milk yield, type of feed

some marketing advantages in that Angus beef can

and frequency of feeding. As a guide for estimating

demand a premium.

DMI the following equation is used:

While there is an increasing amount of embryo trans-

DMI (kg/day) = 0.025 ¥ liveweight (kg) + 0.1

fer occurring and costs have reduced, it is still an

¥ milk yield (kg/day)

uncommon procedure. However, the possible use of

sexed semen does appear to offer considerable possi-

At calving DMI will be 2–3 kg/day lower than calcu-

bilities over the next few years. Its uptake will be very lated, but it will then increase to peak at three to five

Table 4.9

Energy requirements of dairy cows.

Breed

Liveweight

Maintenance

Production

Liveweight gain

Pregnancy

(kg)

(MJ/day)

(MJ/kg milk)

(MJ/kg gain)

(MJ/day)

Ayrshire

500

54

5.3

34

23

Friesian

600

63

5.2

34

23

Guernsey

450

49

5.8

34

23

Jersey

350

40

5.9

34

23

Shorthorn

550

59

5.1

34

23

Table 4.10

Digestible crude protein requirements of dairy cows.

Breed

Liveweight

Maintenance

Production

Pregnancy

(kg)

(g/day)

(g/kg milk)

(g/day)

Ayrshire

500

300

60

150

Friesian

600

350

55

150

Guernsey

450

275

70

150

Jersey

350

225

70

150

Shorthorn

550

325

55

150

months after calving. After peak milk production,

Maintenance

63 MJ

intake decreases slowly through lactation and is lower

Production (20 ¥ 5.2)

104 MJ

during the dry period. DMI can be increased by feeding

Liveweight gain (0.5 ¥ 34)

17 MJ

highly or more digestible feeds such as maize silage.

Pregnancy

23 MJ

Thus cows will eat greater quantities of a 70 per cent

Total energy required

207 MJ/day

digestibility (D) silage then one of 64 D. Also succulent

feeds such as brewers' grains, kale and roots consider-

Protein (see Chapter 9)

ably enhance intakes in an otherwise dry diet of hay or

silage with concentrates. When feeding large quantities

Protein is required for both maintenance and produc-

of concentrates, splitting the feed into three or four

tion. In contrast to the case for energy, body tissues

feeds rather than the conventional two in the parlour cannot be used to make up a shortfall in protein and so

will also increase intake and reduce rumen acidity. This

milk yields will suffer if protein is in deficit, especially

is also why TMR can work well and again it will increase

in early lactation. Protein is often measured as crude

feed intake.

protein (CP) and is given as percentage of dry matter.

In rations it used to be measured in grammes of

digestible crude protein (DCP) per kilogram DM.

Energy (see Chapter 9)

Requirements for maintenance and production are

The energy requirements of a dairy cow depend on

shown in Table 4.10.

her needs for maintenance, lactation, pregnancy and

A refinement of the DCP system is the division

whether she is increasing or decreasing weight (Table

of rumen degradable protein (RDP) and rumen

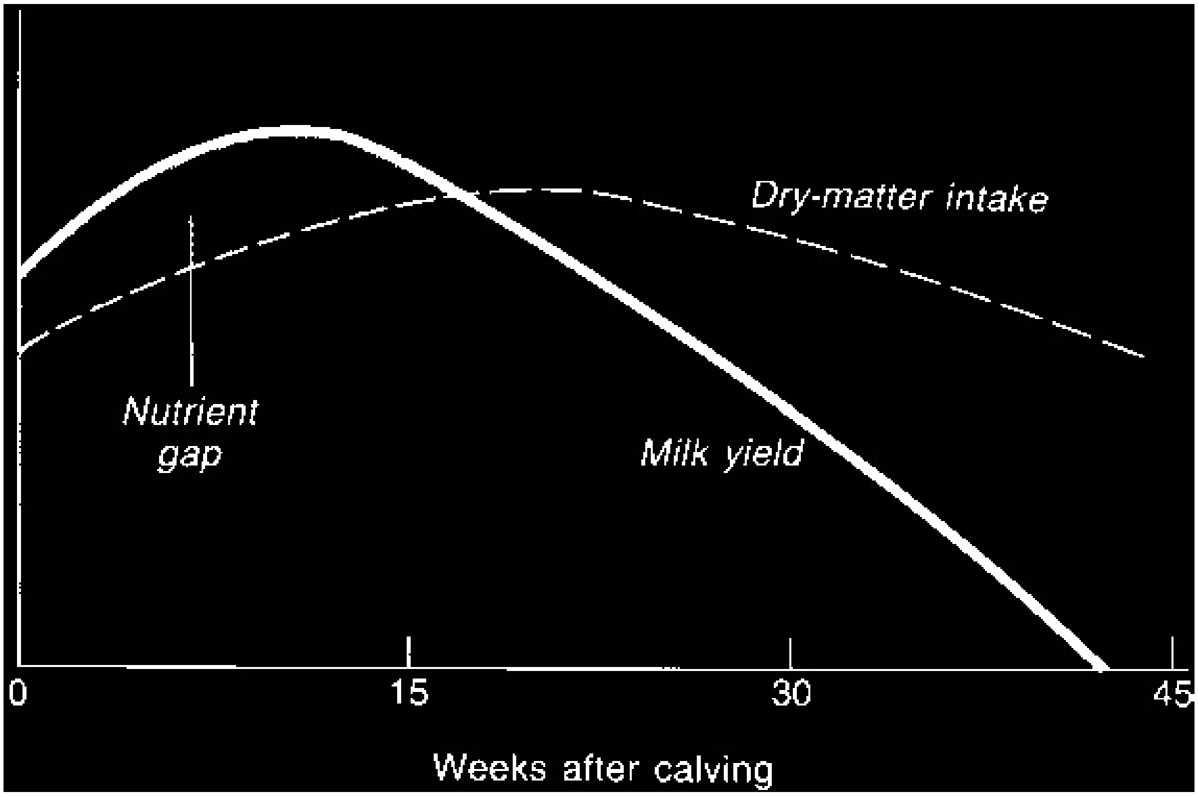
4.9). Energy in diets in Britain is measured as metabo-

undegradable protein (UDP). A dairy cow has a need

lizable energy (ME) and the units are megajoules (MJ)

for both types of protein. The system has been further

per kilogramme dry matter (DM). If dairy cows are in
refined into the metabolizable protein (MP) system.
energy deficit then body fat will be mobilized, causing
This looks at the rate at which protein becomes avail-
liveweight loss to make up for some or all of the deficit.
able within the rumen and is given as quickly degrad-
This will contribute about 28 MJ of ME per kg live-
able protein (QDP) and slowly degradable protein
weight loss. Estimated energy requirements are shown
(SDP). These two (QDP + SDP) form what is known as
in Table 4.9. Thus, for example, a 600 kg Friesian cow
the effective rumen degradable protein (ERDP). A cow
producing 20 kg/day of milk, in calf and gaining 0.5 kg/
has a need for both rumen degradable protein (both
day liveweight would require:
quick and slow) and rumen undegradable protein.



Different feeds contain different proportions or ratings

for the first 120 days of lactation. As yield declines and

of these. Thus silage is about 80 per cent degradable and
appetite increases then balance should be reached
soya is about 60 per cent degradable. Also, degradabil-
and then any liveweight loss in early lactation can be
ity does depend on the form of the feed, thus heating
replaced in mid to late lactation (see Fig. 4.7 and
or formalin treatment reduces rumen degradability. The
Chapter 9). As will be discussed later, a compromise has
rate of passage out of the rumen also has an effect, with
to be achieved between biological efficiency and eco-
higher passage rates increasing the UDP.
nomic efficiency.

In many instances, although the protein supplied may
Very approximately, the most common feeds for
be sufficient in terms of its CP or DCP basis, it may still
dairy cows (grazing grass, grass silage and concentrates)
be deficient in either RDP or UDP. In early lactation
have a relative cost of 1 : 2 : 3. Therefore, greater profits
on a predominantly grass silage diet, any shortfall is
will be shown as the proportion of grass and silage in
likely to be in UDP; this explains the observed good

the total diet increases provided performance does not

response when fishmeal or soya was added. Meat and

suffer (see Fig. 4.8).

bone meal are also a good source of UDP but were

While flat rate feeding of concentrates is popular,

banned in Great Britain in 1988 for ruminants and in

particularly with total mixed rations (TMR), most

the rest of the EU finally in 2001. The EU also decided

farmers feed at least partly to yield. In most instances

to ban the use of fishmeal in ruminant diets from 1

January 2001, resulting in the loss of a major practical

source of UDP. However, it may return.

Feeding strategies

Many textbooks have been written on strategies for feeding dairy cows. The main principles are (i) to maximize DMI and (ii) to provide the cow's requirements as cheaply as possible. These two requirements are associated as the higher the DMI then the lower the energy concentration in the diet and hence the cheaper the production of the ration.

In early lactation of high-yielding cows, it will be difficult to satisfy their requirements within appetite. This

will result in a loss of bodyweight, perhaps 0.5 kg/day,

Fig. 4.7

Nutrient gap.

Fig. 4.8

Feeding silage at a barrier.

Table 4.11

Examples of possible cow diets.

Table 4.12

Main mineral requirement of dairy cows.

Stage of lactation

Ca

P

Mg

Na

Early

Mid

Late

Maintenance (g/day)

Liveweight (kg)

Concentrates (kg DM/day)

8

6

2

400

14

19

6

7

Silage (kg DM/day)

8

12

12

500

18

26

8

9

Total DMI (kg/day)

16

18

14

600

21

32

9

10

Energy supplied (MJ/day)

180

195

145

Energy required (MJ/day)

195

186

133

Production (g/10 kg milk)

Fat content of milk (%)

4.0

28

17

6

6

this is important as dairy cows are not similar enough

5.0

30

17

6

6

in their genetic make-up to allow feeding as if a single

animal. It also cannot work unless cows are all at the

same stage of lactation rather than calving over wide-

spread periods or all the year round. Thus most farmers

do to a certain extent ‘feed to yield’ or requirements,

consider are grassland production and grassland

whereby concentrates are allocated on an individual

utilization.

basis depending on the yield attained and/or condition

loss. In consequence, more concentrates are fed early

Grassland production

on in lactation and are reduced as lactation progresses.

Appetite is dependent on DMI so as concentrate con-

To get optimum production from grassland the basics

sumption increases, forage intake reduces. This has the must be correct. These include climate and soil type

effect of limiting forage intake in early lactation

about which little can be done. Grass grows best on a

as concentrates are normally eaten in preference to

medium loam soil with adequate summer rainfall.

forages. Table 4.11 shows the effect of this on the cow’s

These conditions are most often found in the west of

diet. For correct digestion the dry matter ratio between

England and Wales. Where soil is heavy and water-

concentrates and forage should be in the range 70 : 30

logged, then drainage can give good results. Conversely,

to 30 : 70 in early to mid lactation. Any lower and per-

in dry areas, irrigation has a part to play, although the

formance will suffer, any higher and digestion will

economics of grassland irrigation in Britain are ques-

suffer (see pages 829–32).

tionable on all except the driest farms. Soil acidity

should be corrected to a pH of 5.5–6.5.

Having achieved as near optimum as possible with

Minerals and vitamins

the basics the next area to consider is grass varieties.

The daily requirements for these must be adequately

For grazing, most seed mixtures are based on varieties

met if the dairy cow is to remain healthy and produce

of perennial ryegrass (Fig. 4.9). There are many recom-

effectively. The major essential elements are calcium,

mended varieties in the National Institute of Agricul-

phosphorus, magnesium, sodium, potassium, chlorine

tural Botany (NIAB) lists. Timothy is often sown, which

and sulphur. Table 4.12 gives the daily requirements for

adds some palatability and midsummer growth. Older

four minerals. The main vitamins required are A, D and

grass varieties such as meadow fescue and cocks-foot

E. As milk yields increase the mineral and vitamin

are not often sown now. Most mixtures will also include

requirements become more critical. They should always

some white clover. This provides nutrients by fixing

form an integral part of the ration. When proprietary

atmospheric nitrogen and also increases intake by

concentrates are fed these will usually produce

improving the palatability of the sward. But clover is

sufficient of these nutrients for the productive cow.

difficult to establish and maintain in grassland receiv-

However, where rations are all or nearly all TMR then

ing high levels of fertilizer nitrogen.

addition of adequate amounts of vitamins and minerals

Once established, and with good management, a

is essential.

grazing sward should remain highly productive for 10

years or more. The main enemy to this is grazing in too

wet conditions, when treading and poaching will quickly

Grassland farming

destroy a sward and allow weed grasses to establish.

Swards mainly for cutting are usually based on a shorter

Grass and its derivatives, hay and silage, form an impor-

term perennial ryegrass or Italian ryegrass. These have

tant part of dairy farming. The two major aspects to

a more erect growth habit and are easier to cut but are

Fig. 4.9

Cow set stocking, grazing a rye-

grass sward.

Fig. 4.10

A good response is shown from

nitrogen fertilizer.

not so persistent. They are often grown as a grass break

Having established the grass the fertilizer require-

in an arable rotation for two to three years. Often the

ment must be satisfied. Normal recommendations for

species are sown pure. If clover is required then red

grazing would be an annual application of 300 kg/ha

clover is more suited to a cutting regimen than white

nitrogen, 40 kg/ha phosphate and 40 kg/ha potash.

clover. In between these extremes are many dual

Under a cutting regimen the nitrogen and potash

purpose mixtures that are both grazed and cut during a

would be increased to 350 and 150 kg respectively.

season.

Whilst phosphate and potash are essential for grass

The best time to sow grass is in August–September.

growth the main response is shown to nitrogen. Much

This gives it a chance to establish before winter and

trial work has been undertaken showing a good

to be in full production the following spring. A

response up to 400 kg/ha, but the average nitrogen spring reseed in April–May will lose much of the first

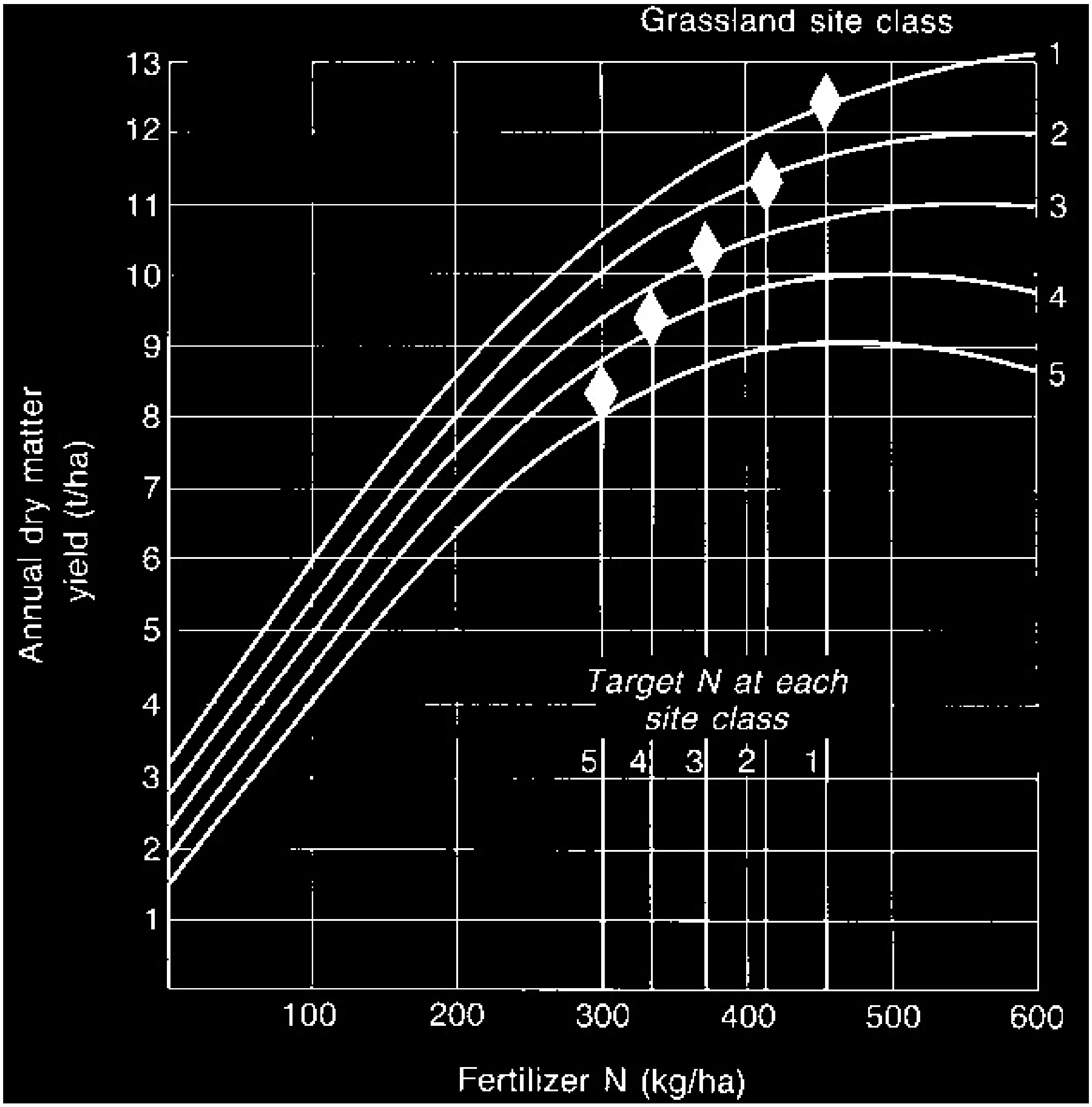
use is still under 200 kg/ha (Fig. 4.10). Researchers

year’s production and can be vulnerable to summer

have defined a target nitrogen use as being the point

drought.

in the response curve where 10 kg of grass dry



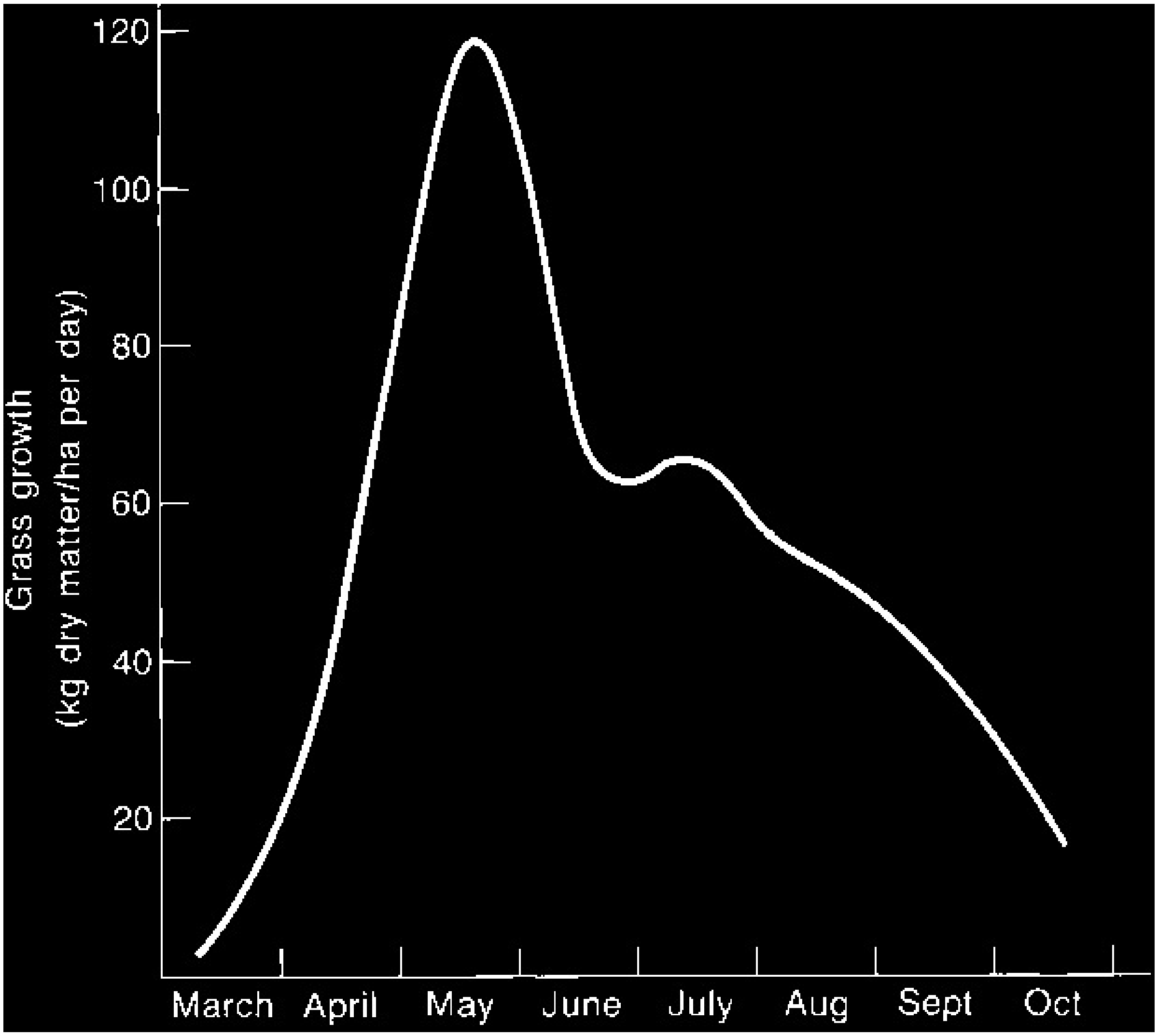


Fig. 4.12

Seasonal pattern of grass growth. Source: *Milk from Grass* (GRI and ICI).

Fig. 4.11

Target nitrogen on five site classes. Source: *Milk from Grass* (GRI and ICI).

matter are produced for each 1 kg of fertilizer maximum area to be cut without affecting milk

nitrogen. Nitrogen use is now controlled in many

production. Maintenance plus 20–25 l/day of milk can

areas.

easily be obtained from spring grass. For an autumn-

Figure 4.11 shows the target point for five site classes,

calving cow, as grass declines so milk yield declines and

class 1 being the most suited to grass growth and class

there should be no need to introduce supplementary

5 the least suitable.

feeding. Spring-calving cows may need supplementary

feeding to sustain yields in the summer. This may be

concentrates or forage crops such as rape or stubble

Grassland utilization

turnips.

Grass growth is uneven through the year with a peak in

Efficient conservation is a vital part of grassland

the spring and then falling away through the growing

management. It both provides a feed for winter use by

season (Fig. 4.12). Grass growth will also vary greatly

the cows and aids grassland management by utilizing between seasons depending mainly on the summer

grass surplus to the grazing requirement. The main

rainfall. Nor are the animal requirements even over the

options for conservation are either hay or silage. There

season. For all these reasons any system of grassland

is a continuing move away from hay towards silage on

utilization must be flexible and adaptable to cover any

dairy farms because:

situation.

• it is more flexible and integrates better with grazing;

The overall aim is to provide the cow with her

• silage is a better feed for dairy cows;

maintenance requirement and as much of her produc-

• silage can be made in poorer (not poor) weather

tion as possible for each day of the year. This will be

conditions; and

achieved with an integrated grazing and cutting system

• silage can respond to higher levels of fertilizer

whereby in early season about one-third of the grass

nitrogen use.

area is grazed and two-thirds is cut. This is reversed in mid season and then the whole farm is grazed in the

However, silage making does require a higher capital

autumn.

investment in both machinery and storage areas (Fig.

The most common systems of grazing management

4.13). Much of this criticism has now been overcome by

are either continuous grazing or rotational grazing with

the use of contractors and with the advent of big bale

paddocks or strip grazing. There is little to choose

silage. These have given even the smallest dairy farm

between systems in terms of output so choice is down

the opportunity to improve grassland utilization and

to personal preference and ease of management.

profitability by changing to silage making.

Under any system, cows should be stocked at a heavy

Whilst grass is the most important forage crop, refer-

density (6–8/ha) in the spring, which will allow a

ence must be made to other forage crops that may have

Fig. 4.13

Silage making with a precision

chop forage harvester.

a place on dairy farms by producing heavier yields

Kale

than grass or producing feed in a season when grass is

This is a high protein green feed grown mainly for

not available. The most popular forage crops are

grazing in the autumn and early winter. It produces a

maize, fodder beet, kale, lucerne, and stubble turnips

high yield of succulent feed that stimulates milk pro-

and rape.

duction. It can be cut and fed to dairy cows in the yards

but is more commonly grazed, which means that it

Maize

should be grown in dry fields with good access. Mud,

dirty cows and bad feet can be a problem. However,

This is increasing in popularity in southern England and

some have successfully made silage.

is normally made into silage but can be fed green. To

be successful it requires high summer temperatures so

even in southern England a sheltered field should be

Lucerne

used. It produces a similar or heavier yield per hectare

than grass and has the advantage of being harvested in

This is a drought-resistant legume that grows well on

one cut. The resultant silage is a very palatable, high

light chalky soils. Being a legume it fixes atmospheric

energy, low protein feed that improves a winter ration.

nitrogen and hence is cheap to grow once established.

It is often mixed with grass silage in the proportion

Cut four or five times during the season it provides

1 : 1 to 1 : 4 maize: grass but can successfully be fed on

good yields of high protein silage, but it can be difficult

its own.

to get a good fermentation in the silage. A useful crop

for organic farms with suitable soils.

Fodder beet

Stubble turnips and rape

This has about the highest yield of dry matter per unit

area of any fodder crop. It can be grown successfully

Although these are not the same they are used for the

anywhere but prefers a heavier soil. It is an arable crop

same purpose – to provide a succulent green feed either

and the farmer needs arable techniques to grow it

in the summer or autumn. For summer use they need

successfully, especially for establishment, weed control

sowing in the spring but autumn grazing can be

and harvesting. It is harvested in October/November

achieved by drilling after harvesting an early cereal

and stored for winter use. It provides a palatable high

crop. They both provide grazing when feed might

energy feed, which helps butterfat percentages.

otherwise be short.

Fig. 4.14

Self-feeding silage.

Winter feeding systems

silage quality is even throughout the clamp, that the

face is not more than 2 m high and that there is enough

A winter feeding system will be partially dictated by the

space at the face, 24 hour access of at least 40 cm/cow.

objectives, high or low milk yields, and by the facilities

To avoid secondary fermentation the silage face

available.

needs to move back by at least 150 cm/day. Self-feeding

In all cases the first requirement is to know the quan-

is labour saving and requires no machinery. It is better

tity of bulk feeds available. Over a 200-day winter a but not essential to have a roof over the silo and intakes

Friesian cow may well consume about 3.5 t of dry

will improve if a light is left on at night. Keep cows back

matter. If there are 2.2 t of silage dry matter per cow

from the silage face with a barrier, either a solid rail or

then this will leave 1.3 t to be made up with concentrates

an electric wire. The latter, however, can often reduce

or other purchased feed. Provided there are about 1.8 t

intake. To prevent waste the face must be kept tidy and

of forage dry matter for a 200-day winter then a rea-

waste silage removed.

sonable feeding system can be devised. This equates to

Mechanical feeding of silage will either involve

about 7 t/cow of fresh weight silage. Anything much less

putting the silage in a trough or behind a barrier with

than this will create problems, not so much from the

a tractor and fore-loader/blockcutter or else loading the

cow's point of view but from the economic side as it will

silage into a forage wagon that will spread it behind the

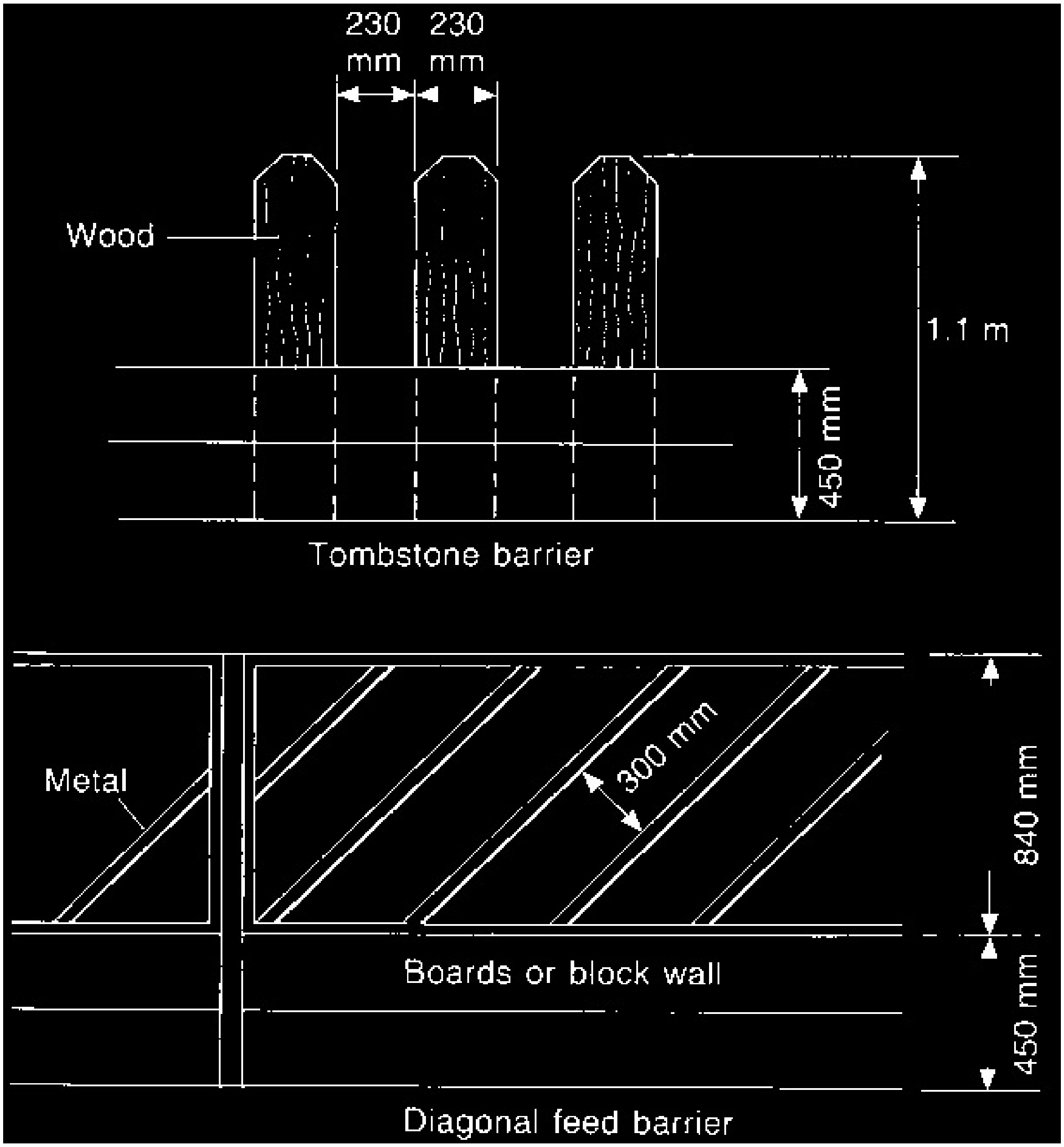
tend to be an unprofitable winter. Anything more than

barrier. Many people claim that this will increase intake

this will be a bonus and an asset to the farm especially
compared with self-feeding by 10 per cent or more. Two
if of a high D value.
simple barrier designs are shown in Fig. 4.15.
All feed changes should be done gradually to prevent
For 24-hour access the herd will need a minimum
digestive upsets. Thus silage should be gradually intro-
feed space of 40 cm/cow, but space of up to 75 cm is now
duced on a limited access basis from calving or by mid-
often recommended for best intakes. Again cleanliness
September, whichever is the earlier. The herd should be
is important and waste silage should be removed on a
housed at night by some time in October depending on
regular basis, preferably at least once daily. It is impor-
conditions and then housed continually from mid-
tant to ensure that silage is always available *ad libitum*.
October onwards, again depending on weather condi-
Leaving the trough empty for two to three hours before
tions. Over this period silage consumption will increase
feeding will suppress intake and can cause digestive
and other feeds can be gradually introduced. The same

problems. It is a tremendous advantage to a winter
principle applies in the spring, when ideally the herd
feeding system to have a trough or barrier available as
should be kept inside at night on silage for seven to ten
almost any feed can be fed behind it, from silage to hay,
days after turning out with grazing time gradually
roots, brewers grains, sugar beet pulp or concentrates.
increased.

This gives a great flexibility. When feeds such as
Silage will either be self-fed (Fig. 4.14) or fed
dried beet pulp or concentrates are fed it is essential to
mechanically behind a barrier or in a trough. Self-
have at least 60 cm/cow of trough space to ensure a rea-
feeding works well for low yields, provided that the
sonably even intake among cows.


230 mm
230 mm
Wood
1.1 m
450 mm
Tombstone barrier
Metal
300 mm
840 mm
Boards or block wall
450 mm
Diagonal feed barrier

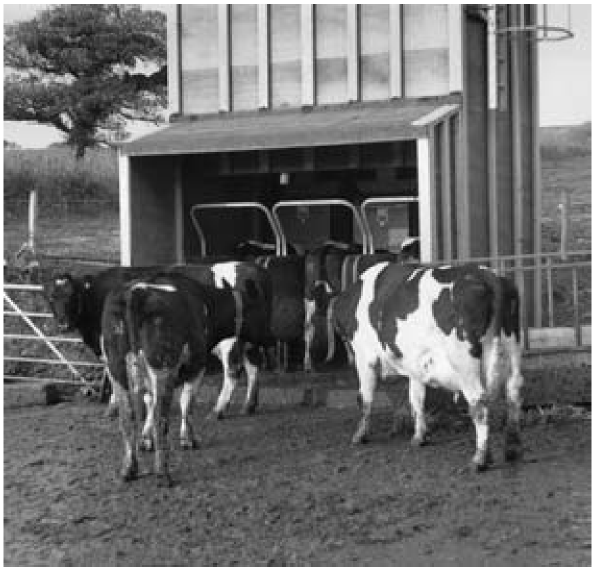


Fig. 4.16

Cows at a computerized out-of-parlour feed station.

Fig. 4.15

Two types of feed barrier.

A sophistication of this system is complete diet

with alternative feeds such as cereals, maize gluten or

feeding or total mixed rations (TMR). Here all the

sugar beet pulp.

feeds are placed in a mixer wagon, which mixes them

A sophistication of this system is with computerized

together and delivers the diet behind a feeding barrier.

out-of-parlour feeders (Fig. 4.16). Each cow has a

Because of the degree of mixing the cow is unable to

transponder identifying her to a feeder station. This is
separate out, say, barley from silage and so eats the
then programmed to allow a specified amount of feed
whole mixture uniformly. Ideally the wagon has weigh
per day in a number of feeds. The cow can then eat up
cells so giving a very accurate measurement of feeds.
to her allowance but no more. Although the capital cost
Use of a mixer wagon allows the feeding of a wide range
of these installations is high they make for very accu-
of feeds that may represent a very economical buy,
rate feeding, based on the sound principle of ‘little and
but which are normally either difficult to feed or
often’. They perhaps demonstrate the way dairying will
unpalatable, e.g. molasses and rapeseed meal. It also
go in the future. Printouts can be obtained for cows not
allows much more satisfactory feed digestion within the
consuming their allocated amounts.
rumen and further down the alimentary tract. Some
In all feeding systems water must not be overlooked.
farmers are now buying straights and producing their
With milk being 86 per cent water any shortage of water

own complete diets, usually with the help of a nutri-

will quickly limit milk production. A dairy cow will

tionist. Attention is being focused on straights and

need 60–100 kg of water per day and being creatures of

ensuring that they are stored in satisfactory containers

habit tend to all want to drink at the same time, espe-

which allow the feed to be kept dry, vermin and bird

cially late afternoon. This makes a large reservoir and

proof. The introduction of herd health and quality

fast flow of water essential. The volume drunk will

assurance schemes has drawn attention to how feeds

increase as milk yield increases and in dry hot weather,

are stored. On some farms forage boxes are used

so that 120 litres or more is not uncommon.

instead of mixer wagons, but these do not really mix up

the feed.

Most milking parlours have facilities to feed concen-

Dairy farm buildings

trates and it is usual to feed these twice per day at

milking time. A limit to be fed during each milking

Because of the diverse nature of dairy farming there are would be 4–5 kg. If anything above this is needed then

almost as many different designs of dairy building units

an out-of-parlour feed at the barrier is beneficial. This

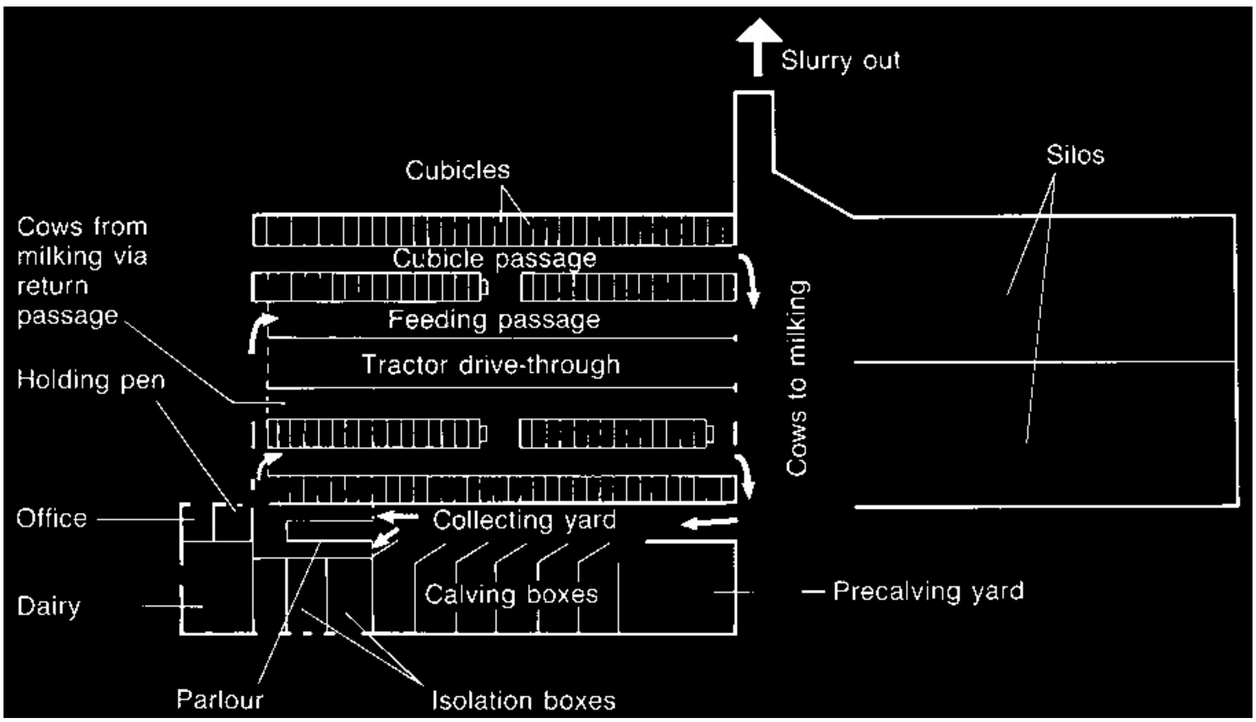
as there are dairy farmers.

not only splits the feeds, which helps digestion, but also

However, if starting from scratch the main needs are

allows a proportion of the concentrate to be replaced

for a milking parlour and dairy, winter housing and



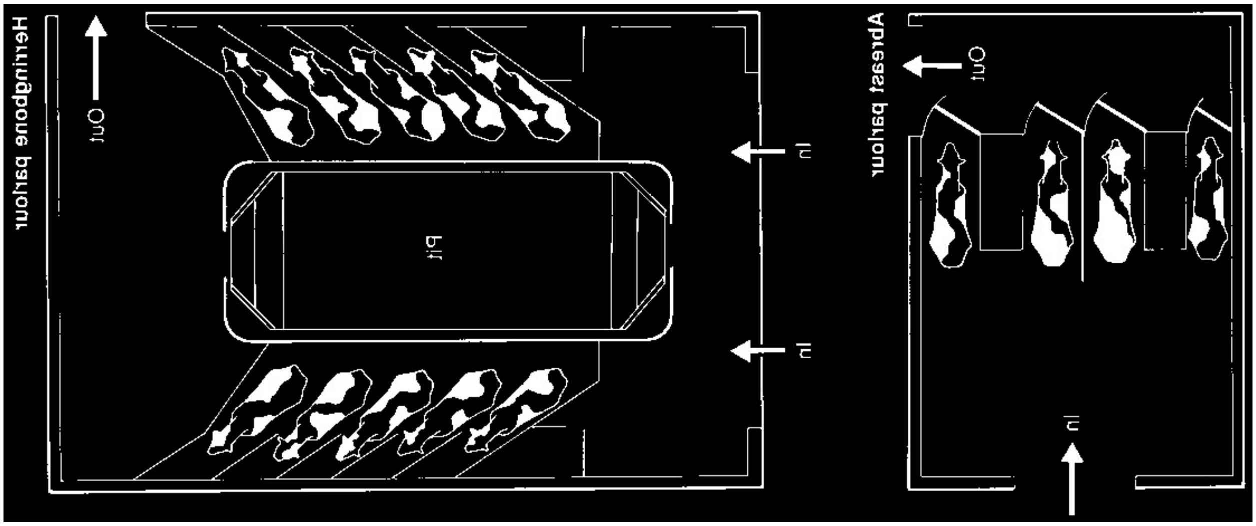


Fig. 4.17

Typical layout of a dairy unit.

feeding barn, food storage area, calving and isolation boxes, slurry handling area and various collecting yards and access concrete. A typical set of dairy buildings is shown in Fig. 4.17.

Important considerations when designing a dairy unit include the following.

- Cow-free access for the milk tanker so that collection can be made at any time.
- Good cow flow so that cows come from the bedded area through the parlour and back with a minimum of narrow passages and sharp corners.

• Good feeding access so that cows can be fed without having to work amongst them.

• Access to silage storage areas away from the cows so that silage making can take place while the cows are in the yards or in for milking.

• Good handling arrangements for veterinary treatment and AI.

• Adequate slurry storage as spreading may be restricted in nitrogen vulnerable zones.

• Thought should be given to the way the buildings blend in with the surroundings. Choice of materials and site are important.

• Adequate loose boxes for calving, sick animals, etc.

Parlour and dairy

This is the key to the whole dairy unit, being used twice (or three times) a day 365 days of the year. Cowsheds are very labour intensive and outdated while rotary parlours in the past have proved unreliable, with no benefits over a static parlour but are now becoming more common again. Automatic (robotic) parlours are also now being introduced. Figure 4.18 shows the most common parlours used, an abreast and a herringbone parlour.

Fig. 4.18

An abreast and a herringbone parlour.

The most simple parlour is the abreast, which is particularly suitable for herds of up to 80 cows with one man milking either with three milking units and six standings or six units and six standings. The cows enter and leave one at a time so a degree of individual treatment for a slow milker or slow eater is possible. The parlour should have a loft above to hold the concentrates, which fall by gravity to the feeder situated between each pair of cows. Milking rate will be about 30–40 cows/hour.

In a herringbone parlour, by far the most common, the milker stands in a pit, which removes most of the bending required. The cows come in and out of the parlour in batches and stand at an angle to the pit on either side. A herringbone parlour is suitable for any sized herd and one man could comfortably milk 100 cows in two hours with a 10 : 10 herringbone, i.e. 10 milking units, 10 standings. For 300 cows or more larger herringbones with two or three milkers are common. A loft above the parlour will hold the concentrates and each standing will have a feeder. In some parlours feeding has been discontinued.

Automatic cluster removers (ACRs) are now available that make it possible for one man to handle more machines without the danger of overmilking.

Fig. 4.19

A feed/sleep arrangement with metal cubicles.

In any parlour the work routine is to let the cow or group of cows in, feed them, dry wipe the udder or wash

and dry if dirty, wash the udder, test the foremilk, attach
3 tonnes per cow), which creates work to cart in and
the cluster, remove the cluster, teat dip or spray, trans-
take out each day. But straw yards do help to alleviate
fer the milk and let the cows out. Pre-milking teat
a problem by reducing the volume of slurry produced.
dipping is practised in some herds, especially those with
Cubicles (see p. 422) have gained in popularity and,
high levels of environmental mastitis.
well designed, can be a very trouble-free system with
The dairy should be adjacent to the parlour and will
a low demand on labour (Fig. 4.19). The main require-
contain some dairy equipment such as the vacuum reg-
ment for comfort is to make the cubicle large enough,
ulator, milk pump, water heater and washing equip-
about 1.2 m wide and 2.2 m long, with a good lying
ment. The bulk milk tank will also be situated here. The
surface. They can be made of metal or timber and a
capacity of the bulk tank is important and must be suf-
typical design is shown in Fig. 4.20. This design is for
ficient to hold the likely peak milk production. Except

Friesian cows and does not offer sufficient flexibility for
in a herd with a very compact calving pattern about
many high-yielding cows and so ones such as in Figs
30–35 litres/cow capacity is normally sufficient.
4.21 and 4.22 are used. Other new models are also avail-
Both the parlour and dairy must be kept scrupulously
able. The measurements of an ideal cubicle are given in
clean and in Britain will be inspected regularly by the
Table 4.13.
authorities. The motors and refrigeration unit should
The cubicle should slope from the head to tail end
be housed separately in an engine house. It is also
and the best surface is concrete with mattresses, mats
useful to have a small area near the parlour where
or sand as a bed. A strategically placed headrail is
the cowman can keep the records necessary for herd
essential to ensure the cow dungs in the scraper pas-
management.
sageway. Passageways should be at least 2.4 m (8 ft)
wide to allow for good cow flow and sufficient width for
the scraper.

Cow housing and feeding barn (Chapter 56)

The whole cubicle and scraper passageway can either

The choice for cow housing will rest between housing

be situated within an open span building or be part of

in straw yards and cubicles.

a purpose-built cubicle building. For all situations it is

Cows often appear more comfortable in a straw yard

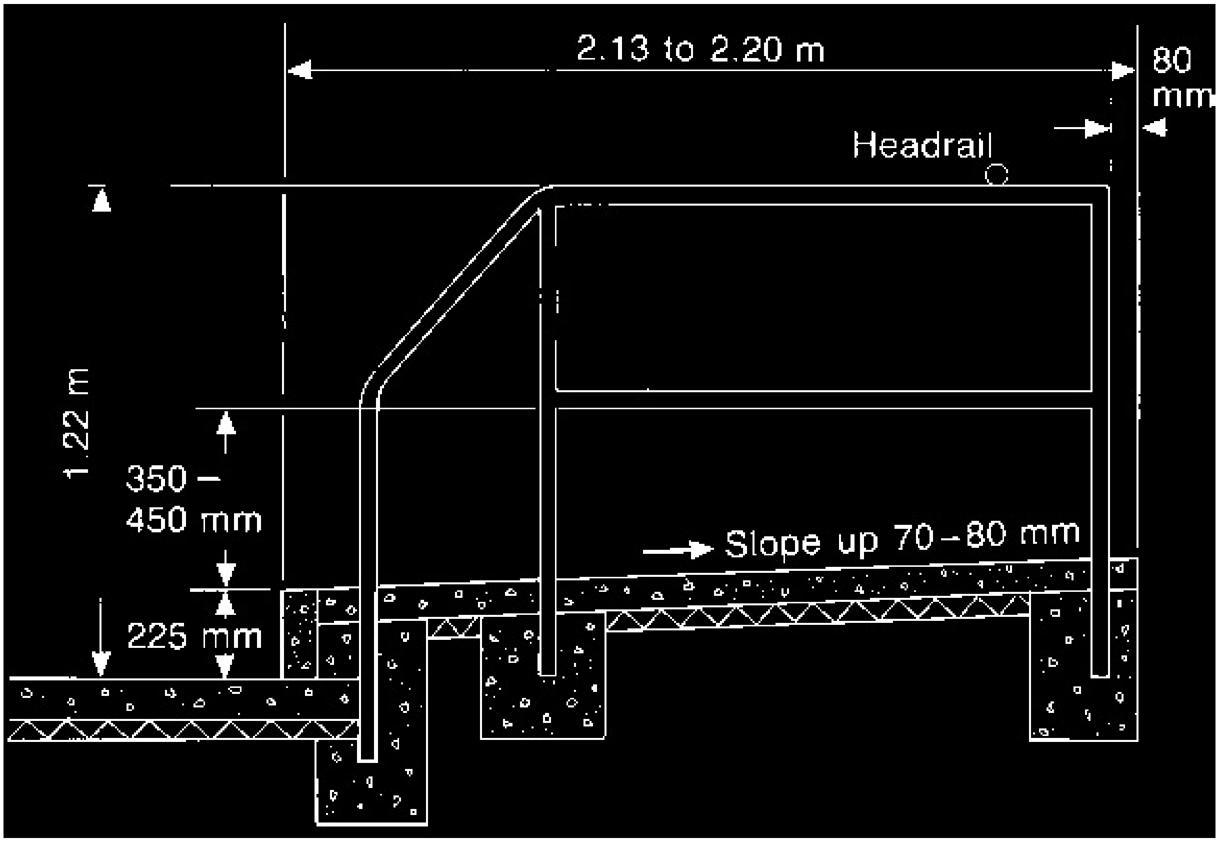
important to have a draught-free environment with

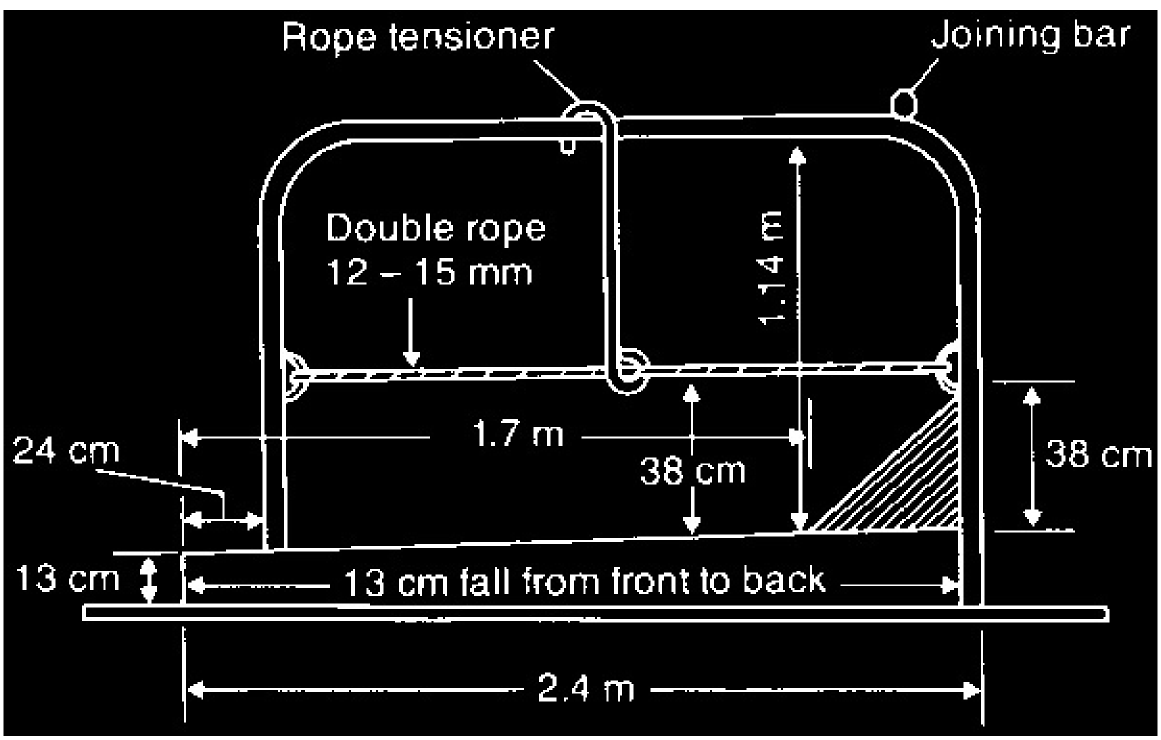
but if they are to keep clean they need about 6 m2/cow.

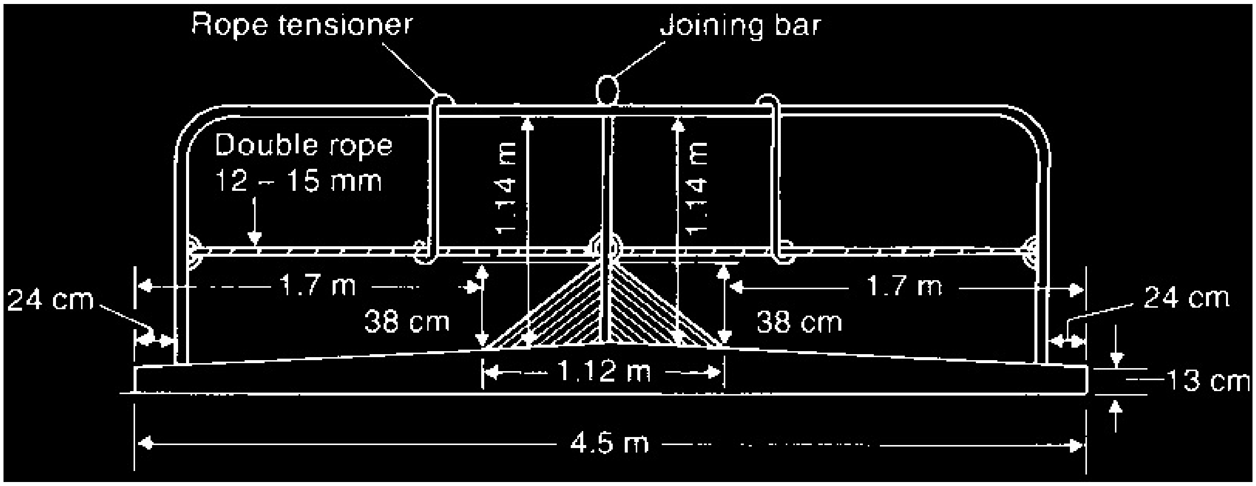
plenty of ventilation. This is normally achieved by the

They also use a lot of straw over a winter (about 2.5–

use of Yorkshire boarding (vertical boarding with gaps


2.13 to 2.20 m
80 mm
Headrail
1.22 m
350 – 450 mm
Slope up 70 – 80 mm
225 mm


Rope tensioner
Joining bar
Double rope 12 – 15 mm
1.14 m
1.7 m
24 cm
38 cm
38 cm
13 cm
13 cm fall from front to back
2.4 m



to allow free movement of air) or with an open ridge to

the whole herd into groups, by milk yield or calving

the building or kennel.

date, which can assist management.

With either straw yards or cubicle beds, the feeding

There has been increasing emphasis on cow comfort,

areas can be either inside or outside the building. An

particularly from the point of view of preventing lame-

inside area is preferable but will add to the cost. An

ness and providing suitable conditions to ensure that

example of an arrangement with a centre feed passage

cows lie down for similar lengths of time as they do when

is shown in Fig. 4.23.

at grass. This is difficult or impossible to achieve with

The advantages of this type of arrangement are that

cubicles and so some farms have altered accommodation

the cows can be shut in the feed area while the cubicles

to straw yards (see Figs 4.24, 4.25 and 4.26). Such alter-

are scraped and vice versa. Feed can be put out without

ations do require sufficient space for each cow (see Table

driving through the cows and it is also possible to split

4.14). They can result in rapid improvement of locomo-

tion scores, and considerably reduce lameness due to

white line disease and solar ulceration (Hughes, 2000).

However, mastitis levels can rapidly increase, particu-

larly due to *Strep. uberis* and *E. coli*, unless great care is taken in producing a satisfactory straw bed. The keys to

success include making available a large quantity of

straw for each cow (about 2.5–3 tonnes) and ensuring

that it is kept dry when stored and the bed remains dry.

Regular cleaning out every 4–6 weeks may help prevent

mastitis problems, but this is possibly less important than

the quality of the straw used. Good ventilation is also

required to help keep the straw bed dry.

Feed storage area

The major item here is the silage storage facility. This can range from a tower silo to a simple hardcore pad.

Fig. 4.20

A metal cubicle division.

Construction of a simple silo is worthwhile to make handling easier and to prevent waste. Clamp silos are the most common and are usually constructed with a concrete base and walls of earth, sleepers or concrete. Safety is essential and in Britain walls must be up to DEFRA (Department for the Environment, Food and Rural Affairs) standards bearing in mind the walls have to contain not only the weight of the silage but also pressure from the tractor when consolidating the clamp. For open silos, guide rails must be provided 900 mm above the wall and for roofed silos sufficient height (5.5 m) must be allowed for tractor clearance. All effluent must be contained in a sealed tank that can be pumped out. For self-feeding of silage the height of clamp must not

Fig. 4.21

A cubicle suitable for a Holstein cow (courtesy of

be more than 2 m and capacity will need to be about

J. Hughes).

12–15 m3 per cow for a winter's storage. If other feeds

Fig. 4.22

A double fronted cubicle suitable for

Holstein cows (courtesy of J. Hughes).

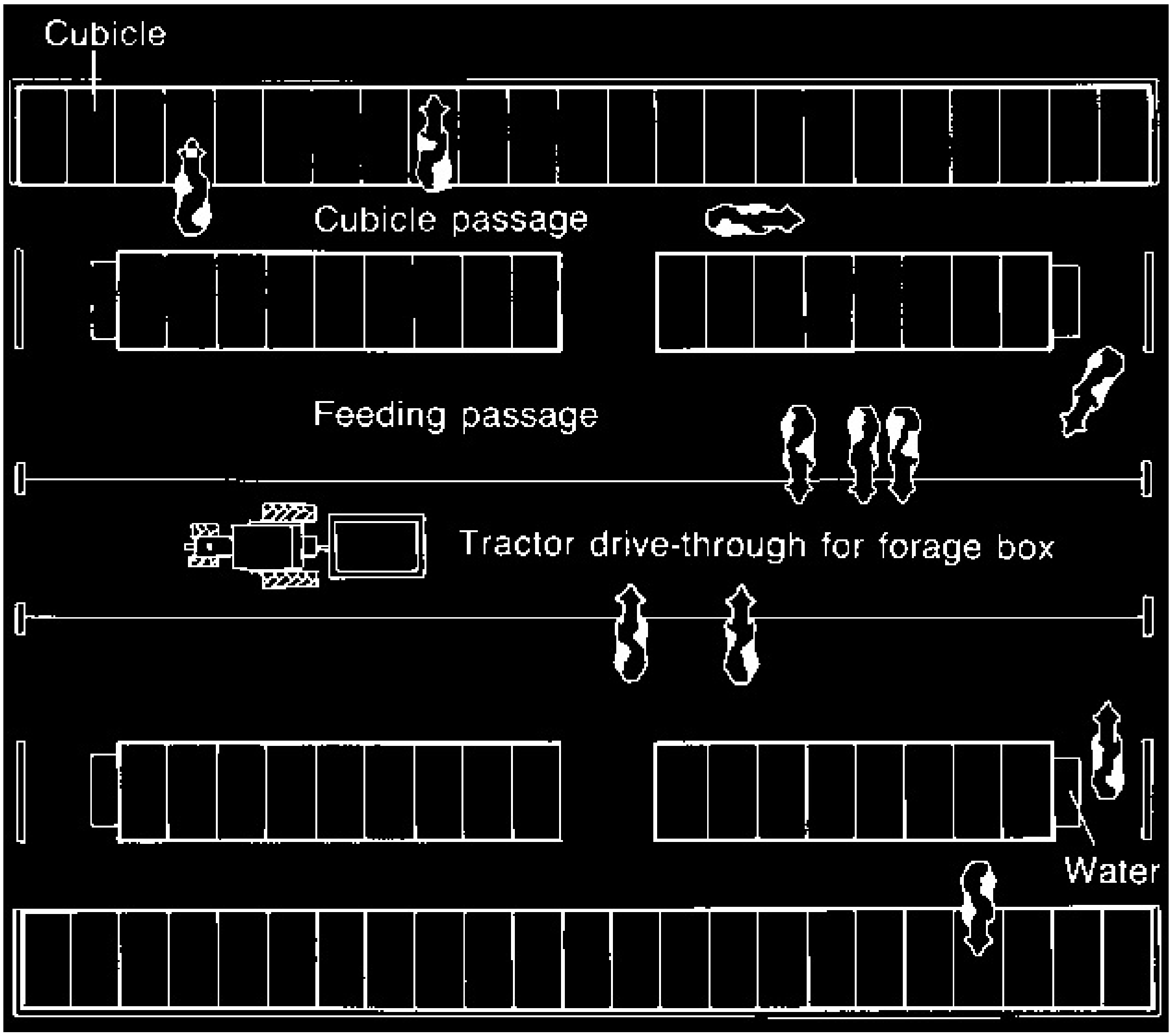


Table 4.13

Measurements of cubicles suitable for high yielding Holstein cattle as determined in Britain (adapted from Hughes, 2000).

Measurement

Metric (Imperial)

Length

2.4 m (8 ft)

If double fronted cubicles with concrete fillet so maximum forward lungeing space length can be reduced to 2.28 m (7 ft 6 inches) Width

1.2 m (4 ft)

If width 1.14 m (3 ft 9 in) there must be a flexible lower barrier Rear step

<150 mm (6 inches or less)

Fall (front to rear)

100–125 mm (4–5 inches)

Division height

1.14 m (3 ft 9 inches)

Lower division rail (flexible)

400 mm (1 ft 4 inches)

Barrier thickness ideally flexible – at least

19 mm (3/4 inch)

Brisket board

100 mm (4 inches)

Brisket board from front

0.75 m (2 ft 6 inches)

Brisket board from rear

1.7 m (5 ft 8 inches)

Sloped concrete fillet (instead of brisket board) height

38 cm (1 ft 3 inches)

Concrete fillet from heel stone

1.7 m (5 ft 8 inches)

Barrier (above fillet) if head to head cubicles

76 cm (2 ft 6 inches)

Head rail (below average wither height) 1/5 cubicle length from front 150–250 mm (6–10 inches)

cows can be restrained for veterinary treatment or

insemination. They require a separate air space.

Boxes should be reasonably spacious and must have

a tying-up ring or some other method to aid cow

restraint. Walls must be rendered so that disinfection

can take place. It is also useful to have a water bowl and

feed rack, tractor access for cleaning out and, maybe, a

milking point so that cows can be milked in the box.

Sick cows may die or have to be destroyed in the boxes

so good access for the slaughterer’s lorry is essential.

For a herd with spread calving pattern, one box for every 40–50 cows should suffice. Placing hinges and a swinging gate against a wall with the fixed end about 0.5 m (2 ft) from a corner is a useful method of restraint. It allows the gate to be swung round to restrain a cow between the gate and the wall.

Fig. 4.23

Sleep and feed arrangements.

Slurry

With more and more farmers using a loose housing and cubicle system, disposal of slurry is becoming an increasing problem. Also, water authorities are rightly are to be stored they must be kept in buildings which demanding more control of pollution. A dairy cow will can be made vermin-free so that the feed remains clean produce about 7000–8000 l (7–8 m3) of slurry over a and dry.

winter. This has quite a high fertilizer value (10 000 l will contain 25 kg N, 10 kg P2O5, 45 kg K2O) but much of this will be lost by leaching if it is spread during the winter

Calving and isolation boxes

when the soil is saturated. Also, the pollution risk is

These need siting in a convenient position to allow for

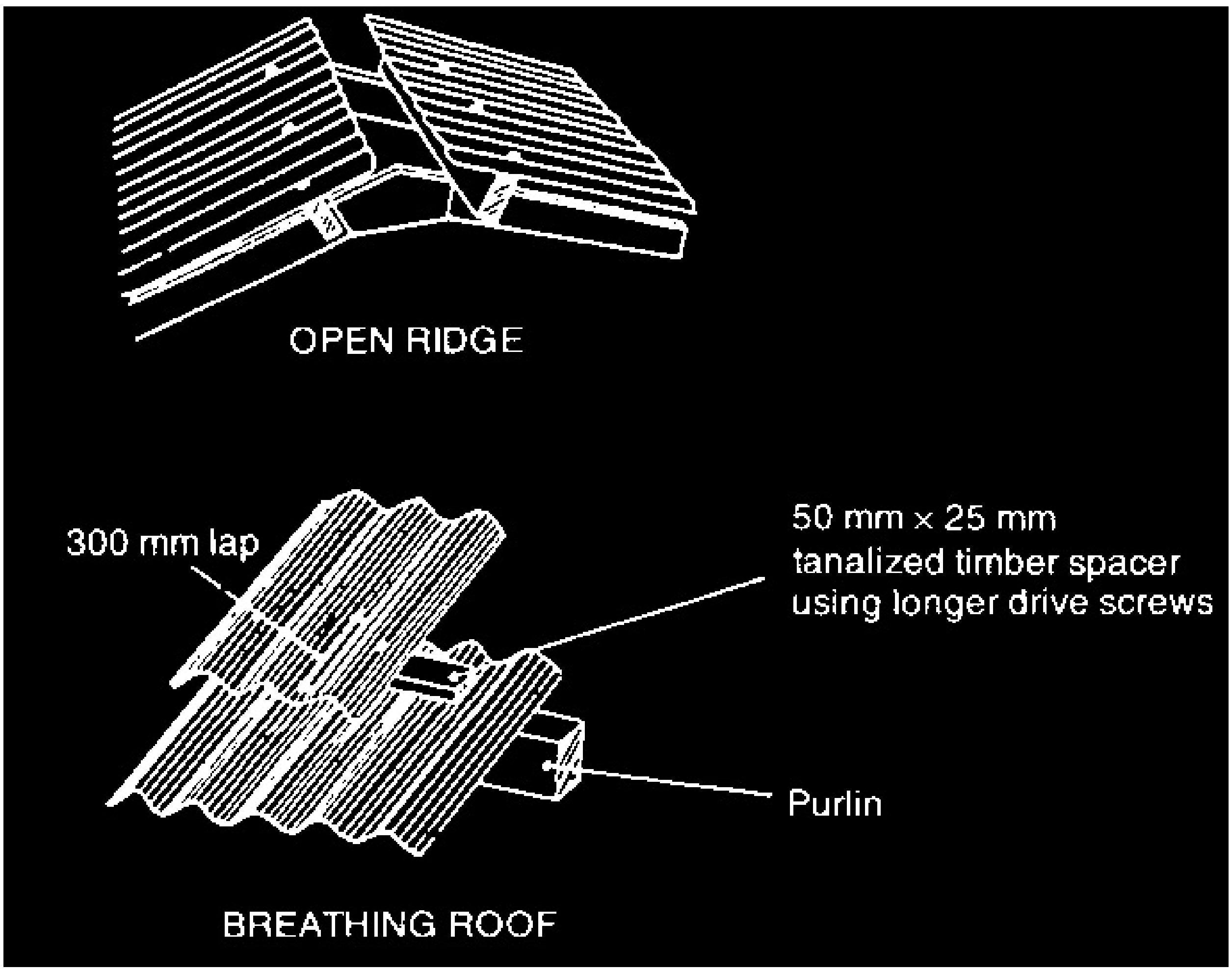
much increased. In the UK there are laws concerning

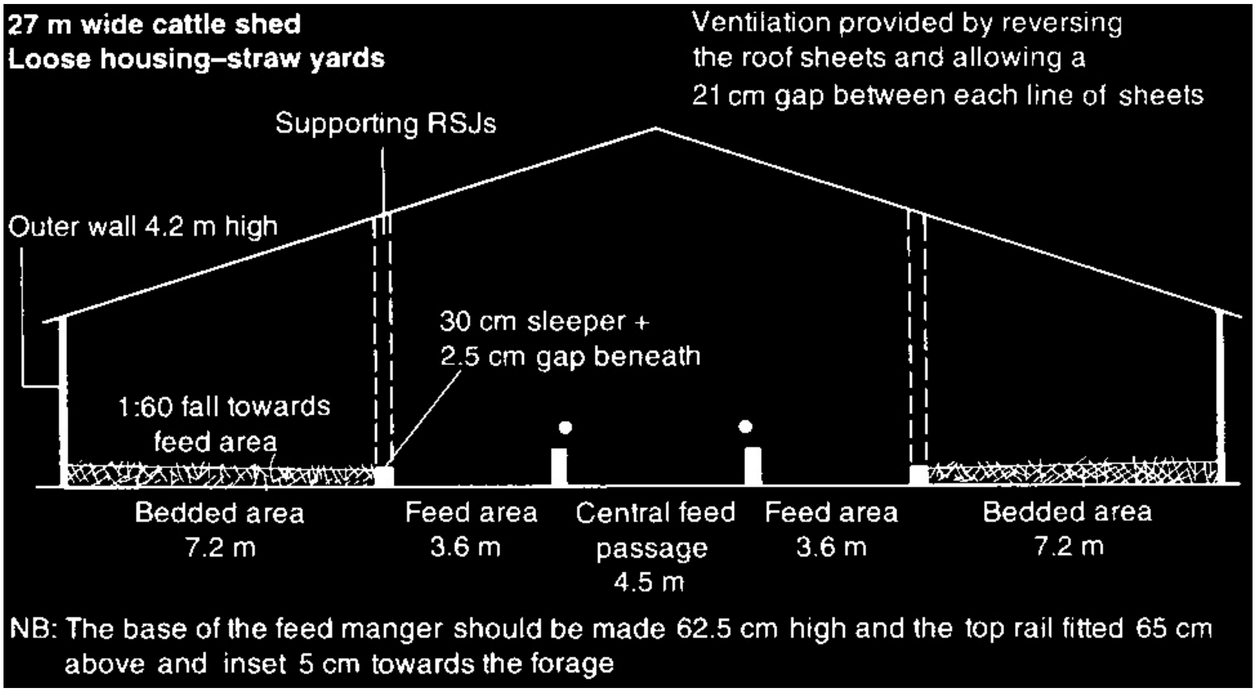
ease of entry and exit for cows. The area would

application in nitrogen vulnerable zones (NVZs).

also probably include a cow handling area where

Therefore, winter storage becomes almost essential.




27 m wide cattle shed
Loose housing–straw yards
Ventilation provided by reversing the roof sheets and allowing a 21 cm gap between each line of sheets
Supporting RSJs
Outer wall 4.2 m high
30 cm sleeper + 2.5 cm gap beneath
1:60 fall towards feed area
Bedded area 7.2 m
Feed area 3.6 m
Central feed passage 4.5 m
Feed area 3.6 m
Bedded area 7.2 m
NB: The base of the feed manger should be made 62.5 cm high and the top rail fitted 65 cm above and inset 5 cm towards the forage

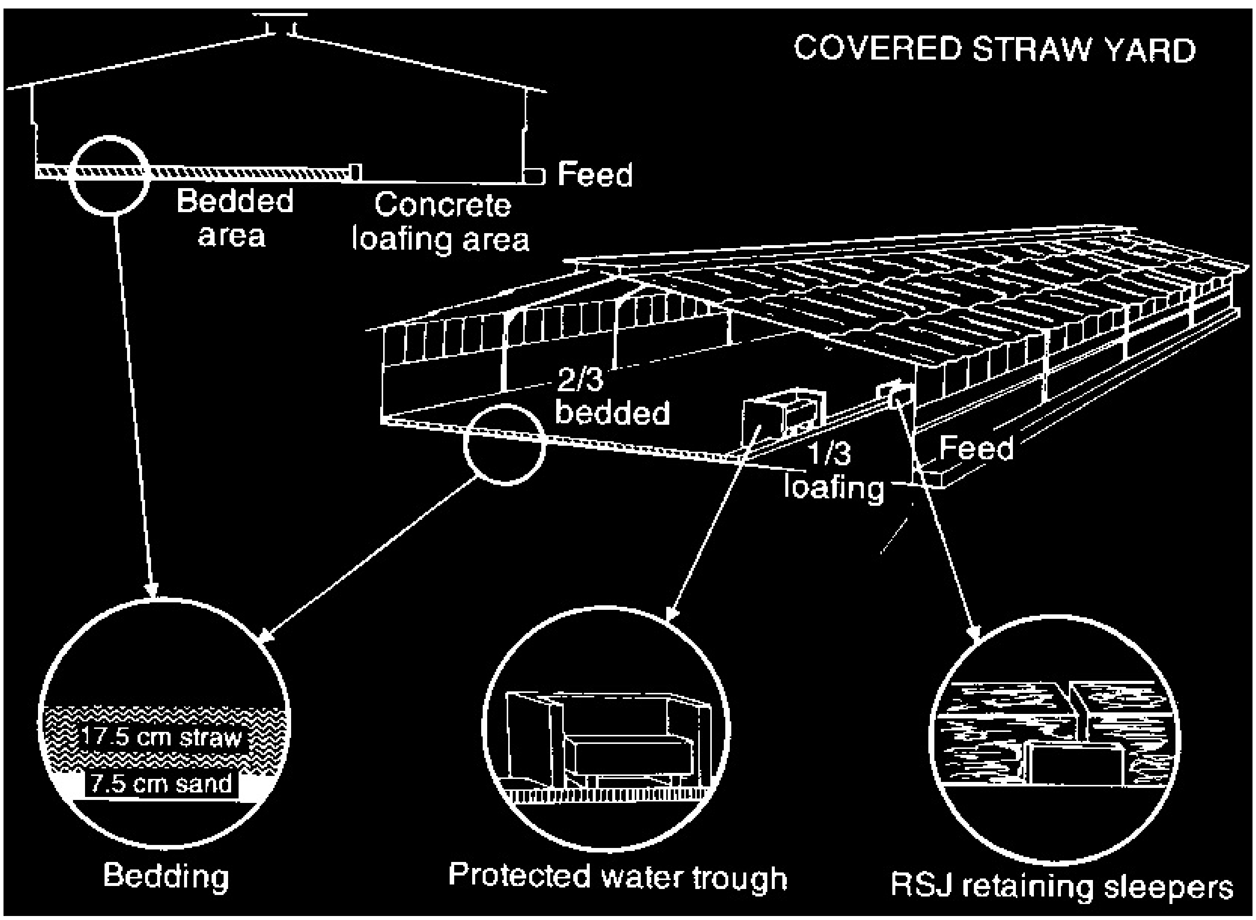

COVERED STRAW YARD
Feed
Bedded area
Concrete loafing area
2/3 bedded
1/3 loafing
Feed
17.5 cm straw
7.5 cm sand
Bedding
Protected water trough
RSJ retaining sleepers

Fig. 4.24

A 27.5 m (90 ft) wide
cattle shed with loose housing
(reprinted from Hughes, 2000).

Fig. 4.25

Structures within a covered straw
yard (reprinted from Hughes, 2000).

Slurry is usually scraped with a tractor-mounted squeegy to the store. The store must be able to cope with slurry, water, waste feed and bedding. It will reduce the volume considerably if clean water from roofs is diverted to a separate soak-away or drain.

Long-term storage can be provided in a sealed tower or a storage compound. With a slurry tower, the slurry is scraped into a reception pit and then pumped into the sealed tower. This is kept agitated to prevent settling or crusting of material. For emptying, the slurry runs back by gravity to the reception pit and is then pumped into the slurry spreader. It provides a good pollution-free system but is expensive to install and can create problems if management is not good leading to crusting and blockage of pumps.

By contrast the storage compound, although not

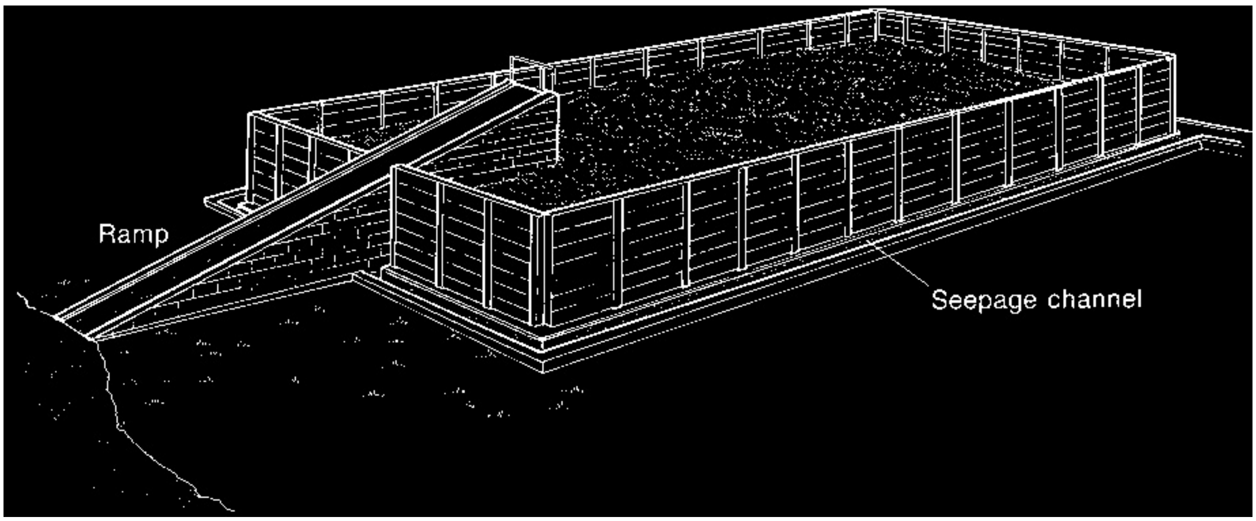
cheap to construct, provides a simple-to-manage system

Fig. 4.26

Ventilation for a covered straw yard (reprinted from

with very few problems. The compound should be large

Hughes, 2000).



enough to hold a winter's slurry, have a concrete or hard

sleepers (Fig. 4.27). This allows water to drain from the

base to facilitate emptying and a shallow ramp to push

slurry, which is collected and spread separately. This

the slurry up for filling. Slurry is pushed in all winter

considerably reduces the volume of material needing to and then at a suitable time emptying takes place with a

be stored for the winter and improves the handling of

tractor and fore-loader direct into spreaders. A sophis-

the remaining material.

tication is a ‘weepy wall’ silo with walls constructed of

timber or concrete sleepers with gaps between the

Herd records

Herd records are essential for management of the herd

Table 4.14

Space allowances for straw yards suitable for high

but they must be simple to keep, understood by the

yielding Holstein cattle as determined in Britain (adapted from Hughes, 2000).

farmer and his staff and of use in the herd management.

Before records can be kept, cows must be individually

Space allocation

Metric

identified. With herds becoming larger and to make

identifying cows by relief staff possible, this identifica-

Strawed area

tion must be permanent and clear.

Freshly calved cow

6.5 m2 (70 ft2)

Freeze branding with liquid nitrogen kills the pig-

Mid lactation cow

5.6 m2 (60 ft2)

ment cells in hair and results in a clear white number

Dry cow

4.6 m2 (50 ft2)

on black cows but is not so successful with light

Plus

coloured cows. Ear tags are also often used and can be

very clear if large. However, there is always the possi-

Loafing area

bility of losing tags. With the coming of new technology

All production stages minimum

2.3 m2 (25 ft2)

Thus total minimum

it is possible that most cow identification in the future

Freshly calved cow

8.8 m2 (95 ft2)

will be by transponder, either implanted into the cow

Mid lactation cow

7.9 m2 (85 ft2)

or worn on a collar or ear tag or placed in the rumen.

Dry cow

6.9 m2 (75 ft2)

For short-term cow identification, e.g. for a cow

needing treatment, etc., spray cans of different coloured

Optimum number per pen = 40 cows

paints or tail tape, sticky coloured tape, can be success-

Area per pen of 40 cows

fully used.

Freshly calved cows

350 m2 (450 yd2)

Computers are now used for keeping records for

Mid lactation cows

320 m2 (380 yd2)

most large herds, but this is by no means essential and

Dry cow

275 m2 (335 yd2)

the capital cost will result in a place for manual record-

• Maximum per pen with sufficient space = 60

ing in small herds for many years to come. Records kept

• Drainage in feeding area = 1 in 60

will be either physical or financial. In many countries

• Straw usage = 2.5t per cow

treatment records must also be kept.

• Feeding passage never less than 3.7m (12ft) wide

• Easy access from bedded area

Physical records

• Water – recess into bedded area but no access from bed

• Ventilation must allow moisture to escape – roof open

The notebook: The herdsman or farmer should always

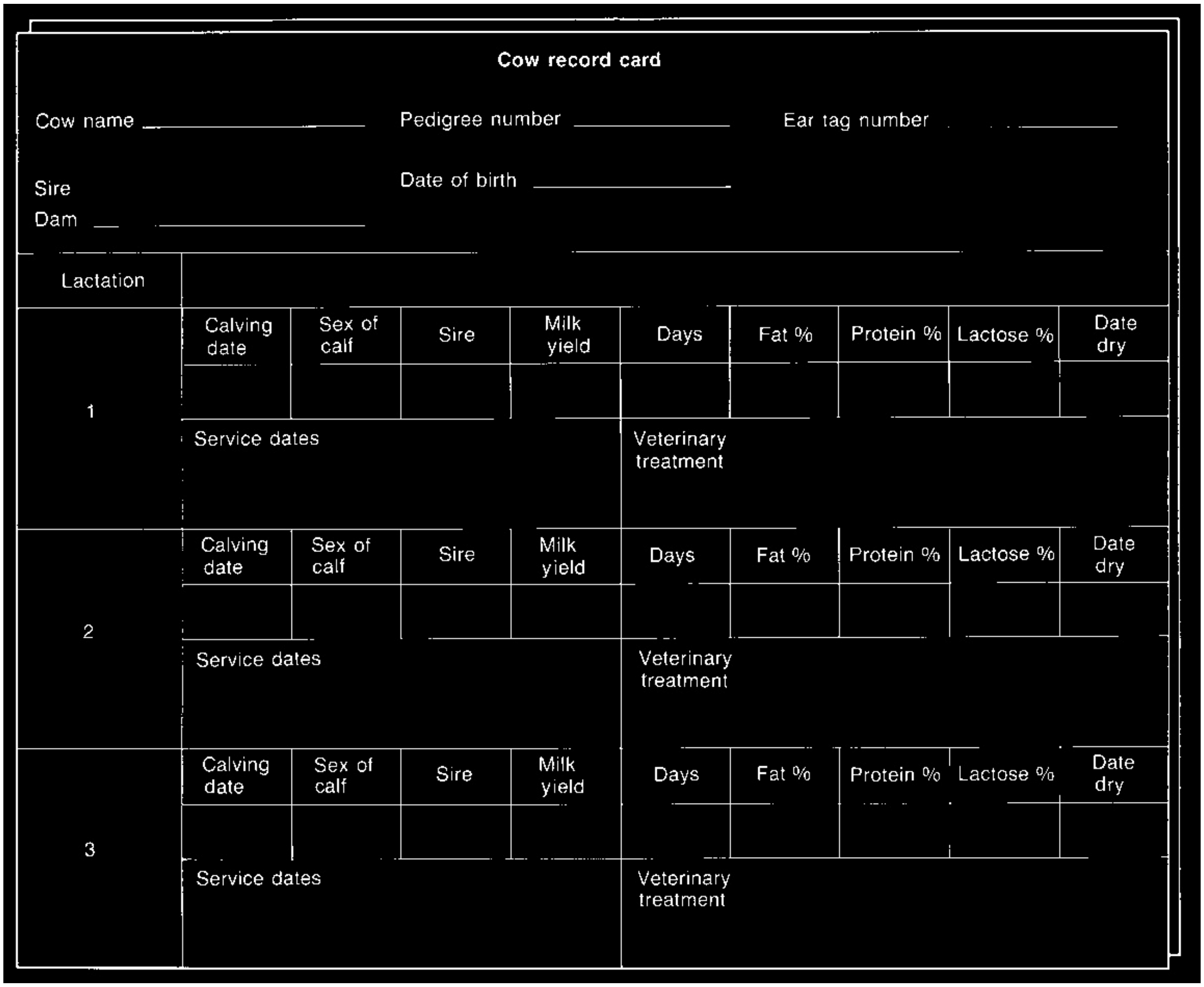
ridged, possibly breathing or gap roof

have a notebook in his pocket to record information

Fig. 4.27

A weeping-walled slurry

compound.


Cow record card

Cow name ______ Pedigree number ______ Ear tag number ______

Sire ______ Date of birth ______

Dam ______

Lactation									
1	Calving date	Sex of calf	Sire	Milk yield	Days	Fat %	Protein %	Lactose %	Date dry
	Service dates				Veterinary treatment				
2	Calving date	Sex of calf	Sire	Milk yield	Days	Fat %	Protein %	Lactose %	Date dry
	Service dates				Veterinary treatment				
3	Calving date	Sex of calf	Sire	Milk yield	Days	Fat %	Protein %	Lactose %	Date dry
	Service dates				Veterinary treatment				

Fig. 4.28

Cow record card.

such as bulling cows when the event is observed, before

successfully maintained with written entries on a card

transferring this to more permanent records.

but often a more visual record is kept. This is usually a

rotary board with pins or magnetic blocks of different

Cow record cards: This will be the cow's 'log book' and colours used to identify cows. These are placed on the

will give a concise picture of each cow's history. It must

board to record events so any cow 'out of line' is quickly

contain basic details such as name, pedigree number,

obvious and can be investigated. If this method is used it

ear tag number, herd number, date of birth, service

is important to have a more permanent back-up in case

dates, calving dates, sex and sire of calf data, production

the pins are accidentally removed. Figure 4.29 shows

details, health records and details of veterinary treat-

examples of these records. Several computerized

ment. An example is shown in Fig. 4.28. Much of this

systems are now available and they are being increas-

information can now be computerized. Today in the UK

ingly used in larger herds. These will usually allow the

each animal also has a Cattle Passport.

creation of various action lists such as those cows to sep-

arate out for routine veterinary examination, those due

to come on heat that week, those due to be served, those

Breeding records

due to be dried off, those due to calve, etc.

Apart from information kept on the cow record card a

simple breeding record should be kept. This will be used

Milk records

to keep dates of calving, pre-service oestrus, services and

identification of sire and expected calving dates. These

Whilst it is possible to record milk yields from cows

records should allow the farmer or herdsman to quickly

personally, most farmers who wish to record milk use

identify any problem cows, such as those not cycling or

National Milk Records. The scheme supplies a milk

not holding to service, so that treatment can be carried

recorder to measure the milk and take a sample, which

out before the calving interval slips. These records can be

is then sent to a laboratory for testing for the percent-

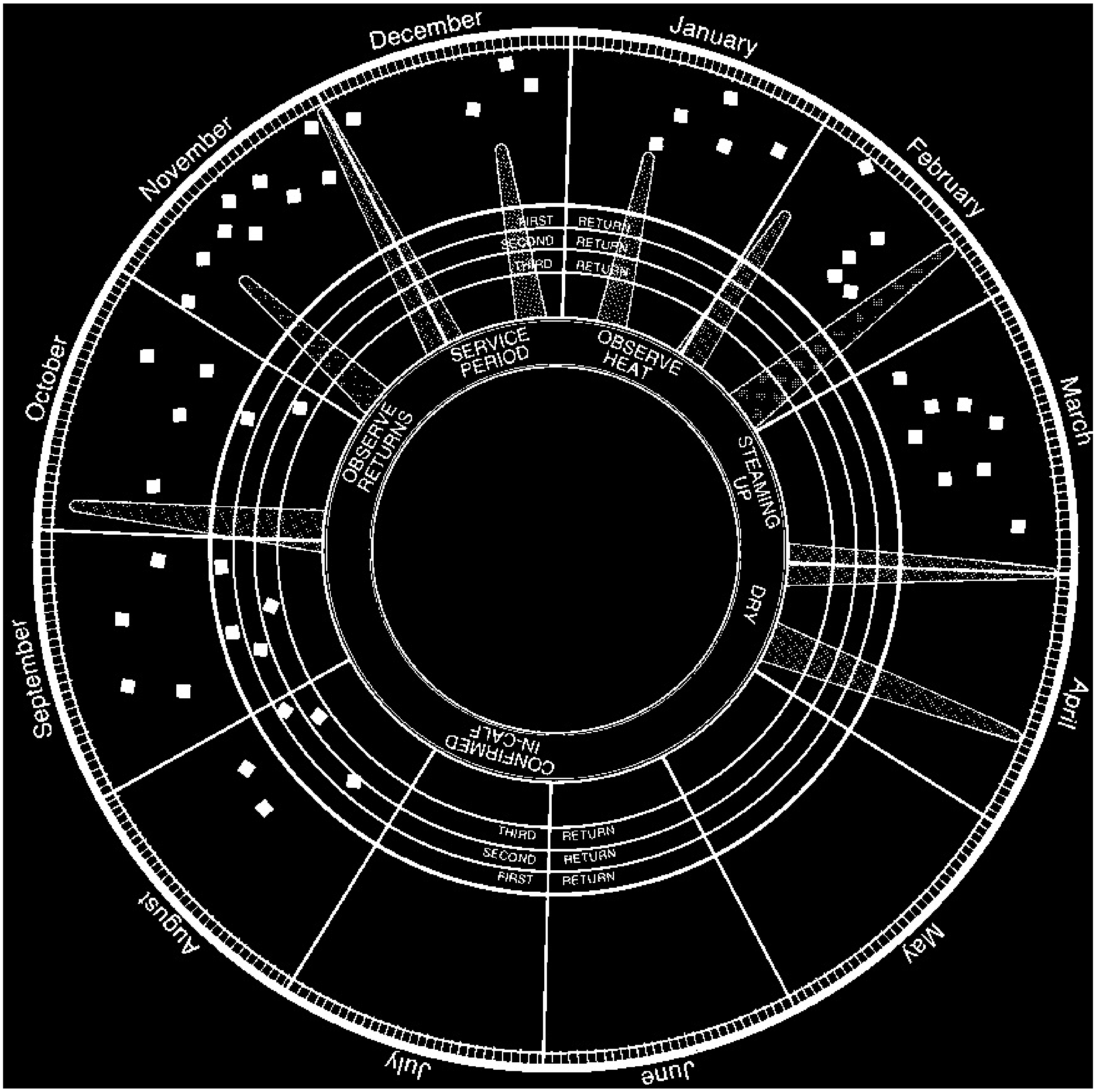

December
January
February
March
April
May
June
July
August
September
October
November
FIRST RETURN
SECOND RETURN
THIRD RETURN
SERVICE PERIOD
OBSERVE HEAT
STEAMING UP
DRY
CONFIRMED IN-CALF
OBSERVE RETURNS
THIRD RETURN
SECOND RETURN
FIRST RETURN

Fig. 4.29

Breeding board.

Fig. 4.30

The milk recorder sampling milk

in the parlour.

age of butterfat, protein and lactose and cell count. The

commencement of lactation. At the end of the lactation

recorder also enters dates of calving, service, drying off

a cow record card is produced. From the dates provided

and culling (Fig. 4.30). The results are sent back to the

an action list is produced for the next month with lists

farmer within a week and contain records not only for of cows due to calve, to dry off, to serve or to pregnancy

that month but also on a cumulative basis from the

diagnose.

Milk records are used for pedigree purposes, to

A herdsman will be one of the most skilled workers

provide information to prepare Improved Contempo-

employed on the farm. He must enjoy working with

rary Comparisons (ICC) for bulls and to assist with cow

cows and be prepared to work the long hours made nec-

selection for breeding purposes.

essary by milking twice a day, seven days a week. He

Apart from this, milk records can be used for man-

must be observant to see signs of unhealthy cows, to see

agement purposes for individually rationing cows or for

cows in oestrus or about to calve and to see signs of

use in a milk prediction scheme.

under- or overfeeding. He must be capable of keeping

records accurately.

Financial records

He must be clean, to produce high quality milk and

to prevent a dirty environment. He must be strong as
Farmers keep many financial records with varying de-
there is still considerable physical work involved in cow
grees of sophistication to assist with the management
feeding and calving especially. Fortunately, the herds-
of the herd. Many farmers use a bureau service pro-
man's job provides a high degree of job satisfaction and
vided by a firm supplying the feed or use a service pro-
interest for a dedicated man.
vided by agricultural organizations or consultants. All
Most herdsmen are paid a fixed wage for the job but
of these measure the main output from the dairy herd,
may also have bonus schemes related to such things as
milk income, and relate this to the main variable cost of
milk yield per cow (less common since quotas), margin
production, namely feed. This then gives a margin over
over feed costs, calving percentage or calves sold.
feed analysis, expressed on the basis of per herd, per
Apart from the main herdsman, relief will be needed
hectare, per cow or per litre. For example, the gross
for weekends, holidays and sickness. Often this relief

margin per litre in England and Wales in 1995–96 was

will be provided by the farmer or another farm worker.

15.34 p/litre and 13.24 p/litre in 1997–98; and that per

Failing this, relief agencies exist which can provide a

cow was £897/cow in 1995–96 and £809/cow in 1997–98.

herdsman often at short notice. At present numbers

Margins in some of the next few years were consider-

of farm workers are decreasing rapidly, resulting in

ably lower (e.g. £807 per cow and 14 pence per litre in

increased numbers of animals being cared for by each

November 2002, taking into account inflation).

individual stock person.

These services are all computerized and rely on the

farmer supplying information monthly on cow num-

bers, milk quantity and quality, feed used and price, fer-

Breeding

tilizer used and price, and land area used.

The aim of a breeding policy must be to get the cows in

The farmer then has the results returned to him and

calf regularly and to provide sufficient replacements of

often has a league table comparing his results with high genetic potential to maintain the herd size at the

other farmers or comparing his results for this year with

optimum level. This will depend on the culling rate,

the previous year or budget.

the age at first calving, the breed of sire used and the

Differences between the various schemes are small

genetic worth of that sire.

but some form of financial monitoring provides an es-

sential part of the dairy herd management.

Culling

Management

Studies have shown that the majority of culls are sold

for reasons such as poor breeding, mastitis, bad feet,

injury, etc. (Table 4.15). These might be termed

Labour

No dairy system will work efficiently without good

Table 4.15

Reasons for culling (%). Sources: Cull cow surveys

labour. In many cases this is supplied by the farmer and

1984 – FMS Information Unit; Milk Development Council, 2000.

his family but for larger herds employing a herdsman is common. In the milk costs survey for 1986–87, 63 per

1984

2000

cent of herds only used family labour. From the same

survey there was an average labour use of 35 hours/cow

Poor yield/quality

12

10

per year. This ranged from 79 hours/cow for herds of

Poor breeder

21

28

below 30 cows to 27 hours/cow for those above 100

Bad legs or feet

9

7

cows. About half of this time was spent milking the cows

Mastitis/cell count

15

18

Udder

8

6

and the other half tending them. Labour costs will vary

Old age

10

5

depending on factors such as herd size, facilities

Injury

5

4

available and type of person employed but will range

Others

20

22

between £250 and £300/cow or about 4 pence per litre.

unplanned reasons and will not lead to overall herd

With many first calf heifers still being bred to a beef

improvement.

bull this gives very limited scope to do other than breed

With good management it should be possible to keep

pure with the dairy cows especially if management is
the annual culling rate to 20 per cent. But the national
below average. However, where choice is available then
average is about 25 per cent. Also, because so much
cows with the highest cow genetic index (CGI) should
of that culling is for the unplanned reasons outlined
be used to breed replacements.
above, the rate of genetic progress is considerably
As pre-sexed semen becomes more available and
slowed. In some countries such as North America
affordable it will become increasingly possible to pro-
culling percentages tend to be higher, while in others
duce all high genetic merit heifers from those cows
such as New Zealand they are lower.
chosen to breed replacements. The remainder can then
be bred to a beef bull and again it will be possible to
choose the calf's sex. Otherwise embryo transfer can be
Age at first calving (see Chapter 5)
used to solve both these management problems.
This is very much linked with culling rate. Table 4.16
shows the effect of three culling rates and three differ-

Genetic worth of the sire

ent ages of first calving. The number of heifer replace-

ments needed more than doubles between options.

The choice here will rest between using natural service

Although heifers need a higher plane of nutrition to

and AI. The chances of being able to use a bull of high

reach sufficient weight to calve at two years old their

genetic merit which was referred to as ‘ICC’ for natural

lifetime yield will exceed those calving at three years

service are very remote, so AI is to be recommended.

(Table 4.17).

Also, AI gives choice for traits other than production

such as ease of calving, conformation or size. Within the

overall traits desired, bulls with the highest ICCs for

Breed of sire used

weight of fat plus protein should be used. Also, it is

Most dairy farmers breed sufficient cows pure to get the

important to choose bulls with a reliable proof, i.e. with

desired number of replacements, the remainder being

a weighting of +40 or above, with daughters in over 20

put to a beef sire to maximize the value of the calf.

herds and with less than 25 per cent of daughters in the

Depending on the factors outlined above this can mean

two herds with most daughters. A wide selection of

between 40 and 80 per cent of the herd will need to be

bulls are available meeting these requirements (Fig.

bred pure.

4.31) (see also Chapters 5, 12). Genetic merit has been

converted into various numbers such as the production

index number (PIN), which is a comparison of milk

Table 4.16

Number of replacement heifers needed per 100

volume and weight of the milk constituents, and index

cows.

of total economic merit (ITEM), which includes both

production and conformation parameters.

Culling rate (%)

Age at first calving (years)

It has always been difficult for farmers to assess a

high genetic merit (HGM) bull in terms of their own

2

21/2

3

herds. The advent of a large number of companies

selling semen and the different methods used to express

15

30

38

45

genetic merit in various countries have also not helped.

20

40

50

60

It has resulted in the production of conversion formu-

25

50

63

75

lae to predict performance. Production information is

Table 4.17

Production associated with age at first calving. Source: Rearing replacements for beef and dairy herds (MLC and MMB).

Age at first calving (months)

23–25

26–28

29–31

32–34

35–37

Herd life (years)

4.0

4.0

3.8

3.8

3.8

Lifetime yield (kg)

18 725

18 708

17 943

17 970

17 637

Yield/day in herd (kg)

13.1

13.2

13.1

13.1

13.2

Yield/day of life (kg)

8.8

8.4

7.9

7.5

7.3

Fig. 4.31

Peckforton Citation River ET—

a high ICC Friesian bull.

expressed as predicted transmitting abilities (PTAs). In

(2)

At service: ensure the cow is on a rising plane of

the UK, production (profit) index number (PIN) has

nutrition and not losing weight. Oestrous detec-

been used for several years, but was biased towards

tion is a skill found in a good herdsman. Four

milk quantity and constituents. This was superseded by

observation periods during the day of at least 20

the index of total economic merit (ITEM) for a time,

minutes each will aid oestrous detection. Oestrous

which included conformation traits as well as those of

detectors such as tail paint, dyes or vasectomized

production. More recently the PLI (production plus

bulls can be used to help detection.

lifespan index) has also been included to provide an

(3)

Post service: cows should still be closely observed

indication of production and lifetime performance.

for repeat heats. Cows apparently in calf should

Other indices have been introduced including mastitis be pregnancy tested at 24 days after service with

and calving interval.

a milk progesterone test or at six to eight weeks

In 2001 a new genetic evaluation system was intro-

after service with a veterinary examination.

duced for Holstein cattle in the UK. The system is based

To achieve a regular 365-day calving interval, first

on the Swedish interbull evaluations for production and

service should be at 50–60 days from calving, which

conformation. The procedure, developed in 1995, is

allows time for one repeat service before losing time.

known as the multiple trait across country evaluations

An MMB report on Checkmate, the Board's fertility

(MACE) and involves the incorporation of data on a

monitoring service, showed a wide difference between

particular bull from its own country and also from any-

the top and bottom 10 per cent selected on the interval

where else it has been used plus parent information from

between calving and assumed conception (Table 4.18).

the home country and abroad. As a bull is used in differ-

New techniques to improve the rate of genetic pro-ent countries it reduces the evaluation contribution of

gress will doubtless be developed further over the

the parents to the overall genetic levels such as PIN. This

next few years. These mainly revolve around embryo

parental contribution can initially be up to a third when

transplants and include possibilities with sexed embryos

the bull has not produced daughters in another country,

and super-ovulated cows producing many embryos for

but reduces to about 1 per cent when it has been widely

non-surgical transplants. As the cost comes down and

used in that country and two or more others. The infor-

the success rate improves these techniques will be used

mation will still be expressed in PIN and PLI values.

on more commercial farms.

The other objective of obtaining a calf per year will

largely depend on herd management. Very few cows are

infertile but many fail to breed regularly. Key manage-

Health

ment times are as follows:

This subject will be dealt with very fully in the main

(1)

Post calving: ensure the cow is clean, has no dis-

text of the book. Suffice to say here that cow health is

charges and is cycling regularly.

paramount to success in dairying.

Table 4.18

Example of overall herd fertility results. Source; Checkmate report, 1985 (FMS Information Unit, MMB).

	Whole sample	**Top 10%**	**Bottom 10%**
Average interval calving: assumed conception (days)	99	81	130
Average interval calving: first service (days)	71	64	80

Services/assumed conception

1.82

1.65

2.22

Table 4.19

Average, bottom 25% and top 25% of farms based on retained profit/litre.

Source: ADAS and HSBC data to April 2000 (after Lott, 2000).

Bottom 25%

Average

Top 25%

Farm size (hectares)

99

102

114

Herd size

146

157

180

Yield per cow (litres)

6 860

6 967

6 863

Total milk produced (litres)

999 977

1 093 000

1 237 000

Output (pence per litre)

20.31

20.55

21.26

Variable costs (ppl)

7.73

7.17

6.78

Gross margin (ppl)

12.58

13.37

14.40

Direct overhead costs (ppl)

8.01

7.23

6.87

Rent, finance and quota (ppl)

4.07

3.66

3.08

Total overheads

12.08

10.89

9.95

Profit before drawings/tax (ppl)

0.50

2.48

4.54

Drawings/ tax (ppl)

2.90

2.58

2.45

Retained profit/ loss (ppl)

-2.40

-0.09

+2.45

Total cost of production (ppl)

22.71

20.64

18.81

Veterinary and medicine charges are usually between

costs are paid wages, power and machinery, sundries,

£35–80/cow or 0.4–0.8 p/litre and are made up of drugs,

property charges, interest and depreciation.

particularly anthelmintics and antibiotics, and veteri-

Each year various farm advisory services produce

nary charges. The main diseases that cause losses to the

reports looking at the economics of specialist dairy

farmer through loss of production, cost of treatment

farms. These analyse the average as well as the top and

or even death of the cow are mastitis (see Chapter 23),

bottom 25% of farms selected by profit/hectare. The

hypocalcaemia (see p. 781), hypomagnesaemia (see p.

results in Table 4.19 are an example and highlight the

787), lameness (see Chapter 32) and calving problems.

differences. The system is now known as benchmarking,

which compares or measures a level of achievement

which is seen as the target for that individual or

Economics of dairy farming

business.

For all the major factors those in the top group out-

perform the others showing the enormous range of

Measures of efficiency

results found on fairly similar farms. However, on very

The overall measure of efficiency on any dairy farm is

many farms full records are not available to carry out

profit. Profit is calculated by deducting from the whole

this type of analysis and simpler records must be used.

farm gross margin the overhead costs of the business.

There are many, such as margin over concentrates,

The gross margin (GM) is the output of milk, calves and

margin over all purchased feed (MOPF) or gross

cull cows less the herd replacement charge to give the

margin, all per litre, per cow or per hectare. Statistical

gross output. From this are deducted the variable costs,

analysis shows none of these measures to be closely

of production, purchased feed, forage costs, veterinary

correlated to profit. The best measures are those where

costs, and medicine and sundry costs. The overhead land area, and hence intensity of farming, are taken into

Table 4.20

Analysis by margin over purchased feeds (MOPF) (£/cow).

MOPF (£/cow)	< **575**	**575–625**	**625–675**	**675–725**	> **725**
Milk yield (l/cow)	4741	5118	5414	5724	6245
Concentrate use (kg/l)	0.30	0.28	0.27	0.27	

0.27

MOPF (p/l)

10.95

11.76

12.02

12.26

12.38

MOPF (£/cow)

519

602

651

702

773

Stocking ratea (LSU/ha)

2.24

2.15

2.18

2.18

2.27

MOPF (£/ha)

1079

1195

1314

1425

1634

a MOPF: margin over purchased feeds; LSU: livestock stocking units.

Table 4.21

Analysis by margin over purchased feeds (MOPF) (p/l).

MOPF (p/l)

< **10.5**

10.5–11.1

11.1–11.7

11.7–12.3

> **12.3**

Milk yield (l/cow)

5730

5677

5621

5494

5270

Concentrate use (kg/l)

0.33

0.29

0.27

0.24

0.21

MOPF (p/l)

9.7

10.8

11.3

11.9

12.6

MOPF (£/cow)

616

663

686

697

700

Stocking ratea (LSU/ha)

2.30

2.24

2.20

2.14

2.11

MOPF (£/ha)

1275

1370

1401

1395

1398

a MOPF: margin over purchased feeds; LSU: livestock stocking units.

Table 4.22

Analysis by margin over purchased feeds (MOPF) (£/ha).

MOPF (£/ha)

< **1100**

1100–1300

1300–1500

1500–1700

> **1700**

Milk yield (l/cow)

4975

5309

5538

5821

6172

Concentrate use (kg/l)

0.27

0.26

0.27

0.27

0.29

MOPF (p/l)

11.76

12.09

12.19

12.18

11.83

MOPF (£/ cow)

585

642

675

709

730

Stocking ratea (LSU/ha)

1.73

2.02

2.23

2.42

2.80

MOPF (£/ ha)

940

1195

1389

1598

1916

a MOPF: margin over purchased feeds; LSU: livestock stocking units.

account. Provided the overhead costs are not excep-

Milkminder report, which analysed data from 2459

tionally high, then margin over feed/ha (Table 4.22) will

herds, and *Genus Management Costed Dairy Farming*

have a large influence on profit.

1989–90.

However, with the quota system now limiting pro-

A high margin per cow results from a high yield per

duction on farms, many people are now saying that

cow with modest concentrate use. Stocking rate does margin per quota volume and hence margin per litre

not change substantially over the range of results.

has become the most important measure (see Table

Farms with a high margin per litre had a lower milk

4.19). Tables 4.20–4.22 show that, depending on the cri-

yield per cow but with a much lower concentrate usage.

teria chosen, very different methods of production give

Stocking rate also fell so there was little improvement

the best results. These tables are based on the 1986–87

in margin per hectare. Those with a high margin per

Table 4.23

Details of spring- and autumn-calving systems.

an audit and accountability trail from the animal to the

end consumer. They will usually involve regular peri-

Spring

Autumn

odic inspections of the accommodation, management,

health and record keeping of the farm. These visits may

Yield (l/cow)

5228

5634

be undertaken by veterinary surgeons or other inspec-

Concentrate use (kg/cow)

946

1409

tors. The aim is to provide reports and, where necessary,

MOPF (p/l)

13.0

12.4

to enforce improvements within given time periods. In

MOPF (£/cow)

678

698

Britain the schemes are mainly run or approved by the

Stocking rate (cows/ha)

2.29

2.30

MOPF (£/ha)

1553

1605

milk purchasers. While at present they are limited in their effectiveness they do provide the mechanisms to improve both animal health and welfare.

hectare had a higher yield produced with increased concentrate usage and with a much higher stocking rate.

Organic farming

The intensity of farming was much greater.

All these different systems of producing milk can

In the United Kingdom and other parts of Europe there

lead to good profits if carried out efficiently. Therefore,

has been rising interest in organic farming. At present

depending on the farm situation and the circumstances

in Great Britain only about 5 per cent of milk is pro-

appertaining, different systems can suit different farms.

duced in this way but the volume is growing. While

A vigorous debate also ensues about the merits of sea-

there are strict criteria to follow, the farmer is at present

sonality of calving and its effect on profits. Both spring

rewarded with a higher milk price. However, as stock-

calving and autumn calving are very defined systems that

ing rates are lower and also costs of organic feeds

can be successful and profitable if operated efficiently.

are high, margins tend not to be greater than in

Table 4.23 shows the differences between the systems.

conventional farms.

A British spring-calving herd (calving February–

This method of food production has been receiving

April) produces a lower yield with less purchased feed

increasing attention over the last 15 years. Its main aim

than an autumn-calving herd (September–December).

is to ensure that production is undertaken in harmony

This gives a higher margin per litre but lower margin

with the environment and that as much is returned to

per cow and per hectare.

the land as is removed from it. The system has been

Both systems can be equally profitable but as the

taken up in many countries especially those of Europe.

margin per cow is lower for the spring calver then the

Organic farming is defined in EU law under EU Regu-

overhead costs must also be lower to show the same

lation 1804/99. The system involves meeting various cri-

profit.

teria before a farm can be defined as organic and this

Thus the level of overhead costs goes a long way to
involves a conversion period which involves the land
determining the farm system. Where overhead costs are
and, in Britain, usually takes about 2.5 years. The objec-
very low (i.e. an owner-occupied farm with no rent, no
tives of the system are to sustain the animals in good
borrowed money, no paid labour and little machinery),
health by the use of effective management systems,
then a very extensive system with low yields and low
good stockmanship and suitable diets and by prevent-
outputs can be practised and still show a good profit.
ing conditions where remedial treatments have
However, if the overhead costs are high then the farm
previously been used. The use of alternative and com-
must be intensively run with high yields and high stock-
plementary medicines is indirectly encouraged by the
ing rates, putting surplus land into arable crops to gen-
increase in stated withdrawal periods, usually by at least
erate a high gross output. Only then will a satisfactory
100 per cent. The EU regulations only allow three ‘syn-
profit be generated.

thetic drug treatments' a year (except for vaccines and

There are many ways of making a profit in dairy

antiparasitic preparations). At present a premium is

farming. The skilled operator and the one making the

paid for organic milk, which makes it an attractive pro-

greatest profit will be the one managing the resources

position for some dairy farmers, but this is reducing.

of land, labour, capital, stock and quota most efficiently.

The future

Farm assurance and herd

health schemes

While milk quotas remain within the EU it is probable

that they will be further reduced for most nations in the

These are another initiative to ensure high management

short term and then gradually or rapidly abandoned.

and health standards on dairy farms. They help provide

The commodity price will eventually have to become

closer to world milk prices under the direction of

markets and the internet, or indirectly via shops of all

various World Trade Organization initiatives. In several types.

parts of the world cow numbers and milk production

Those doing the job well will survive although they

are being geared up to meet this. In most European

will have to keep their eye very much on the various

countries there will be a reduction in dairy cow

trends which develop concerning milk and its products.

numbers as yields increase. There will also be fewer

Whilst political decisions and the further reduction or

farms with larger numbers of cattle and proportionately

demise of milk quotas will close many doors, it is

fewer people employed. This will inevitably lead to

probable that others will open and there will be good

more cows or animals per stock person and an

opportunities in dairy farming for many producers.

increased requirement for mechanisation. Feeding

practices will continue to change to allow the expres-

sion of genetic merit with its increased yields per cow.

References

Sexed semen will facilitate a reduction in the number

of cows made pregnant to produce herd replacements

Farm Management Services Information (1990) Checkmate

and will also then allow poorer producing cows to be

report. Milk Marketing Board, Thames Ditton, pp. 1–17.

bred to beef bulls again, often with sexed semen.

Federation of United Kingdom Milk Marketing Board (1984)

Increasing movement of animal products may lead to

United Kingdom Dairy Facts and Figures, Thames Ditton,

more interest being paid to the methods of production

pp. 1–200.

in those countries which are primarily exporters. The

Federation of United Kingdom Milk Marketing Board (1990)

global transportation of food will probably also result

United Kingdom Dairy Facts and Figures, Thames Ditton,

pp. 1–209.

in increased levels of disease in those which are major

Genus Management (1990) An Analysis of Genus Man-

importers of animals and animal products. Unless

agement Costed Dairy Farming 1989–90, Crewe, pp.

disease levels in importing countries are allowed to rise,

1–24.

increased emphasis must be placed on health control

Hughes, J. (2000) Internal cattle building design and cow

and monitoring in the exporting regions.

tracks. In *The Health of Dairy Cattle* (ed. by A.H. Andrews), Dairy farm incomes are likely to be further squeezed,

pp. 278–98. Blackwell Science, Oxford.

resulting in the formation of various producer groups

Lott, E. (2000) Benchmarking – a vital tool to British agricul-to give improved bargaining power with milk buyers.

ture. *UK Vet*, **5**, No. 6, 28–31.

Such milk producer groups will also be able to purchase

Meat and Livestock Commission (1999) Life after CPAS. *Beef* creameries and milk processing plants to improve inte-Management Matters, No. 6, 1–16.

gration of the supply chain. Much of the price structure

Milk Development Council (2000) Longevity – Controlling

Culling to Improve Herd Profitability. Publication 51

will still depend on the prices which the main super-

(03/00), Cirencester, pp. 1–12.

markets are prepared to pay. However, as prosperity

Milk Marketing Board (1986) EEC Dairy Facts and Figures,

increases more people will eat less at home and more

Thames Ditton, pp. 1–178.

outside the home. This will allow the development of

Milk Marketing Board (1990) EEC Dairy Facts and Figures,

the catering market at all levels and again will provide

Thames Ditton, pp. 1–210.

marketing initiatives. There will be more niche market-

National Dairy Council (2001) Dairy Facts and Figures 2001

ing, either direct to the public via farm shops, farmer

Edition, London, pp. 1–275.

Chapter 5

Heifer Rearing – 12 Weeks To Calving

B. Drew

Introduction

54

more intensive methods, particularly where the land

Age at calving

55

involved could be used for alternative, more profitable,

Month of calving

55

enterprises.

Rearing management, 3–6 months

55

The low priority given to heifer rearing is supported

Management and housing

55

by DAISY survey data (Kossaibati & Esslemont, 1996)

Feeding

56

which stated that in the average herd, 22 per cent of

Rearing management, 6–12 months

56

dairy heifers born were lost before they started their

Management at turnout

56

Supplementary feeding

56

first lactation, with a further 14 per cent culled before

Optimum growth rates

56

they completed their first lactation, while in the worst

Grazing systems

57

herds, almost 60 per cent of heifers failed to calve for a

Autumn management

58

second time.

Rearing management, 12–15 months

58

Calving at two years is more profitable than calving

Housing and management

58

at two and a half to three years as little over half the

Feeding for fertility

58

area of land is required, lifetime milk yield is greater

Stress

59

and the amount of feed, housing, labour and working

Breeding policy

59

capital required for the rearing enterprise is reduced.

Sire selection: breeding replacements from heifers

60

A policy of calving at two years can only be achieved

Selecting a sire

60

if the majority of cows calve within a relatively short

Selecting for longevity

60

Selecting for a low incidence of dystokia

61

period or a proportion of herd replacements are taken

Service management

61

from heifers.

Controlled breeding

61

The management of a dairy heifer between 12 weeks

Rearing management, 15–18 months

62

old and calving has a considerable effect on her poten-

Rearing management, 18–22 months

62

tial for milk yield, fertility, the incidence of dystokia and

Rearing management, 22–24 months (2 months precalving)

62

on longevity. Insufficient growth rates during the

Growth rates in pregnancy

62

rearing period result in the production of small-framed

Fly prevention

63

heifers with disappointing milk yields due to their inabi-

Cubicle training

63

lity to compete with older cows during the first lactation.

Minerals and trace elements

63

Poor growth rates at around the time of service result in

Management factors affecting dystokia and calf mortality

64

low pregnancy rates and delayed entry into the herd.

Management prior to calving

64

Management at calving

65

The faster a heifer grows, the more efficient she is in

Targets for growth for two-year calving

65

converting feed into liveweight gain. This could suggest

Management during the first lactation

65

that heifers should be fed to grow as rapidly as possi-

Survival rates

66

ble, especially during the summer months when grass

provides an abundant and relatively inexpensive source

of feed. However, in some circumstances, high growth

Introduction

rates during the first year can result in lower milk

yields due to the effect of rapid growth on the relative

Dairy heifer rearing is generally considered to be a

proportion of fat and milk secretory cells in the

non-intensive, low-profit enterprise. Indeed, few farmers

developing udder.

would rear heifers at all if it were not for their interest

The potential of a heifer will only be maximized in herd improvement and disease control. However,

if she is reared to a plan with careful control over

planned heifer rearing is the starting point for

performance at all stages of the rearing period. Target

profitable dairying. An increasing number of farmers

growth rates and intermediate target weights should be

now realize the importance of this and are adopting

set as soon as the predicted date of first calving has been

decided. Optimal growth rates will depend on age at

Table 5.1

Effect of age at calving on first lactation milk yield.

calving, estimated mature body size, management after

Source: Furniss *et al.* (1986).

calving and average herd yield.

Dairy heifer rearing is a specific farm enterprise

Age (years)

involving capital, land and labour. It should be managed

2

3

and recorded with the same attention to detail as

that given to the other enterprises on the farm, with

Milk yield (305 days) (kg)

4544

4980

preplanned target rates of growth being achieved

Calving interval (days)

386

401

throughout the rearing period.

A detailed description of the management and

targets required for autumn-born heifers reared to

months. It is known that the average life expectancy

calve at two years is given in this chapter. The pattern

of two-year calvers is greater and the lifetime milk

of growth and targets for weight-for-age for spring-born

production higher than heifers calving at three years

heifers calving at two years are similar. There is less

(Table 4.17).

pressure to maintain steady weight gains when the aim

There are a few circumstances when it is preferable is to calve at an older age and there are periods when

to adopt a policy of calving heifers at two and a half to

lower growth rates are acceptable.

three years. Calving at an older age reduces the man-

agement pressures imposed by the two-year system and

Age at calving

permits the utilization of marginal land unsuitable

for cropping. It also enables replacements to be taken

from cows of high genetic merit even if they calve

The younger a heifer is at calving the less land, housing

later in the season. Calving at three years can only be

and capital are required during her rearing period but

justified when there is a large area of outlying rough

heifers should not calve at less than 23 months because a

grazing.

higher incidence of calving problems can be expected

and subsequent milk yields are disappointing. With

a high stocking rate of 0.4 ha/livestock unit, the area

Month of calving

of land required for each replacement unit is 0.4 ha for

heifers calving at two years, 0.5 ha for heifers calving

Most dairy farmers plan to calve their heifers in a batch at two and a half years and 0.7 ha for heifers calving at at one season of the year. Autumn-calving herds find three years. When the stocking rate is 0.5 ha/livestock difficulty in maintaining this seasonality in the pattern unit the area required for heifers calving at three years of calving unless either herd fertility is high or a is twice that required for heifers calving at two. The proportion of the calves reared for replacements are housing and capital required to sustain a two year system taken from heifers. The optimum month of calving is also reduced. For instance, a 100 cow, autumn-calving varies with the relative prices of milk and compound herd calving at two years needs 40 replacements requir- feed and with the management pressures from other ing accommodation for calves and yearling heifers. enterprises. Once the optimum month of calving for a However, a similar herd calving at three years must herd has been established the heifers should be mated maintain 60 heifers and house the third-year heifers to calve at the same time or shortly before the earliest during their third winter when space requirements are

calving cows.

approaching those of adult cattle (Table 4.16).

Calving heifers before the cows reduces the stress

The first lactation milk yields of heifers calving at two

imposed following introduction to the herd and allows

years are likely to be lower than if the age of first

for a longer interval between calving and service. How-

calving is delayed. Milk yields of two-year-old calving

ever, some farmers prefer to calve heifers at the same

heifers at the ADAS Bridgets Research Centre aver-

time as the early calving cows as they find that they

aged 4544 kg milk as compared with a yield of 4980 kg

are then easier to manage in the parlour.

for heifers calving at three years (Furniss *et al.* , 1986), However, when differences in the mean calving

interval are taken into account the effect on yield was

Rearing management, 3–6 months

marginal (Table 5.1). This is supported by more recent

research (Pirlo *et al*., 2000) which showed that as age of

Management and housing

first calving increased there was generally an increase

in milk yield and milk fat percentage, but at the same

Heifers should be housed in semi-covered yards such

time rearing costs increased. The optimum age for

as that shown in Fig. 5.1. The calves should be given

first calving still appears to be approximately 23 to 24

as much fresh air as possible with a draught-free lying

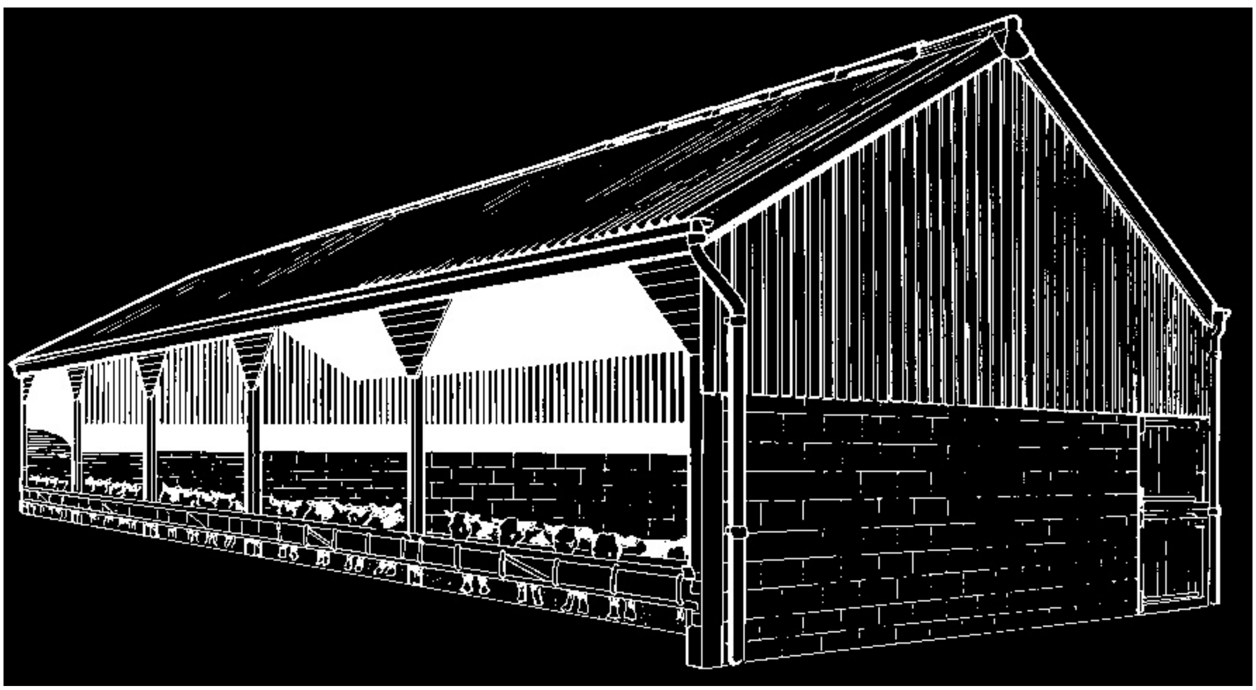


Fig. 5.1

Example of a well-ventilated calf

house.

area. Autumn-born heifers should be housed through-

Rearing management, 6–12 months

out the period but spring-born heifers may be turned

out towards the end of the period if aftermaths are

Management at turnout

available.

Autumn-born heifers should be turned out to pasture

when weather and soil conditions permit. After turnout

the winter ration should be continued until the forage

Feeding

intake declines, generally within one to two weeks. The

Minimum target growth rates during the first year of life

compound can then be withdrawn. Spring-born heifers

should be based on estimated mature body weight. A

are normally housed until aftermaths become available.

steady liveweight gain at a rate equivalent to the esti-

mated mature body weight in g/day is required. Thus a

Supplementary feeding

Jersey heifer with a mature weight of 500 kg should be

predicted to grow at 500 g/day (0.5 kg) while a Holstein

Following withdrawal of compound feed soon after

should be expected to grow at a minimum of 700 g/day turnout, no supplementary feed should be required until

(0.7 kg).

late August or early September. Attention should be

It is important to maintain a constant rate of gain.

given to mineral and trace element supplementation,

Poor growth rates, whether caused by an inadequate

especially in areas of known deficiency (see Chapter 21).

diet or disease, are likely to lead to compensatory

gain at grass, which can have an adverse effect on

Optimum growth rates

subsequent milk yield.

From 12 weeks of age the calves should be fed to

Stocking rates should be adjusted to maintain a steady

achieve target growth rates, with either a silage, hay or

rate of liveweight gain over the summer. During May

straw based diet offered, supplemented with concen-

and June when grass is of high quality it is not unusual

trate feed as either a rearing nut or home mix. The total

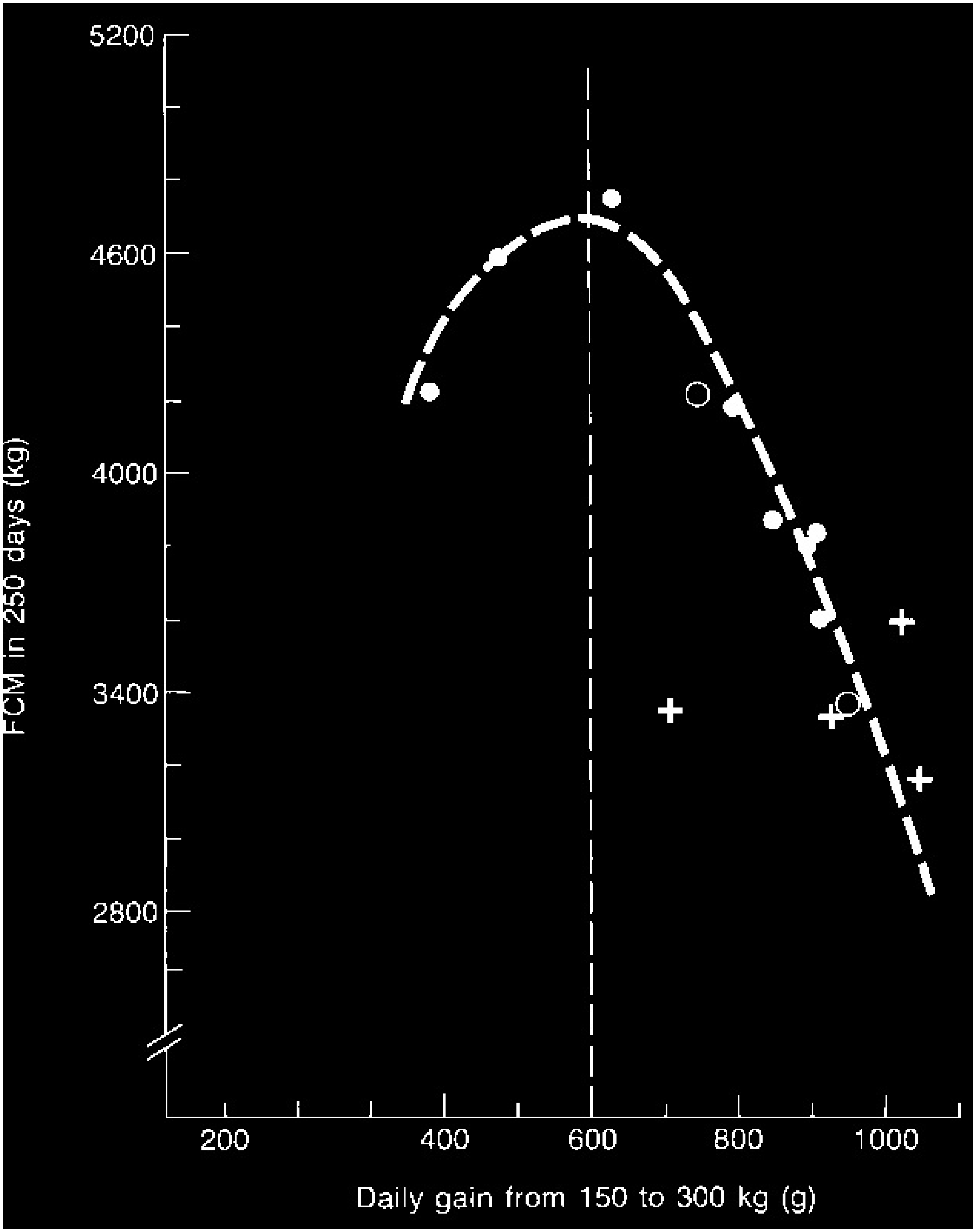
for heifers to grow at 0.8–1.0 kg/day unless a tight stock-

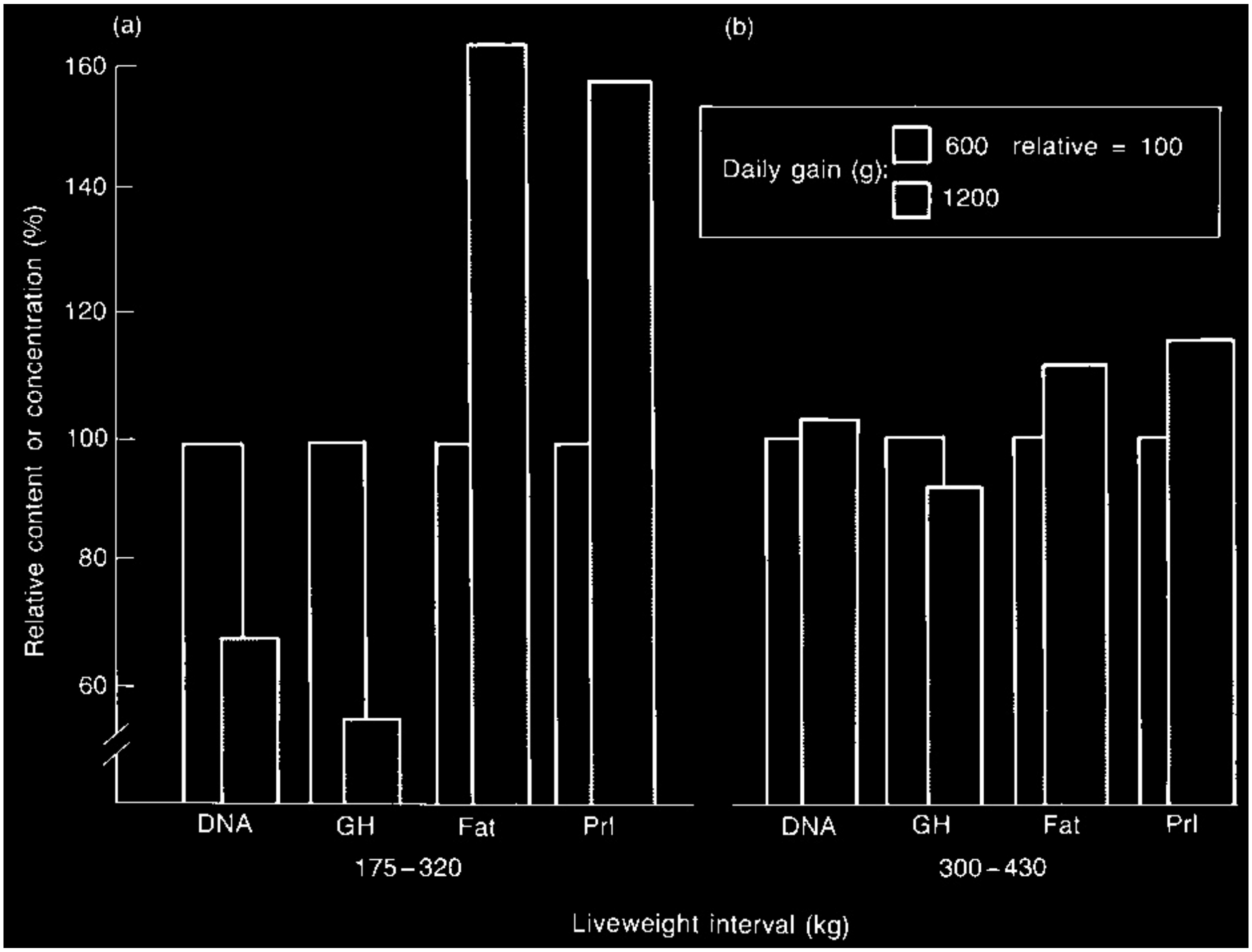
diet at this stage would typically be approximately 16

ing density is maintained. In the months leading up to

per cent crude protein. The amount of concentrate feed
puberty it is desirable to restrict daily liveweight gains
offered should be varied according to forage quality
to approximately 0.7 kg/day for Holsteins or equiva-
and the growth rates required. Forage should be of high
lent for smaller breeds based on the animals' predicted
quality, fresh and palatable. Calves should not be given
mature weight.
forage that would be unacceptable to cows. Calves fed
It is known that high growth rates in prepubertal
silage should also be offered clean barley straw and can
heifers are detrimental to milk production (Little &
be expected to take about 5 per cent of their roughage
Kay, 1979; Drew & Altman, 1982). A typical relation-
in this form. Regular monthly weighings are essential
ship between early liveweight gain and the first lacta-
to monitor progress and adjust nutrition. On infected
tion milk yield of heifers is shown in Fig. 5.2. Mammary
farms consideration should be given to vaccination
growth and development is under hormonal control
against lungworm prior to turnout (see p. 274).

and serum concentrations of some of the hormones





involved are affected by plane of nutrition (Sejrsen & Foldager, 1992; Sejrsen, 1994). It is likely that the negative influence of a high plane of nutrition on mammary growth is caused by changes in the secretion of these hormones. Rapid growth before puberty has been shown to coincide with impaired development of the mammary epithelium, decreased serum growth hormone and elevated serum prolactin concentrations

(Foldager & Sejrsen, 1982). After puberty there is little or no effect (Fig. 5.3).

Summary evidence from recent studies at ADAS Bridgets suggests that there are production and economic benefits from restricting the rate of liveweight gain (to around 0.7 kg/day) in the prepubertal period, in terms of subsequent milk yield performance, with little or no loss in terms of onset of puberty or first calving age and weight. There is also a potential benefit to be gained from a period of cheaper feeding followed by compensatory growth.

Grazing systems

Ideally, calves should be turned out to pasture with a low level of parasite challenge. Up to late June this can be classified as land that falls into one of the following categories: new seeds after an arable rotation and grassland used only for conservation in the previous year.

After mid July a pasture can be assumed clean if either it is an aftermath or not grazed by cattle earlier in the year (Chapters 19, 60).

If parasite-free calves are turned out to and remain on a clean pasture it should be safe to graze for the

remainder of the season. Unfortunately, in intensive

dairy systems it is seldom possible to provide clean

Fig. 5.2

First lactation milk production in relation to early life

grazing as such. On permanent pasture, helminth egg

liveweight gain (after Foldager & Sejrsen, 1982).

output can be suppressed by anthelmintic treatment.

Fig. 5.3

Relative content of DNA

and fat in mammary glands and serum

growth hormone (GH) and prolactin

(Prl) concentrations in (a) prepubertal

and (b) post pubertal heifers raised on

two planes of nutrition (after Foldager

& Sejresen, 1982).

Overall it is important to reduce parasitic challenge in

veterinary treatments required during the period. They

the heifers' first grazing season whilst allowing suffi-

should be housed in semi-covered yards with a total cient challenge for them to build up natural immunity.

space allowance of approximately 6 m2/animal. A clean

Individual parasitic control programmes should be

concrete loafing area should be included to encourage

drawn up for each herd (Chapter 19).

good hoof development. A special area of cubicles can

In continuous grazing systems the stocking rate

be left to train the heifers.

should be adjusted to match the grass available and the

required growth rate, aiming for a sward height of 5–6

Feeding for fertility

cm in spring, 7–8 cm in mid summer and 9–10 cm in

autumn. In what is known as the ‘1–2–3’ grazing system

It is known that the level of nutrition over the service

the grazing area dedicated to the heifers is divided into

period is important in ensuring high pregnancy rates

three blocks. In spring the heifers graze one area while

and entry into the herd at the optimum time. In a study

the other two blocks are cut for silage. Later the heifers

undertaken on six commercial dairy farms, the fertility

graze the two silage aftermaths while the grazed block

of heifers fed rations considered to be adequate by
is cut for silage. At the end of the season all three blocks
the farmers was compared with the fertility of heifers
can be used for grazing.
fed the same diets supplemented with cereal (Drew &
An alternative grazing system is described as the
Pointer, 1977). The supplemented diets were calculated
'leader–follower' system. This is a rotational grazing
to provide an additional 20 MJ/day metabolizable
system of eight to twelve paddocks where the youngest
energy (ME) and were fed for a 12-week period
heifers graze each paddock ahead of older heifers
commencing six weeks prior to service. Ovulation was
(Kossaibati & Esslemont, 1986).
controlled and the heifers were inseminated at a fixed
Grass growth and supply should be monitored
time. Semen and inseminators were used equally over
throughout the summer to achieve the required
all groups.
growth targets. Concentrate supplementation should be
The calving rates to fixed time insemination are

provided if required.

shown in Table 5.2. There was a wide variation in

fertility between farms, but on each farm a higher pro-

Autumn management

portion of heifers fed the improved ration calved to the

synchronized service. The calving rates to first service

During the period May–August target liveweight gains

for the heifers on the farm ration ranged from 32 to 67

should be achieved without difficulty. At the end of this

per cent and for the supplemented groups from 59 to

period the heifers should be well grown for their age

79 per cent. In this study, no significant relationship

and breed without any obvious fatness (Table 5.9).

between body condition score and fertility was found.

Heifers calving at two years require supplementary

However, other workers have reported a relationship

feeding from late August or early September depending

between body condition and fertility, with lower preg-

on grass growth, soil and weather conditions. Growth

nancy rates occurring at each end of the score range.

rates decline rapidly from this time and if additional

It is likely that change in body condition score

energy is not supplied liveweight gains will be low. A

has a greater effect on fertility than the actual score

compound feed or home mixed cereal ration supple-

at service. Holstein/Friesian heifers weighing 350 kg

mented with minerals and vitamins should be fed.

require to grow at a rate of approximately 0.8 kg/day in

Regular weighings are essential at this time for

order to maintain body condition. As it has been shown

both autumn- and spring-born heifers programmed for

calving at two years. Heifers being reared to calve at

three years can be allowed a store period.

Table 5.2

The effect of level of nutrition on the fertility of dairy

Autumn-born heifers should be assessed for size and

heifers.

suitability for service. Actual weights should be com-

Farm

Number of

Percentage calved to the

pared with targets. If any animal is found to be below

heifers

synchronized insemination

target but, with additional feeding, could attain the

minimum service weight, she should be housed at the

Control

Supplemented

beginning of September and fed an appropriate ration.

1

62

40

67

2

58

59

75

Rearing management, 12–15 months

3

56

32

59

4

37

67

79

Housing and management

5

78

54

69

6

73

53

67

Heifers reared for two-year calving should be housed

Mean

61

50.0

68.9

at least six weeks prior to service and given any routine

that loss of body condition is associated with low preg-

Table 5.3

The effect of the parity of the dam on lactation

nancy rates a ration calculated to provide for mainte-

performance of heifers.

nance and at least 0.8 kg/day liveweight gain should be

provided to Holstein/Friesian heifers over the service

Dam

period. Rations for other breeds should be adjusted

Heifer

Cow

according to relative body size.

Attempts to reduce the period of supplementary

Weight at first service (kg)

370

360

feeding to three weeks before and after service have

Weight at calving (kg)

496

503

been only partially successful. Reducing the period of

First lactation yield (305-day) (kg)

4977

4742

supplementary feeding to three weeks prior to service

Proportion rebred

0.8

0.8

should only be considered if Friesian heifers are in

condition score 2.5–3.0 (Holstein and Jersey 2.0–2.5), or

heifers are to be mated by natural service or observed

oestrus artificial insemination (AI) and the reduced

period of feeding does not affect the time of housing.

must be good to achieve acceptable results and avoid

The period of supplementary feeding after service

disappointment.

should not be shortened as it is likely to increase the

The cost of keeping a bull is often less than AI but

incidence of early embryonic loss.

the risk of disease and injury are greater. The increased

In addition to providing a ration to satisfy the above

cost of using AI can only be justified if a pure bred sire

standards it is important to avoid major changes to

is used and the female calves reared for herd replace-the composition of the diet during the ten days before

ments. A few farmers are still reluctant to take replace-

and after service. Changes in diet are almost always

ments from heifers, preferring to use mature cows with

associated with disappointing pregnancy rates.

a proven record of performance. The rate of genetic

progress will be greater when replacements are taken

from heifers, providing a sire of high genetic merit is

Stress

used.

Stress, such as that caused by noise, physical trauma,

A study by Furniss *et al.* (1988) of the first lacta-

overcrowding or some routine veterinary treatments,

tion and breeding records of 569 heifers calving in a

can alter the concentration and pattern of secretion

Friesian/Holstein-based herd showed that those heifers

of the reproductive hormones and is, therefore, poten-

born to heifers yielded significantly more milk in 305-

tially detrimental to fertility. In intensive manage-

day lactation than those from cows (Table 5.3).

ment systems it is difficult to eliminate the possibility

Rearing replacements from heifers and the earliest

of stress, but with careful planning it can be reduced to

calving cows enables a two-year calving policy to

a level at which pregnancy rates are not likely to

be adopted, with herd replacements entering the herd

be affected.

at the optimum time. The management of the heifer

Housing should be undertaken six weeks prior to

rearing enterprise is simplified as it should only be

service as oestrous behaviour is suppressed during

necessary to rear calves born over a six to eight

the first oestrous cycle after housing. It is important to

week period. It also assists in the maintenance of the

ensure that sufficient trough space is provided to avoid

optimum calving pattern as the later calving cows can

competition. There should be an adequate loafing area,

be mated to a beef bull.

the building should be well ventilated and the floor such

The incidence of dystokia need be no greater with

that animals in oestrus will not slip. If AI is to be used,

a selected AI Holstein/Friesian bull, than a Hereford the handling facilities should be designed to allow for

bull used in natural service. In a survey of 61 herds

quiet and efficient movement of animals. The heifer

recording aspects of rearing and calving experience

should be presented standing at the same level as the

with heifer calvings, the incidence of dystokia associ-

inseminator and restrained from sideways movement.

ated with Hereford sires, averaged over all data, was

almost identical to that associated with Friesians (Table

5.4). There was no difference between the breed in calf

Breeding policy

mortality rates. When using Holstein/Friesian AI bulls

for heifer inseminations there is no need to restrict the

Some farmers consider oestrous detection in heifers to

selection to those noted to be easy calving although

be too difficult and time consuming for Al to be practi-

those recorded as having greater than average calving

cal. This is likely to be a problem when groups of heifers

difficulties should generally be avoided. The most

graze outlying fields away from satisfactory handling

critical factor is overall heifer rearing management to facilities. Synchronization offers a possible solution to

ensure that they are large but not fat at the time of

this problem but the management standards on farms

calving.

Sire selection: breeding

many can lead to unnecessary complication and lack

replacements from heifers

of uniformity in the herd. There are two key economic

indices used to describe the overall production poten-

tial of sires in the UK: these are profitable life index

A survey of farmers breeding replacements from

(£PLI) and production index (£PIN). £PLI and £PIN

heifers showed that the main selection criterion was

are used to describe the average net margin per cow per

‘ease of calving’. It would appear that it is not unusual

year which the bull is likely to pass to his daughters and

for this issue completely to override all the principles

bulls can be ranked on these values for comparison. A

taken into account when selecting replacements from

short list of sires based on their £PLI and their overall

cows. Any heifer mated to a pure-bred bull is poten-
type merit can be produced as a starting point. The cut-
tially a dam of the next generation. The bull used must
off point for this list is likely to vary depending on the
be at least as good as those used on the cows and should
genetic merit of the existing herd, with high genetic
also be genetically superior to the sire of the heifer to
merit herds having to apply higher standards of selec-
which it is mated. Only by adopting these basic princi-
tion to ensure progress continues to be made. It must
ples can genetic progress be made. When a bull is
be ensured that the average £PLI of the bulls selected
considered to be of sufficient merit to be a sire of the
is higher than the average £PLI of the cows/heifers to
next generation, attention should be given to the effect
be mated. The predicted (production) transmission
that he may have on the incidence of dystokia.
ability (PTA) indicates the relative production poten-
tial in terms of milk volume and composition. The reli-

Selecting a sire (see p. 48–9)

ability of PTAs should be considered: the higher the reliability, the greater the confidence in the predicted

Genetic improvement has long-term effects on herd

values. Generally, sires with a PTA reliability of 70 per

performance and profitability. The effect is cumula-

cent or greater should be selected. Once a short list of

tive, making the inclusion of heifers in the breeding

top production bulls has been produced, the selection

of replacements important for maximizing genetic

should be refined using factors such as milk composi-

progress (Table 5.5). It is advisable to select a ‘team’ of

tion and functional conformation traits including

several sires (typically three or four) for a herd, includ-

udders, legs and feet, SCC and calving difficulty.

ing two or more which are suitable for use on maiden

heifers. Using several sires reduces risk, although too

Selecting for longevity

Few studies have been undertaken in this country on

Table 5.4

Effect of breed of sire on dystokia in heifers.

the relationship between conformation (type), produc-

tion and longevity. Many studies of these relationships

Breed of sire

Percentage of calvings

have been undertaken in the USA and show that first

lactation yield is the best early indicator of longevity

(No. of heifers)

Unassisted

Assisted

Difficult

and lifetime yield of dairy cattle. Type scores may add

a little to the accuracy of prediction, but not nearly as

Friesian (1181)

63

25

12

much as is commonly assumed by breeders. To a great

Hereford (753)

63

24

13

extent, longevity in cows depends on the management

Table 5.5

Example of accumulating genetic merit in younger animals.

Lactation No.

No. of animals

Average £PINa

Average PTAb

Average

Milk (kg)

Fat (kg)

Prot (kg)

Fat (%)

Prot (%)

reliability

Young stock

289

53

460

13.0

14.6

-0.08

-0.01

27

1

97

48

417

11.6

13.3

-0.07

-0.01

44

2

130

37

314

10.1

10.1

-0.04

0.00

51

3

90

34

312

9.3

9.5

-0.05

-0.01

54

4

73

23

224

5.6

6.5

-0.05

-0.01

59

5

31

10

148

4.1

3.1

-0.03

-0.03

61

a PIN, production (profit) index number.

b PTA, predicted (production) transmission ability.

decisions of the farmer. However, differences in

bulls that were the easiest calving overall, while other

longevity between cows within the same herd are

farmers reported that heifers calved without assistance

now believed to be heritable and factors thought to in-

to bulls that caused the most problems generally. In

fluence longevity are being included in genetic selection

view of the considerable variation between farms and

parameters.

farm/bull interactions it is not possible to be certain

whether dystokia will occur on an individual farm.

Heifer calves are generally smaller than bull calves

Selecting for a low incidence of dystokia

and with the advent of sexed semen it is now possible

The service sire has a considerable effect on dystokia.

to inseminate maiden heifers with ‘female’ Holstein

The results of a detailed analysis of 1485 heifer calvings

semen to ensure maximum genetic progress in the herd

to six Friesian/Holstein bulls used equally on 58 farms

and at the same time reduce calving difficulties.

showed that the differences between the bulls used in

Other factors involved in dystokia are discussed in

the percentage of assisted and difficult calvings were

the section on ‘Management at calving’ (see p. 65).

statistically highly significant (Table 5.6). However, the

effect of the bull was far less marked than the manage-

ment on the farm on which the heifer calved. Of the 58

Service management

farms in the study, 18 reported mean calf mortality rates

of 1.3 per cent born dead or died within 24 hours and

Controlled breeding (see also Chapter 42)

recorded a low incidence of dystokia with all bulls.

Twelve farms reported mean calf mortality rates of 26.9

The introduction of synchronization techniques in the

per cent, which on some farms was associated with a

mid 1970s offered farmers a unique opportunity to

high incidence of dystokia. On the farms with low mor-
exploit the use of AI without the time consuming and
tality, none of the bulls was associated with an incidence
difficult task of oestrous detection or the need to sepa-
of dystokia of more than 4 per cent, while on the high
rate individuals from a group for service. The results
mortality farms no bulls resulted in an incidence of less
of numerous studies have shown that the pregnancy
than 20 per cent. In this study the bulls used were
rates following prostaglandin or progestagen treatment
known to be breed average or less for both dystokia on
are similar to those obtained with untreated controls
cows (<2.7 per cent) and gestation length (<281 days).
inseminated at observed oestrus. Despite these findings,
In Table 5.6 only bulls 1 and 3 were specifically
the uptake of commercial techniques to control the
recommended for ease of calving. This highlights the
bovine oestrous cycle have fallen well short of expec-
importance of ensuring that if a recommendation is
tations, as in the field results can be disappointing
based on heifer calvings, that the bull has been used

where herd management or supervision of the breed-

on sufficient farms for the data to be reliable.

ing programme are not of a sufficiently high standard.

In general, bulls with short gestation lengths give

There are many reasons why group synchronization

easier calvings. The mean gestation lengths of bulls in

of heifers has failed to become a technique in wide-

this study ranged from 273 to 279 days. Providing a bull

spread use. Initially, farmer expectation was too high.

is not known to be above breed average for dystokia on

Many had been accustomed to running heifers with a

cows, he can be considered for use on heifers, especially

natural service bull for perhaps nine to twelve weeks.

if the gestation length is also less than the mean for the

By this time around 90 per cent should have become

breed. However, some farmers reported dystokia with

pregnant, even with modest levels of performance.

Farmers have, therefore, become used to finding the

majority of heifers confirmed in calf when manually

examined as a group and tend to expect similar results

from a single AI mating.

Table 5.6

The effect of bull on dystokia in heifers.

Compared with natural service, the cost of a con-

Bull (number of

Percentage calvings

trolled breeding programme with AI is likely to be at

calvings)

least £25–£35 if a double insemination is given. If only

Normal

Assisted

Difficult

40 per cent of served heifers produce a calf and 50 per

cent of those are male the service cost per heifer calf

1 (236)

52

37

11

born could easily be in excess of £100.

2 (231)

70

25

5

Although pregnancy rates of 40 per cent are not

3 (249)

79

19

2

unusual, the management factors affecting fertility in

4 (221)

71

24

5

dairy heifers are generally well understood. Providing

5 (261)

79

19

2

the recommendations given in the section ‘Rearing

6 (263)

63

31

6

management, 12–15 months' (see p. 58) are followed,

pregnancy rates of 65–75 per cent should be achieved.

levels according to size at this time enables the heifer

At this level of fertility the use of synchronization

group to become more evenly matched. High-quality

becomes more attractive if used only for a proportion

silage and barley straw without further supplementation

of the group.

should be sufficient for well-grown heifers. A mineral

Several synchronization techniques (p. 678) are now

mix should be fed to heifers given silage and straw alone.

routinely used for controlled breeding of heifers,

including the use of prostaglandins, progestagen and

GnRH. The oestrous response following synchroniza-

Rearing management, 18–22 months

tion in heifers is generally precise and pregnancy rates

to fixed time insemination satisfactory. However, a

Autumn-born heifers should be turned out as soon as

proportion of heifers do not show oestrus within the

soil and weather conditions permit. Nitrogenous fertilexpected window after treatment and programmes may

izer with phosphate and potash according to soil

therefore recommend AI only at observed oestrus or

requirements should be applied. The sward height

AI at a fixed time followed by either AI at subsequent

should be maintained at about 6–8 cm. Target stocking

observed oestrus or natural service.

rate at this stage should be six to seven livestock

An example synchronization programme would be a

units/ha.

system whereby the heifers are housed or moved to a

field adjacent to the handling facilities six weeks before

commencement of service. At the same time the heifers

Rearing management, 22–24 months

are weighed and the diet adjusted to ensure a minimum

gain of 0.8 kg/day with adequate mineral supplementa-

(2 months precalving)

tion. Any routine veterinary treatments necessary are

undertaken and a check made to ensure that the heifers

In the two months before calving heifers should be

can be clearly and easily identified. After a minimum of housed or grazed with the dry cows of a similar stage

four weeks all heifers are injected with prostaglandin

of gestation as this reduces the stress of introducing

and observed closely for standing oestrus. Heifers not

them to the milking herd post calving. If heifers are

inseminated after the first injection are given a second

to be managed and milked as a separate group during

injection and inseminated at a fixed time, either once

their first lactation, precalving heifers can be managed

at around 84 hours after treatment or twice at 72 and

as a separate group. In the last two months of pregnancy

96 hours after injection. Following the synchronized

the growth rate of heifers should be controlled to

mating either the heifers are observed for repeat Al, or

approximately 0.7 kg/day.

a bull of another breed is turned in as soon as the period

of intense oestrous behaviour has subsided, which is

Growth rates in pregnancy

usually on the fifth or sixth day after the second

injection.

Target growth rates between the third to eighth month of pregnancy should be approximately 0.8 kg/day, but

should be adjusted to ensure adequate calving weights.

Rearing management, 15–18 months

The target calving weight for a heifer depends on her

estimated mature body size and the management

Housed heifers should be allowed approximately

routine during the first lactation. The target calving

7 m2/head from this age. The preservice ration should be

weight for a Holstein heifer is around 650 kg precalv-

maintained for at least six weeks. As soon as it is known

ing. In management systems where heifers are fed as a

that pregnancy has been established in the majority of

heifer group in the first lactation there is obviously less

heifers, decisions can be taken on the level of nutrition

competition than where heifers are competing with

for the remainder of the period. Their weights should be

older cows.

recorded and compared with target (Table 5.9). They

Two-year calving heifers competing with cows in self-

should be grouped according to size. Required growth

fed silage systems are at the greatest risk as not only are rates should be calculated using the target calving

they relatively small in weight and stature but they are

weight and feed adjusted accordingly, with higher levels

also changing their teeth at this time.

of supplementary concentrate feed offered to the

In an investigation involving Friesian/Holstein

smaller heifers. Growth rates of up to 1 kg/day or more

heifers calving at two years, Keown (1986) showed that

are not uncommon in Holstein heifers at this age. It is

growth rate during pregnancy has a significant effect

likely that, at this age, the variation in weights of heifers

on milk production, with the heavier heifers at calving

of similar age will be around 80–100 kg. Adjusting feed

producing the most milk (Fig. 5.4).

900

800

700

600

500

400

300

200

Increase in milk yield (kg)

100

0

Fig. 5.4

The effect of weight at calving on

408

431

454

476

499

522

544

567

590

612

635

658

680

first lactation yield (increase in first lactation

Body weight post calving (kg) based on American data (Keown, 1986) milk yield). Data used with permission.

Weight, height and pelvic length at calving were

Cubicle training

found to affect milk yield. All these relationships were

Some dairy heifers can show clinical signs of laminitis

statistically significant and suggest that while rapid

early in their first lactation. This is frequently a stress-

growth in the prepubertal heifer is detrimental to milk

related condition associated with changes in the envi-

yield, the converse applies during pregnancy.

ronment, social grouping and feeding, which occur at

The initial results suggested that there is a positive

the time of first calving. It has been shown that housing

relationship between body condition score and milk

heifers for a few weeks during a period when cubicles

yield throughout the condition score range. However, a

are not occupied by cows has two advantages. Firstly,

more detailed analysis showed that when heifers are fed

the heifers become accustomed to using cubicles and

adequately during the first lactation there is no benefiare less likely to reject them following introduction

cial effect on milk yield of feeding to calve them at body

into the herd, and secondly, as one of the postparturi-

condition scores above 2.5 for Friesians or greater than

ent stresses is eliminated, the incidence of laminitis and

2.0 for Holsteins or the Channel Island breeds. This

other stress-related metabolic diseases is reduced.

information is reassuring in view of the fact that an

Providing a clean concrete loafing area whenever the

increased level of assistance at calving was required

animals are housed, throughout the heifer rearing

when heifers calved at condition scores of 3.0 or more

phase, encourages better hoof formation and reduces

(see pp. 10–11).

problems when heifers move into cubicle yards post

To a considerable extent, dystokia can be avoided by

calving.

careful management in the ninth month of pregnancy.

Growth rate should be restricted at this time.

Minerals and trace elements

A detailed description of some of the minerals and

Fly prevention

trace elements of particular significance to the dairy

Summer mastitis can be a cause of loss in heifers (see

heifer is given in Chapters 21, 46. In view of the fact

Chapter 24). It is most likely to occur between the fifth

that dairy heifers receive relatively little compound

and eighth month of pregnancy, usually in July, August

feed, deficiencies are more likely than with the milking

and September. The incidence of summer mastitis can

herd. The advice given regarding minerals such as

be reduced by grazing large open fields away from

phosphorus, copper, cobalt, selenium and manganese

woods and streams and by the use of fly repellent meas-

fed to dairy cows applies equally to dairy heifers (Chap-

ures. Impregnated ear tags, sprays and pour-ons have

ters 18, 21).

proved to be of benefit in preventing disturbance and

Although iodine deficiency may not be a widespread

irritation caused by flies and reducing the incidence of

problem, it can be responsible for serious losses on indi-

New Forest eye and summer mastitis. The incidence of vidual farms (see pp. 253–60). If perinatal calf mortal-

the latter can also be reduced by regular (e.g. weekly)

ity in heifer calvings has exceeded 10 per cent in

teat treatment with proprietary fly repellents.

previous years an investigation into the iodine status of

the herd is recommended early in the season and treat-

Table 5.7

Effect of weight gain during pregnancy on dystokia.

ment undertaken during the fifth to eighth months of

pregnancy.

Weight gain

Calf

Percentage calvings

Magnesium supplementation is normally given to

(kg/day)

mortaity

(%)

Normal

Assisted

Difficult

dairy cows prior to calving in order to reduce the inci-

dence of hypocalcaemia. As heifers are less prone to

<0.4 (49)

19

61

35

7

this condition, supplementary magnesium is not always

0.41–0.60 (348)

10

74

25

3

provided (see Chapter 46). Data from ADAS trials

0.61–0.80 (854)

11

69

26

5

suggest that magnesium supplementation in the month

>8.0 (199)

14

64

28

8

prior to calving reduces the incidence of dystokia.

As the energy intake should be restricted at this time

Number of cattle recorded at each weight gain is given in brackets.

it is usually most convenient to provide this via the

water.

Table 5.8

Farms with calf mortality rates below 5 per cent com-

pared with farms with calf mortality rates above 20 per cent.

Management factors affecting

Heifer measurements

Low

High

dystokia and calf mortality

mortality

mortality

Management at around the time of calving has a major

Number of farms

18

12

effect on dystokia and calf mortality. Management

Number of heifers

447

212

Average number/farm

25

18

prior to service and during the first eight months of

Mean age at calving (days)

731

734

pregnancy is generally considered to have little effect,

Mean weight at service (kg)

330

323

although opinion is divided. The results of a large-

Mean weight at calving (kg)

504

492

scale investigation into the factors affecting dystokia

Mean height at service (cm)

117

118

showed a tendency for calf mortality and dystokia to

Mean height at calving (cm)

128

127

be greater at each end of the growth rate range

Mean distance hook to pin

44

43

(Table 5.7).

at service (cm)

On the basis of this study, high weight gains during

Mean distance hook to tail

38

38

pregnancy should not result in unacceptable levels

head at service (cm)

of dystokia, especially if liveweight gain is restricted during the final month of pregnancy. An analysis of the

precalving weight and height records showed there to

be no significant relationships with dystokia.

relating to the management of the heifer at around the

In order to study the effect of management on the

time of calving.

factors affecting calving difficulty and calf mortality, the

performance of the 18 farms with calf mortality rates

below 5 per cent was compared with the performance

Management prior to calving

of the 12 farms with calf mortality rates over 20 per

cent. There was no difference between the groups in the

Providing weather conditions permit, it is preferable to

growth rates of the heifers (Table 5.8).

graze heifers in a field or paddock adjacent to the dairy

These figures suggest that growth rate of the heifer

complex, where the forage is naturally sparse or can be

has little effect on dystokia. Equally, there appeared to

deliberately restricted to ensure that the optimum body

be no differences between the groups in the size of the

condition at calving is achieved. The heifers should have

calves born, farmers with both low and high mortality
the opportunity for exercise. The diet offered should be
rates recording a similar proportion of small, medium
a correctly formulated transition diet which introduces
and large calves. The high mortality rate farms assisted
the heifer to the main forages and feeds which she will
a greater proportion of heifers in all of the size group
be fed post calving. Mineral supplementation remains
categories and classified 58 per cent of large calves as
as for dry cows. Supplementary magnesium should be
difficult calvings compared with only 8 per cent of the
provided.

large calves on the low mortality rate farms.

The group should be observed at least four to five
There is no evidence from these data to suggest
times daily from three weeks prior to the estimated date
that the management of the heifer during pregnancy
of the first calving. Care should be taken to adjust the
accounted for the differences obtained. The differences
'due to calve' dates for the gestation length of the bulls
would, therefore, appear to be due mainly to factors

used.

Management at calving

A study involving 179 small-framed Friesian heifers

calving at two years, all the progeny of one sire, com-

Grazed heifers should calve in their allotted field or

pared the milk yields and longevity of heifers fed with

paddock if possible; housed heifers should calve in

or without competition during their first lactation. The

buildings with which they are familiar.

first lactation milk yields and survival rates to the end

There is evidence to suggest that moving a heifer to

of the fifth lactation of heifers at a range of service

a calving box increases the risk of dystokia and there-

weights are shown in Table 5.10.

fore it is preferable to avoid movement unless this is

On this farm no allowances were made for the size

essential for adequate assistance (Chapter 67). The field

of heifer or the effect of competition on milk yield. A

should be well fenced to avoid the possibility of heifers

higher percentage of heifers in the group fed with cows rolling into positions from where it would be difficult to

were therefore culled on grounds of disappointing milk

assist. The herdsman should be trained to recognize

yields.

fear, abnormal pain or distress and instructed on the

In a subsequent study, the lactation records of 1346

correct use of calving aids.

cows on 54 farms were examined to determine the

extent to which heifers were affected by competition

with cows. The farms were allocated to one of three

groups according to the method of management during

Targets for growth for

the first lactation:

two-year calving

Group 1: fed as a heifer group throughout the winter

period.

The targets shown in Table 5.9 refer to heifers calving

Group 2: housed with cows. Fed a complete diet or

at two years. The target growth rates for heifers calving

manger fed.

at 2.5 or 3.0 years are less as they can grow at a slower

Group 3: housed with cows. Fed on self-feed silage.

rate overall and during growth they can be allowed a

store period. The maximum growth rates suggested for

Heifers fed as a heifer group (group 1) gave more milk

the first year and the minimum growth rates during the

than those fed in competition with cows (Table 5.11).

immediate preservice period apply.

Farmers electing to feed cows in groups are more

likely to be aiming for high yields than those where the

Management during the

first lactation

Table 5.10

The effect of competition on first lactation milk yield

and survival rates to the end of the fifth lactation.

Heifers fed in competition with cows during their first

lactation are likely to give less milk in the first lactation

Weight at service (kg)

Milk yield (kg)

and have less chance of surviving to calve for a second

time than when fed in a heifer group.

Competition

No competition

225–259

2892 (33)a

3852 (37)

260–279

3334 (46)

4070 (73)

280–299

3639 (18)

3992 (52)

300–349

3131 (21)

3857 (32)

Table 5.9

Growth targets for two-year calving of Holstein

heifers.

a Numbers in parentheses represent survival rate percentage.

From

To

Daily Target

liveweight liveweight

(kg)

gain

(at end of

(kg)

period)

Table 5.11

Mean first lactation milk yields.

Birth

Weaning

0.50

65

Group 305-day

yield

Total

Lactation

Weaning

4 months

0.90

150

(No.)

lactation

length

4 months

10 months

0.65

280

Milk

Fat

Protein

yield

10 months

13 months

0.80

350

13 months

17 months

0.90

460

1 (207)

5200

209

170

5369

319

17 months

22 months

0.90

595

2 (580)

4504

180

146

4641

308

22 months

Calving

0.65

630 (pre calving)

3 (559)

4274

174

140

4358

whole herd is managed as a single unit. When the milk

Survival rates

yields are compared with the average herd yield it can

be seen that the true effect in heifers between herds is

On average, cows in Britain fail to survive in the herd

some 5 per cent of mature potential (Table 5.12).

for sufficient time to fulfil their mature yield potential.

Although heifers fed in competition with cows during

The mean length of herd life is less than 3.5 lactations,

their first lactation are likely to yield less milk, it is not while mature yields are not obtained until the fourth,

always possible, feasible or economic to manage, milk

fifth or even the sixth lactation. It is also estimated that

and feed them separately.

some 40 per cent of all heifer calves born alive fail to

The effect of competition can be minimized by ensur-

calve for a second time. The main reasons for disposal

ing that heifers are well grown prior to calving. Size is

are fertility and low milk production. It is evident that important, but not the only factor determining the peck

the rate of growth during the rearing period influences

order within a group of cows.

milk yield; the level of nutrition at around the time of

Immediately after calving a heifer is maternally ori-

service affects pregnancy rates and the management of

entated and may be weakened by a prolonged and dif-

the heifer at calving the incidence of dystokia and calf

ficult calving. She is, therefore, least able to establish her mortality. It must be emphasized that attention to detail

place in the peck order. Bullying following introduction

and good management throughout the rearing period

to the herd can be reduced by ensuring that the

have a considerable effect on longevity and overall herd

heifer has regained her strength after calving and by

profitability.

allowing her to join the herd in the late afternoon or

early evening when there appears to be less aggressive

behaviour. Competition for food can be reduced by

providing access to ‘easy’-feed silage in self-fed sys-

tems. It is as well to remember that heifers calving at

References

two years of age are changing their teeth at this time

and find difficulty in extracting silage from well-

Drew, S.B. (1988) The influence of management factors during

consolidated clamps. The problem is obviously most

rearing on the subsequent performance of Friesian heifers.

British Cattle Breeders Digest, **43**, 41–8.

acute on farms where the width of the silage face is

Drew, S.B. & Altman, J.F.B. (1982) The effect of weight at first inadequate or where true 24-hour access is not pro-insemination on the subsequent performance of Friesian

vided. Silage or other forage should be fed in mangers

dairy heifers. *Animal Production*, **34**, 371.

or cut from clamps and fed behind an easy-feed barrier.

Drew, S.B. & Pointer, C.G. (1977) The effect of level of nutri-The newly introduced heifers should be observed care-

tion on fertility in Friesian heifers in autumn and early

fully to ensure that they are maximizing forage and con-

winter. EAAP 28th Annual Meeting, Brussels, 22–27 August

centrate intake. Sufficient loafing areas and loose

1977. Commission on Animal Health and Production Paper

housing or cubicles should be provided for all the cows

77/8, pp. 1–3.

in the herd. There is a tendency for farmers to provide

Foldager, J. & Sejrsen, K. (1982) Nutrition of replacement 5 per cent fewer cubicles than cows in the group on the

heifers affects mammary development and their ability to

assumption that not all the animals will wish to lie down

produce milk. World Congress on Diseases of Cattle, The

Netherlands, vol. I, p. 45.

at the same time. Heifers will not always lie in empty

Furniss, S.J., Kirby, S.P.J. & Smith, G. (1988) The effect of cubicles between older cows and therefore it is recom-dam's parity on the performance of daughters. *British Cattle* mended that one cubicle is provided for each cow and

Breeders Conference Digest, **43**, 49–50.

heifer in the group.

Furniss, S.J., Stroud, A., Barrington, H., Kirby, S.P.J., Wray, J.P.

& Dakin, P. (1986) The effect of dams' parity on first

lactation performance of dairy heifers. *Animal Production*, **42**, 463.

Hafs, H.D., Manns, J.G. & Drew, S.B. (1975) The onset of

oestrus and fertility of dairy heifers and suckled beef cows

Table 5.12

Mean first lactation yields (kg) as percentage of

treated with prostaglandin. *Animal Production*, **21**, 13–28.

mature yields in different management systems.

Keown, J.F. & Everett, R.W. (1986) Effect of days carried calf, days dry and weight of first calf heifers on yield. *Journal of* **Group**

Mean

Mean

Yield

Heifer yield as

Dairy Science, **69**, 1891–6.

heifer

cow difference

percentage

of

Kossaibati, M.A. & Esslemont, R.J. (1996) *Understanding the* **yield**

yield

cow yield

Rearing of Dairy Heifers – A Stockman's Guide. BCVA,

NMR, DAISY, Forte Dodge.

1

5200

6265

-1065

83

Little, W. & Kay, R.M. (1979) The effects of rapid rearing 2

4504

5630

-1126

80

and early calving on the subsequent performance of dairy

3

4274

5479

-1205

78

heifers. *Animal Production*, **29**, 131–42.

Pirlo, G., Miglior, F. & Speroni, M. (2000) Effect of age at first Sejrsen, K. & Foldager, J. (1992) Mammary growth and milk

calving on production traits and on difference between milk

production capacity of replacement heifers in relation to

yield returns and rearing costs in Italian Holsteins. *Journal* diet energy concentration and plasma hormone levels . *Acta*

of Dairy Science, **83**, 603–8.

Agricultura Scandinavica Section A. Animal Science, **42**, Sejrsen, K. (1994)

Relationships between nutrition, puberty

99–105.

and mammary development in cattle. *Proceedings of the*

Nutrition Society, **53**, 103–11.

Chapter 6

Tropical Cattle Management

R.D. Fielding and R.W. Matthewman

Introduction

68

the absence of very low temperatures; grass species

Statistics

68

capable of greater energy capture and dry matter yields

The productivity of tropical cattle

68

than temperate grasses; vast land areas un-utilized or

Production strategy

69

underutilized; labour availability, much with strong

Calf management

69

animal keeping traditions; and many locally adapted

Preweaning management

70

breeds that have been selected for production in

Weaning

71

adverse environments.

Post weaning management

71

Onset of puberty

72

Counteracting these advantages are several con-

Monitoring growth

72

straints, which include: high temperatures which

Adult production

72

depress production and food intake; long periods

Grass production

73

without rain when grass growth is impossible; animal

Systems of production

74

diseases, such as trypanosomiasis and those transmitted

Management of dairy cows

77

by ticks; communal grazing systems that inhibit invest-

Management of beef production

78

ment and the use of improved management techniques;

and a lack of effective local demand and infrastructure

to stimulate and support production. These advantages

Introduction

and constraints are discussed in greater detail in the

subsequent sections.

In the following sections an overview is given of tro-

pical cattle management and the tropical production

The productivity of tropical cattle

systems in which cattle are found. Attention is paid to

the main differences between tropical and temperate

The productivity of tropical cattle is sometimes said to

production systems in order to introduce them to the be low. This is often untrue when total output is con-

unfamiliar reader. The majority of tropical cattle are

sidered. Absolute production levels of milk or meat are

kept in extensive subsistence systems that differ funda-

usually low compared with temperate cattle, but capital

mentally in their management objectives from

inputs are also usually low. Productivity levels, in terms

commercial temperate enterprises. The latter tend to be

of use of capital as opposed to production levels, may

specialized single product units whilst in the tropics

therefore be relatively high.

livestock units are usually multi-purpose with

The multiple outputs of tropical cattle systems include

important social as well as commercial objectives.

milk, meat, dung, hides and draught power (Fig. 6.1).

Additional functions include acting as a saving mecha-

nism, as a means of realizing emergency cash, as a means

Statistics

of fulfilling social obligations and as a symbol of wealth

Asia, Africa and South America contain approximately

and status within the community. These outputs are not

74 per cent of the world's cattle (Table 6.1) and if other
reflected in commonly used measurements of perform-
tropical areas are taken into account such as Central
ance such as offtake, which refer only to products and
America then over 78 per cent are found in the tropics
animals that are sold. Social offtake, barter offtake, sub-
and subtropics. The same tropics produce only 59 per
sistence offtake, increases in herd size and the use of
cent of the world's beef and veal and 55 per cent of the
animals for draught power are not reflected in normal
world's milk (Tables 6.2 and 6.3).
offtake measurements. The difference between the
This discrepancy represents a challenge for those
number of animals sold each year from subsistence
involved in tropical cattle management, since the
systems and from commercial ranches of 8–10 per cent
tropics have many advantages for bovine production.
and 18–20 per cent respectively may be explained largely
These include: a potential year-round growing season in
by these differences in objectives and products.

Production strategy

support this view. Intensification and specialization are

certainly inhibited by the need for multi-purpose pro-

Some people have argued that the tropics are suited to

duction. However, as development evolves it will prob-

multipurpose low input/low output systems. The envi-

ably promote the type of specialization that has taken

ronmental constraints on high producing animals and

place in temperate areas. The speed of this evolution

the lower quality forages and byproducts of the tropics

will be determined by our ability to counteract the

direct and indirect negative environmental effects on

the production systems and to capitalize on the positive

Table 6.1

World cattle numbers by continent (1000 head).

ones.

Source: Food and Agriculture Organization (1998)

1989–91

%

1998

%

World

1 294 020

1 318 386 (+1.9)

Calf management

Africa

187 534

14.5

217 388 16.5

North and

160 074

12.4

158 195 12.0

In traditional cattle systems, such as pastoralism and

Central America

settled extensive systems, reproductive cycles follow

South America

272 829

21.1

299 947 22.8

seasonal climatic variation. The peak of calving often

Asia

400 563 (FMR)

31.0

450 389 34.2

occurs in the early wet season. In Sudan, in southern

Europe

123 383 (FMR)

9.5

156 212

11.8

Darfur, most calvings occur in April, May and June.

Oceania

31 759

2.5

36 254

2.7

South of the Equator in Zambia the corresponding

USSR

117 877

9.0

–

–

peak occurs in October and November. In humid areas

FMR: formerly; prior to break-up of USSR.

where there is less seasonal nutritional stress, calvings

Number in brackets is the percentage change 1989–91 to 1998.

occur throughout the year.

Table 6.3

World milk production from cows, by continent

(1000 t, whole, fresh). Source: Food and Agriculture Organization **Table 6.2**

World beef and veal production by continent

(1998)

(1000 t). Source: Food and Agriculture Organization (1998)

1989–91

%

1998

%

1989–91

%

1998

%

World

475 154

466 347 (-1.9)

World

52 718

53 695

(+1.9)

Africa

15 221

3.2

17 913

3.8

Africa

3 319

6.3

3 805

7.1

North and

84 146

17.7

91 385

19.6

North and

13 217

25.1

14 710

27.4

Central America

Central America

South America

32 013

6.7

45 325

9.7

South America

9 044

17.2

9 886

18.4

Asia

56 674 (FMR)

11.9

82 871

17.8

Asia

5 269 (FMR)

10.0

10 023

18.7

Europe

167 194 (FMR)

35.2

207 768

44.6

Europe

11 056 (FMR)

21.0

12 726

23.7

Oceania

14 126

3.0

21 086

4.5

Oceania

2 188

4.1

2 546

4.7

USSR

105 779

22.3

–

–

USSR

8 625

16.3

–

–

FMR: formerly; prior to break-up of USSR.

FMR: formerly; prior to break-up of USSR.

Number in brackets is the percentage change 1989–91 to 1998.

Number in brackets is the percentage change 1989–91 to 1998.

Fig. 6.1

Draught cows in Guadaloup.

Preweaning management

For the first two months the calf should ideally be

kept in an individual stall measuring about 2 ¥ 1.5 m. In

In pastoral systems, young calves are separated from

warmer areas, portable calf pens may be used. The most

the grazing herd during the day and kept in special calf

practical indoor system is a shed sited in a gravel or con-
areas. After evening suckling cows and calves may again
crete yard where the calves may exercise. The house
be separated. In Nigeria, Fulani pastoralists allow
must provide shelter, be easily cleaned and should keep
calves to suckle briefly in the morning to induce milk
calves warm in cool weather and cool in warm weather.
let-down and then tether them until milking is com-
It may be no more than a simple roof over a concrete
pleted. After milking the calves suckle until the herds
base. Slatted-floor houses have advantages, but are
move off for grazing. Calves seldom receive supple-
more expensive (Fig. 6.2). No walls are necessary in the
ments and may not even receive adequate milk due to
humid tropics, but adequate overhangs are required in
overmilking for human consumption. This is typical of
high rainfall areas.
pastoralism in Africa and the Middle East.
Housed calves, if properly managed, tend to perform
Calf management inputs in these systems are
better than calves on pasture. A typical home mixed

minimal and this is reflected in the levels of production.
ration to accompany whole milk is a mixture of 50 per
In arid areas gains may be as low as 200 g/day with
cent ground guinea corn and 50 per cent groundnut
liveweights of 60 kg and 150 kg at 6 and 18 months
cake from two to three weeks of age.
respectively. Calf mortality rates of 15–20 per cent in
The calf cannot utilize average quality tropical forage
pastoral herds and of up to 40 per cent in sedentary
successfully until it is four or five months old. Conse-
herds are normally encountered.
quently, it is desirable to suckle or bucket feed for as
Environmental stress, principally due to high ambient
many months as possible and to feed concentrates
temperatures, is best minimized through correct time of
and high-quality roughage. In intensive systems, the
grazing, use or planting of shade trees and provision of
provision of some good quality forage is beneficial to
simple open houses that offer protection from the
stimulate rumen development.
direct rays of the sun, but ensure maximum air flow.

Major calf diseases in intensive systems include

As production systems improve indoor rearing

scouring (gastroenteritis) (see Chapter 14), pneu-

systems may be adopted. Semi-intensive and intensive

monia (see Chapter 17) and worms (roundworms,

calf rearing systems found in the tropics include the

following.

• Single suckling for beef calves where the objective is to achieve greatest calf growth rates and conversion of milk to meat.

• Dairy ranching where calves are separated at night and the cows are milked once in the morning and limited or restricted suckling is allowed throughout the day. If management will allow evening milking, suckling all night and separating the cow and calf during the day is a better option, as carried out by some pastoralists.

In the tropics calves may be reared inside, outside or a combination of both. Calves can be reared outside all year, though a number of disadvantages are associated with outside rearing on grass paddocks.

• It is difficult to keep grass sufficiently young and nutritious for calves.

• It is difficult to keep calves free from internal parasites if they are grazing in small enclosed areas.

• Environmental stress (temperature and radiation) can be high, even if good shading is available.

The combination of poor nutrition, parasites and climatic stress is a major constraint to calf rearing. Adequate nutrition is the key to success and to enabling a stable host–parasite relationship to be established.

Fig. 6.2

Australian dairy Zebu calves in Malaysia.

thread-worms, hookworms, lungworms and tapeworms)

rainy season, but weight loss frequently occurs in the

(see Chapter 19). Suckling systems tend to have lower

dry season caused by combined energy and protein

mortality rates than bucket feeding systems. The advan-

deficiencies. Of the two, protein is usually the more

tage is due to the avoidance of disease caused by incom-

important. Levels of nitrogen in dry tropical grasses

plete sterilization of buckets and equipment, and
commonly fall to around 0.5 per cent, equivalent to 3–4
suckled calves may receive more milk at more frequent
per cent digestible crude protein (DCP) in the dry
intervals. In herds with many calves to be fed twice a
matter. At this level of protein, grass digestibility is low
day, maintenance of sanitation is difficult and the inci-
and intake falls. The calf may enter a negative nitrogen
dence of gastrointestinal disorders and indigestion in
balance as metabolic faecal nitrogen loss exceeds
bucket-fed calves is often high (Chapter 16).
nitrogen intake. Young cattle allowed only poor
Restricted suckling can overcome many problems
quality roughages thus tend to develop a ‘bloated’
and is the system commonly practised in pastoral and
appearance.
semi-intensive systems. It is also widely used in the
Breeds differ in their ability to recover from weight
dairy ranching systems of South America. Calves are
loss. These differences include the ability to reduce
housed separately, either at night or during the day, and

metabolic rate during feed shortage and the efficiency
are then allowed to suckle for one minute to achieve
of water conservation in periods of water shortage. The
let-down before the cows are milked in the morning or
latter may lead to increases in feed digestibility due to
evening. The cows are fully milked-out and the calves
slower rates of passage. The risk with major weight loss,
then run with the cows for the rest of the day or night.
in excess of 15–20 per cent, is permanent stunting and
When properly managed, restricted suckling systems
increased disease susceptibility.
have several advantages including better calf growth
During ‘normal’ dry seasons deaths are often rare,
and health, higher milk yields including more saleable
but once the rains begin, losses may occur due to the
milk and are associated with reduced mastitis in the
stresses of wetting, lower temperatures and highly
cows.
succulent grasses causing digestive upsets.
Provided that the dry season weight loss is within the
range of tolerance of the breed type, then rearing cattle

Weaning

usually show compensatory growth during the subse-
In many systems calves are naturally weaned when the
quent rainy season and make rapid gains (Hogg, 1991).
milk supply from the cows ceases due to the poorer
Tropical cattle have been naturally selected to cope
nutrition of the dry season. This leaves calves at varying
with recurring periods of undernutrition and then to
liveweights and different degrees of readiness for sur-
compensate effectively. This is a characteristic of great
vival during the dry period. Where cows continue to
importance which may be threatened by the increased
produce milk, the chances of reconception are reduced,
introduction of exotic genes. The physiological mecha-
often to such an extent that a calving pattern of a calf
nisms that allow compensation involve reduced
every two years develops.
metabolic rate, induced by a period of undernutrition,
In some systems weaning is effected earlier by tradi-
and increased voluntary food intake during realimen-
tional methods. These may include thorns tied to the

tation. The period of realimentation and compensation
calf's head or sacks tied around the cows' udders. Dairy
is determined by the length of the rainy season. This is
heifers in less extensive systems are best weaned at four
often short and animals again enter a period of under-
to five months of age, depending on the availability of
nutrition resulting in further weight loss. A 'zig-zag'
alternative feeds of adequate quality. Beef calves
pattern of animal growth thus characterizes many trop-
should have maximum benefit from the cows' milk and
ical rearing systems. Whilst dry season losses can be
hence should be weaned as late as seven months. Heifer
avoided by supplementation this is rarely justified
calves should be weaned early enough to prevent them
economically.
conceiving to the bull running with the cows. Avoiding
An understanding of compensatory growth is impor-
early conceptions is difficult in many extensive tradi-
tant for reasons of rearing economy and in the man-
tional systems, though in many zebu breeds maturity
agement of feeding trials involving measurement of

does not occur until a greater age (i.e. 18 months plus)

liveweight gain. Animals that are in a compensation

when animals have reached approximately 66 per cent

phase may give a misleading result if compared with

of their mature weight.

animals not in a compensation phase.

The consequences of the weight gain/weight loss

pattern of growing tropical cattle are several and

Post weaning management

include delayed oestrus, reduced lifetime performance,

Once weaned, calves usually encounter a period of sub-

reduced selection opportunities and also increased

optimal nutrition. Reasonable gains can be made in the

susceptibility to disease.

When rearing stock are housed or confined they may

Castration is carried out in many traditional cattle

still suffer extended periods of poor nutrition when

systems, but is usually left until the animal's potential

they are fed adult diets, such as sugar-cane tops or

has been assessed. Inferior animals are castrated in other low-quality byproduct feeds. In pastoral systems

order to stop them mating. However, sometimes the

greater care is normally given to female stock because

'biggest and best' are castrated to produce draught

of their importance in producing calves and milk. Sub-

oxen.

optimal management of rearing stock is common in all

ruminant systems, tropical or temperate. It is unfortu-

nate that the consequences cannot be better communi-

Monitoring growth

cated to the livestock owners and herders so as to

motivate them to improve the management of their

In traditional systems, monitoring of liveweight is by

rearing stock.

eye, but in more controlled systems regular weighing is

desirable. If weighing facilities are not available on the

farm, heart-girth measurements can be taken using a

Onset of puberty

weigh-band. Attention should be paid to the breed for

Oestrus

which the weigh-bands were initially designed, and if possible the accuracy should be checked against actual

In heifers, the period between weaning and calving can

weighings and the bands calibrated appropriately.

be divided into two phases: weaning to first service and

Direct weighing and heart-girths do not always fully

first service to calving. The aim is to achieve optimum

define the state of the animal and condition scoring may

growth with the earliest maturity at the lowest cost. To

be appropriate. Systems of condition scoring for *B.*

achieve this small quantities of concentrate or supple-

taurus cattle (pp. 10, 11) may not be appropriate for *B.*

ment can be a great benefit. A check in growth occurs

indicus breeds, and scoring systems designed for tropi-at weaning, but can be compensated for by the addition

cal cattle should be used (Pullen, 1978; Nicholson and

of concentrates.

Butterworth, 1985). Pullen suggested a score range

The onset of oestrus occurs at a particular weight

of 0–5 from emaciated to fattest while Nicholson and

according to breed. Under good conditions regular

Butterworth suggested a nine-point scoring range.

cycling may be achieved at 13–14 months. In the tropics

low nutritive quality of grasses, disease and environ-

mental stresses usually result in delayed oestrus com-

pared with temperate conditions. Whereas *Bos taurus*

Adult production

reach puberty at 30–40 per cent of mature weight, *B.*

indicus reach puberty at around 60 per cent of mature The different tropical cattle production systems are the

weight (Macfarlane and Worrall, 1970).

result of differing levels of dry matter production per

The weight of the young heifer at first service and its

unit area available for grazing. This varies from very

rate of growth up to calving have an important effect

low levels in the arid areas (<1000 kg/ha per annum) to

on milk yield in later lactations. If early calving is com-

high levels (>10 000 kg/ha per annum) in the humid

bined with underfeeding in the rearing stage, heifers

areas, reducing again to low levels where intensive crop

may be permanently stunted and milk production

production limits grazing to roadside verges and

reduced.

intercrop areas.

Once heifers are cycling normally and have achieved

Grazing utilization is often complicated by land

an adequate body weight, mating or service should be

ownership, which includes ‘ownership’ by nation, tribe,

timed to ensure calving at the optimum time of the year.

group or individual. Most grazing is communal and

This is often assumed to be the beginning of the rains,

herders have the right to graze as many animals as they

but it may be better to aim for calving just before the

wish. Individual ownership and/or leasing of grazing

rainy season. This will allow the calves to start grazing

land are increasing and this may stimulate intensifica-

during the rainy season before the quality of the

tion and improvement. Much depends on the availabil-

herbage falls and as the dry season approaches.

ity of employment opportunities for those who are

unsuccessful when land rights are allocated. If such

opportunities are not available enforcement of land

Sperm production

ownership is difficult and social pressure tends to result

The onset of sperm production is not as critical as the

in the continuation of communal grazing.

onset of oestrus. Only where conditions are very poor

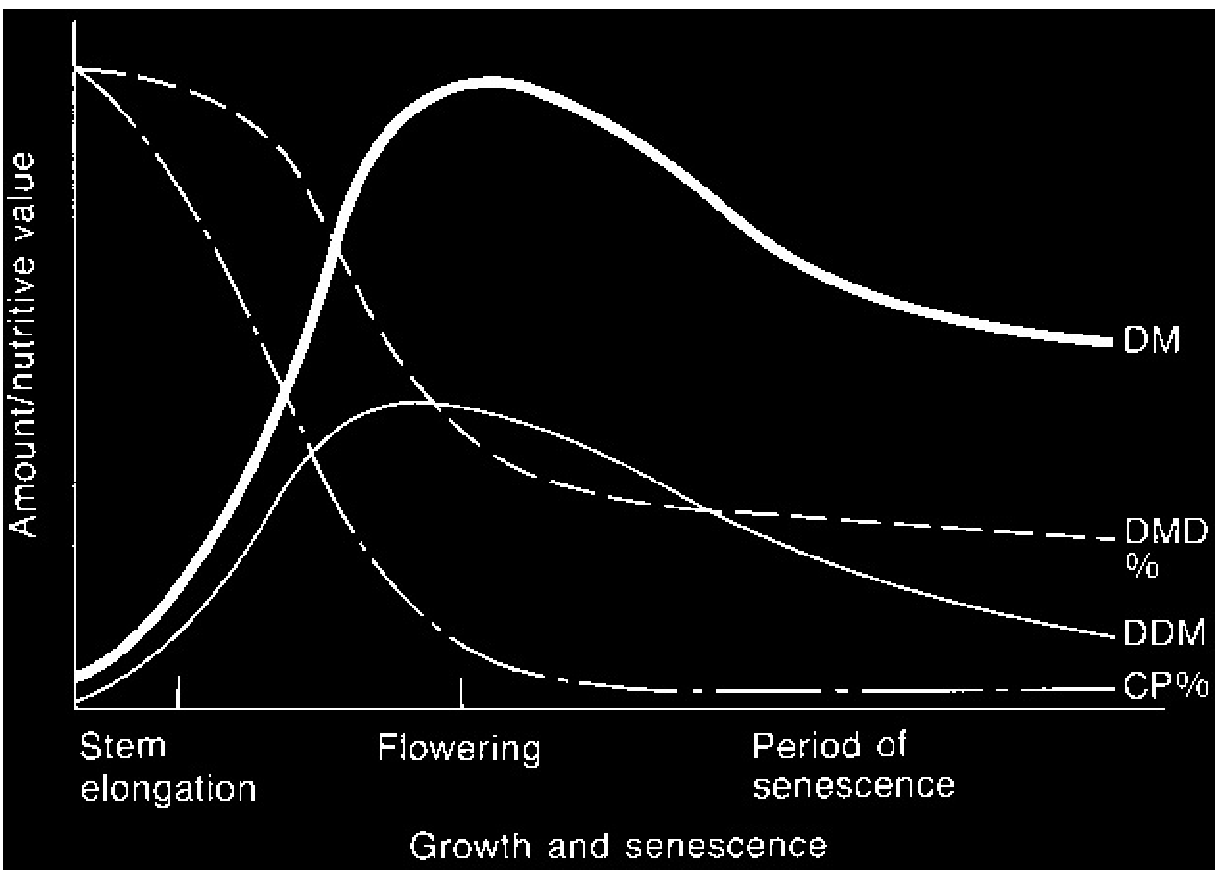
Since grazing is crucial in cattle nutrition, the follow-

and liveweights low is the onset of sperm production

ing sections highlight important aspects of grassland

delayed.

production.



Grass production

Grass represents the major link between the sun as the
ultimate source of energy and the grazing animal. For
the grass, however, the grazing animal can be regarded
as a parasite. It is thus important that this relationship
is not a destructive one for the grass. Animal produc-
tivity depends on a vigorous grass sward and manage-
ment must safeguard the viability of the herbage above
all else.

The factors that determine grassland dry matter pro-
ductions are amount of light, leaf area, efficiency of
species, amount of carbon dioxide, temperature, water
and nutrients.

In the short term the manager can determine leaf

Fig. 6.3

Generalized changes in the amount and nutritive value

area and nutrient level and in the longer term the

of herbage during growth and senescence of the herbage. DM,

species and possibly water level, through run-off

dry matter available for grazing – determined by species and

control. Many tropical grasses are physiologically dif-

available nutrients; DMD, dry matter digestibility – falls from over ferent from temperate grasses. They fix carbon as C4

65% to around 40% largely as a result of changes in the crude

rather than C3 compounds and are regarded as biolog-

protein level; DDM, available digestible dry matter – the result-ically more efficient than temperate grasses. This is

ant of DM and DMD; CP, crude protein – falls from over 12% to

partly the result of the structure of tropical grasses,

around 2%.

which are taller and more effective in sunlight

interception.

Tropical grasses have evolved to survive short rainy

seasons. They grow quickly, reproduce and senesce.

that can be visited annually to assess the degree of soil

Whilst grass breeders have extended the growing

erosion and ground cover. The botanical species are

period of many species, the short life cycle of grasses is

identified and the increase or decrease in particular

still a problem when grazing animals require dry matter

species is recorded. Botanical trend monitoring is

throughout the year.

appropriate for stable ecosystems where changes occur

Figure 6.3 illustrates the changes in the nutrient

only slowly. In arid and semi-arid areas with variable

composition of grasses with time.

rainfall changes can occur relatively quickly. When

The fall-off in crude protein (CP) percentages

rains are adequate and grazing pressure reduced areas

reduces the rate of degradation of dry matter and rate

that appeared seriously overgrazed can recover dra-

of passage and thereby dry matter intake. While

matically through the germination of seeds of annual

growing conditions are good in the wet season, CP

grasses (Behnke *et al.* , 1993).

levels can be as high as 12–14 per cent, but can be as

low as 2–3 per cent in the dry season. The aim of the

Management to maximize voluntary food intake

manager is to counteract low dry matter intake by

appropriate management measures as discussed below.

Maximization of voluntary food intake is the underly-

ing objective in ruminant feeding management.

Range monitoring

Tropical grasses are less digestible at the same stage of growth than temperate grasses, due to greater lignifica-

The interaction between animals and range is con-

tion. The lower digestibility reduces rate of passage and

stantly changing and the result may be a long-term

hence reduces food intake. Some breeds of tropical

improvement or deterioration. A knowledge of the

cattle may have evolved to cope with poor quality feeds

direction of this trend is very important and regular

through a greater dry matter intake capacity per unit

observation (monitoring) should be carried out using

body weight than temperate cattle.

the following methods.

Management strategies to maximize voluntary intake

involve maximizing food production, avoiding food

Remote sensing: This involves the use of satellites or losses and stimulating intake as follows.

aircraft to determine land use, land potential and

changes in herbage production over time.

(1)

Provision of adequate water and water harvest-

ing through the use of pounds and micro terraces.

Soil and botanical trend monitoring: This involves

(2)

Control of grazing time, intensity and frequency

establishing specific points or transects on the range

to maximize grass production, i.e. maintenance of

a sustainable carrying capacity according to the

Systems of production

manager’s objectives.

Management and production levels are determined by

(3)

Inclusion of legumes in the sward or as browse.

factors such as the herder’s objectives, climate and

(4)

Fire control to prevent destruction of accumu-

land tenure. In communally owned dry areas that are

lated standing hay in the dry season and in

marginal or exclude crops pastoral livestock systems

ranching systems to control bush encroachment.

are found with cattle (Fig. 6.4), sheep, goats and camels.

(5)

Exclusion of wildlife and non-authorized grazers.

In wetter areas small-scale mixed farming systems

(6)

Provision of minerals and, in the long term,

have developed where sheep and goats are important

correction of soil mineral deficiencies.

and where cattle and buffaloes may have a role for

(7)

Simple rotation and grazing by appropriate

milk, meat, dung and draught power. In tropical high-

herding, or use of fencing under intensive

land areas where the climate is less severe milk pro-

systems.

duction is often based on exotic cross cattle (Fig. 6.5).

(8)

Division of the herd into units of need, i.e. young

Where land is privately owned, particularly in South

stock, dry cows, lactating cows.

America, more intensive dairy farming methods

(9)

Good herding practices, including choice of area

occur in combination with large-scale dairy and beef

to be grazed and duration of grazing.

ranching.

(10)

Routine health maintenance.

Fig. 6.4

Fulani cattle in Nigeria.

Fig. 6.5

Sahiwal ¥ Friesian cattle in

Malaysia.

Pastoralism and settled extensive systems

Milk production

of production

Milk is produced under a variety of systems, ranging

from one-cow zero-grazed units in Mauritius where

Low and unpredictable rainfall coupled with communal

cows are fed on sugar-cane tops and roadside grasses,

land-use rights have led to migratory and seasonal pat-

to large-scale extensive dairy ranching in Central and

terns of grazing. Such systems are found throughout the

South America, intensive large-scale milk cooperatives

Sahel from Mauritania to Sudan and through Ethiopia,

in India, and very large, zero-grazed, environmentally

Somalia, Kenya, Uganda and Tanzania. Cattle owners

controlled exotic cow units in Saudi Arabia.

include the Fulani (Fulbe), Tuareg, Dinka, Borana,

Consumers in the tropics accord a high value to milk

Karamajong and Masai. Pastoralists keep cattle to meet

as a human food. The rate of increase in milk produc-
subsistence needs in areas unsuitable for crops. Milk is
tion has been considerably greater in tropical countries
a major product that provides a daily source of food or
than in traditional milk producing and exporting
tradeable produce and allows herders to exploit remote
nations (FAO, 1998). World milk production actually
areas. Due to recurring droughts and increased popu-
declined between 1989–91 and 1998, but increased by
lation pressure resulting in loss of traditional grazing
18 per cent in Africa and 42 per cent in South America
areas, these patterns are changing in many areas.
over the same period (FAO, 1998). Milk production can
Pastoralists are being forced to settle and engage in
be an important enterprise in rural development for
agriculture or some other activity.
several reasons:
Settled production occurs where cattle are combined
with crop production. In Nigeria the term 'mixed
• it provides a year-round source of income for the
farming' has been used to denote the use of cattle as

farmer;

draught animals for cultivation. Draught animals are

• it contributes to family nutrition;

common throughout the tropics and because of their

• it can utilize crop byproducts;

vital role in the production of subsistence crops such as

• it serves to transfer money from urban to rural

maize, sorghum, millet or rice their management is

areas; and

often better than that of cattle which are not used for

• it creates rural employment opportunities.

draught.

These advantages have led to many development ini-

Most settled farming is subsistence in nature and

tiatives involving local/exotic crossbreds and sometimes

except where used for draught, livestock have a sec-

pure exotics. There have been many disasters and fail-

ondary role to crop farming. Management inputs are

ures, but also some notable successes as in India with

often relatively low. Land is seldom individually owned

Operation Flood, and in Kenya and Uganda with and communal grazing is a major method of food

smallholder milk production schemes.

supply. The management and improvement of commu-

The major challenges for milk producers in the

nally owned land are limited by the difficulties associ-

tropics include:

ated with getting people to cooperate.

Food inputs are natural pasture, browse, crop

• achieving a high intake of good quality food

residues and supplements. Crop residue grazing is sea-

throughout the year;

sonal, but important for extensively managed cattle.

• coping with disease challenges;

Millet and sorghum residues provide early dry-season

• storage and transporting a bulky and perishable

food and may be stored in stacks for use in the dry

commodity.

season, although they are often grazed off quickly in a

'free for all'.

Extensive systems: dairy ranching: Dairy ranching is an One technology that has been proposed for improv-extensive system of milk and calf production particuing the system as a whole is that of fodder banks.

larly associated with South America, and countries such

Fodder banks are fenced areas of high-quality forage

as Bolivia and Columbia. It is a flexible, dual purpose,

that are made available for grazing for only a few hours

low input low output system that depends for its success

per day and for only the most needy stock. The estab-

on the plentiful availability of low cost land and labour.

lishment of fodder banks has been described by Otsyina

Dairy ranching occurs particularly in those areas where

et al. (1987) using *Stylosanthes* species such as *S. guia-conditions are hot and humid. There is enough mois-*

nensis cv. Cook and S. hamata cv. Verano. Fodder banks ture to produce sufficient food throughout the year but

have had limited success as has the oversowing of

the temperature is too high to permit specialized high

rangeland with legumes. The latter depends for success

output milk production.

on the control of grazing, which with extensive grazing

A wide range of genotypes are used in dairy ranch-

is virtually impossible.

ing. Crossbreds between Bos indicus and Bos taurus are *commonly encountered. In the more favourable envi-*

flies and rats which multiply on the wastes associated

ronments high grade cattle are used whilst in the more

with livestock farming in confined conditions (Waters-

difficult areas use is made of pure Bos indicus types.

Bayer, 1995). Urban livestock farming, and dairying

Similarly, there is a wide range of production systems.

in particular, has largely developed without outside

Some farmers milk their cattle twice a day whilst others

involvement in response to people's needs for income.

milk their cattle only once a day. Some depend entirely

They are undertakings that have usually been ignored

on grazing whilst others use concentrates. In most cases

by traditional ministries and organizations. However, if

the presence of the calf is used to stimulate milk let-

cities and towns in the tropics are to be developed in

down and one or more quarters are left for suckling by

keeping with governments' aspirations and hopes then

the calf after milking. The calves are allowed only

policies to limit and perhaps relocate urban dairying *limited access to the cows. However, much depends on*

and livestock production are urgently needed.

the relative prices of meat and milk. If meat is in high

demand then the calf may be allowed more milk in

Semi-intensive and intensive dairy production: In South order to promote growth. If the price of fresh milk is

America, exotic breeds are used intensively in highland

high then the amount allowed for the calf may be

areas. Highland areas are found throughout South

severely restricted, which sometimes leads to increased

America and also in Africa on the Jos Plateau in

calf mortality.

Nigeria, the Kenyan and Ethiopian Highlands and in

The total milk production from dairy ranching in

parts of Tanzania such as Arusha.

South America is considerable and may represent half

of the total milk consumed in a country such as Colom-

Kenya Highlands: The smallholder dairy industry in

bia. One of the great advantages of dairy ranching is

Kenya has grown impressively over the last 25 years.

its flexibility and the regular income from milk sales

There are now over 400 000 smallholder dairy farmers

that it offers. It has been adopted as a system by

producing 70 per cent of milk sold. It is estimated that

many farmers throughout South America and clearly

there are over 3 million dairy cattle in Kenya, concen-

therefore must be meeting their needs.

trated for the most part in peri-urban areas. The major-

ity include some amount of Friesian in their genetic

Smallholder dairying: the Indian model: India is famous make-up, but other breeds including Sahiwal, Brown

for its Anand pattern of dairy development. It is the

Swiss, Ayrshire and Channel Islands have a significant

fourth highest milk producer in the world after

role (Fig. 6.6). The pure exotics are found in the high

Europe, the Russian Federation and the USA and since

potential areas in the highlands where lower tempera-

1950 it has more than doubled its output. This has

tures and more dependable rains and food supplies

involved the setting up of dairy cooperative societies

make them a sustainable option. Dairy crosses with

which all milk producers are eligible to join. Farmers *local Zebus are found in the harsher lower potential*

are usually paid for their milk within 12 hours of deliv-

environments.

ery to a collection point. Payment is based on quality

In the most fertile highland areas the production

and quantity.

system is based on zero-grazing of Napier grass (Pen-

The societies are formed into milk unions, which

nisetum pupureum) together with the use of roadside

provide collection, processing and marketing ser-

grasses and available byproducts such as maize stover,

vices, and may market livestock feed and provide

banana stems and sweet potato vines. The use of forage

artificial insemination (AI), veterinary and other

and tree legumes is being encouraged. So intensive is

services.

the system that 29 per cent of smallholders buy forage

to feed their cows at some time during the year. Com-

Urban dairying in Africa: Recent years have seen a

mercial concentrates are widely used. Grazing systems

huge increase in urban dairying in and around cities and *of varying intensity are encountered in less fertile areas.*

major towns throughout the tropics. Whilst such devel-

In these systems use is made of grasses such as Kikuyu

opments provide a regular income for producers and

grass (Pennisetum clandestinum) and Rhodes grass

readily available fresh milk for the consumers they

(Chloris gayana).

are also associated with a number of problems. These

Yields of around 2500 kg per 10-month lactation

include urban pollution due to waste accumulation and

period are commonly obtained. The median calving

undesirable smells and noises. Disposal of the carcasses

interval amongst the better smallholder herds has been

of dead animals is a further problem as are the various

estimated at 426 days. Fifty per cent of herds use artifi-

threats to human health. The latter arise directly from

cial insemination with an approximate success rate of

the consumption of milk and meat containing organ-

50 per cent. Zero-grazed systems do not lend them-

isms that cause diseases, such as tuberculosis and bru-

selves to easy heat detection and this is an area for *cellosis, or indirectly from the increased activities of*

continuing extension inputs and training.

Fig. 6.6

Sahiwal and Sahiwal ¥ Friesian

cattle in Kenya.

East coast fever (pp. 750–53), transmitted by ticks, is

Beef may remain a byproduct of milk and draught

the biggest threat to exotic breeds, although zero-

power in Africa and Asia for the foreseeable future. It

grazing represents a significant tick avoidance strategy.

is appropriate therefore to focus research on ways of

Smallholders are increasingly adopting strategic hand-

feeding and managing culled cows and oxen so as to

spraying methods of tick control rather than using gov-

maximize their value as meat animals.

ernment dips.

In South America the situation is different and spe-

Many smallholder households in Kenya have bene-

cialized high quality ranch beef from extensive systems

fited both nutritionally and financially from their dairy-

has found a ready market in America, Europe and the

ing enterprises. Perhaps regrettably, intensification and

Far East for many years.

commercialization of milk production tend to be asso-

There are indications that the demand for meat is

ciated with the control of income from milk moving

growing rapidly in urban areas of the tropics. This rep-

from the women to the men. Nevertheless, it is hoped

resents a tremendous opportunity for beef producers,

that the accumulated expertise and improved tech-

large and small, in tropical areas (Delgado et al. , 1999).

nologies will allow the continuing expansion of small-

holder dairying into the low potential areas of the

Management of dairy cows

country (Reynolds et al. , 1996).

The general objectives of management can be assumed

to be broadly the same for all types of dairy cattle.

Beef production

Ideally, dairy cows should produce a calf every year,

In Africa and Asia beef has traditionally been a byprod-

since milk production is usually maximized with a 305-

uct of milk and draught power production. Govern-

day lactation and yearly calving. Since gestation lengths

ments have often been disappointed with the level of

vary between 275 and 287 days, it is necessary for the

beef production from their traditional herds. This has

cow to conceive again within 80–90 days of calving. First

led to the mounting of many projects aimed at increas-

service should be at about 50 days after calving. This

ing beef output. These have included group ranching

is seldom achieved in tropical systems, and calving

schemes as in Kenya and parastatal ranching initiatives

intervals of up to 500 days occur. The main reason is a

as in Uganda and several other countries. Most of these

delayed return to oestrus due to poor nutrition, suck-

projects have ultimately proved uneconomic, although *ling and other stresses including those of climate and*

private commercial ranches have usually been more

disease.

successful.

Artificial insemination is not widespread in the

Increased beef production from medium- to large-

tropics, but in some countries, such as Kenya and

scale intensive feedlots has also been attempted with

Pakistan, insemination services have been operational

the aim of drawing immature stock from the rural areas

for many years. The benefits of genetic improvement

for finishing to produce improved quality beef. These

from AI are constrained by the problems of detecting

initiatives have not usually been successful and small-

oestrus, which are especially acute in smallholder one

scale finishing schemes are proving a more successful

cow units. The achievement of optimum breeding

form of intensification.

patterns and milk production also depends on the

provision of suitable environmental conditions and

Table 6.4

Typical rations for dairy cows using combinations of

proper feeding.

feedstuffs. BF = butterfat.

A major objective of the management of dairy cows

in the tropics should be the reduction or the avoidance

Feedstuff

Diet (kg fresh weight)

of environmental heat load. This can be achieved in a

360 kg cow

540 kg cow

number of ways:

• Where possible animals should be grazed at night.

Diet 1

Diet 2

• Concentrates should be fed early in the morning

Legume hay (average)

1

1.6

and late in the afternoon.

Maize silage (average)

11

16

Grass hay (mature)

2

3.9

• *Adequate water should be provided.*

• *Natural and constructed shade should be provided.*

Diet 3

Diet 4

• *Buildings and shelters should be made of appropri-*

Legume hay (average)

4

4

ate materials.

Maize silage (average)

18

27

• *Houses and yards should be sited so as to take full*

Maintenance + 4 litres

(4.5% BF)

(3.5% BF)

advantage of prevailing winds.

• Calving should occur in the coolest season, if nutri-

Diet 5

Diet 6

tion allows.

Green lucerne (early flower)

11

3

• Animals should be managed indoors wherever

Grass hay (average)

3.5

18

possible, so as to reduce muscular work.

Maize silage (average)

9

4.5

• Animals should be sprayed with water during the

Maintenance + 4 litres

(4.5% BF)

(3.5% BF)

hottest periods to facilitate cooling.

The effect of adverse tropical environmental condi-

tions can be overcome to a large extent if cost is not a

constraint. In the Middle East, exotic breeds of dairy

cattle are maintained in intensive systems and can

throughout lactation and optimum levels of fertility so

achieve yields in excess of 8000 l/cow per year (Chap-

that cows produce calves at regular intervals. In addi-

ters 8, 71).

tion it is necessary to rear a healthy calf to weaning and

to first calving. Attention must be given to a number of

Feeding (see also Chapter 9)

disease and general health problems.

Dairy cows require higher levels of feeding than

Tick-borne infections, trypanosomiasis (Chapter 45),

growing or working animals. Energy inputs for lactation

helminths and liver fluke (Chapter 19) are major prob-

may equal or even exceed maintenance requirements,

lems in many areas, as is streptothricosis (see p. 886)

though in the tropics requirements for lactation will

in parts of Africa. Exotic animals are particularly

not usually exceed maintenance. For a 300 kg cow pro-

susceptible to many of the endemic diseases.

ducing 1000 l in a 300-day lactation, average daily

Adequate attention to disease prevention is of

metabolisable energy (ME) requirements will be

primary importance in the tropics, where veterinary

approximately 30 MJ for maintenance and 15–20 MJ

services are often unavailable (Chapter 69).

for lactation depending on the butterfat (BF) content

In hot climates it is better to milk at the cooler times

of the milk. Such levels of milk production can be

of day. Milk cooling can present problems where con-

achieved by a number of rations and feeds can be com-

stant electricity supplies are not present. Water supplies

bined according to their degradability, ME content and

to local dairies are often poor and hygiene may be

their CP content. Some typical dairy rations used in

neglected.

southern Africa are shown in Table 6.4.

Other rations can be devised for different tropical

regions based on a knowledge of locally available foods

such as groundnut cake, wheat bran, maize, oats/barley,

Management of beef production

green grain, tapioca, rice bran, urea, molasses and

cottonseed.

Ranching

In commercial ranching systems both land and animals

Health and hygiene

are under the control of the same active management.

The two prime considerations of dairy cow health are

This contrasts with pastoral systems where land is

the need to maintain optimum milk production

communally owned but rarely communally managed.

Table 6.5

Example of routine management programme for an East African cattle ranch.

Month

Approximate monthly

Operation

rainfall (mm)

December/January/February

110

Calving; ear tagging,

weighing and recording

February

100

Check breeding bulls and

cows; cull and replace

March

160

Improved nutrition for

breeding bulls and

cows (bulls throughout

mating season)

March/April/May

140

Brand, castrate, dehorn

last year's calves

April/May/June

110

Join breeding bulls to

herd of breeding cows

Sell marketable stock;

steers, surplus heifers,

culls

May/June

60

Supplementation of

lactating cows

Conserve forage

July

10

Remove bulls from

breeding herd

July/August/September

10

Wean

August

10

Pregnancy diagnosis;

remove non-pregnant

stock

Under some circumstances a system with two 70-day breeding seasons at four month intervals can be applied and may improve annual calving percentage and economic returns.

Animals are owned by individuals or groups of indi-

important husbandry tasks are designated to be carried

viduals who try to maximize rather than optimize their

out at particular times during the year. All concerned

use of the communal land.

then know what should be done and when it should be

Ranching can operate throughout a range of inten-

carried out. Table 6.5 shows an example of a routine

sity levels. Extensive systems may involve a one-herd

programme for a cattle ranch in East Africa. The pro-

system with little or no monetary investment other than

gramme of activities is determined by seasonal feed

in the cattle. Intensification may involve one or more of

availability, which is determined by rainfall.

the following stages.

Government and parastatal companies have often

involved themselves in ranching to intensify cattle pro-

• *Water development, e.g. boreholes or small dams.*

duction away from subsistence systems. The attempts

• *Routine health care.*

have rarely been successful. The reasons have usually

• *Mineral supplementation.*

been economic, arising from indifferent managements,

• Construction of handling and dipping facilities.

low meat prices and the high costs of intensification,

• Correct use of fire, e.g. creation of firebreaks.

which have rarely been justified. Most successful

• Multiple herd systems, e.g. young stock, steer herds,

ranching is in the purely commercial sector.

etc.

• Protein supplementation.

• Fencing, e.g. perimeter and paddock.

• Forage conservation.

Supplementation

An important aspect of ranch management is

Tropical cattle commonly suffer a period of weight

organizing routines. A routine approach means that the

loss during the dry season. Compensatory growth

can overcome the worst effects, but feed supple-

Drought: Drought conditions represent a special case

mentation may be feasible where it can be controlled.

for supplementation where survival is the objective. An

The practical approach should include the use of

early difficulty is establishing that drought, as opposed

sustainable stocking rates, fire control, deferred

to a long dry season, exists. When the fact is established

grazing, seasonal control of breeding and tactical

a number of options are available: (i) do nothing;

marketing. Once supplementation is accepted as

(ii) sell some stock and buy feed; (iii) sell all stock and

a workable option two considerations arise: the

restock later; or (iv) move animals to an area with

nature of the supplement and the stock to be

grazing.

supplemented.

Where supplementation is adopted it is important

not to start supplementing too soon, but to allow

animals to lose some weight to reduce their mainte-

Nature of the supplementation: The supplement should

nance requirements. Bovines have adaptive mecha-

improve the quality of the overall diet rather than act

nisms for dealing with drought, one of which involves a

as a substitute for a part of that diet. The effective uti-

reduction in metabolic rate. Such mechanisms should
lization of nitrogen supplementation in the form of urea
be activated prior to survival supplementation.
mixed in a carrier such as molasses depends upon there
Animals at greatest risk and females required to
being a deficiency of degradable protein in the rumen.
continue the herd after the drought should be given
This is not always the case and the response to urea sup-
priority for drought feeding. Once a decision has
plementation has not always been as predictable as
been taken to provide survival feeding the feedstuff
anticipated.
is usually determined by cost and availability.
Other forms of background supplement such as min-
Infrequent feeding of large amounts is probably pre-
erals are important over the long term, but have no
ferred so as to ensure every targeted animal gets some
effect on reducing dry-season weight losses. The pos-
feed.
sible exception is salt, which may serve to stimulate the
intake of poor-quality roughage. In Nigeria, a naturally

occurring and renewable mineral supplement known as

Kanwa is fed to both settled and transhumant cattle

Feedlots

owned by Fulani and agropastoralists. Kanwa contains

Feedlots have been set up in different forms and for

1.5 per cent Na, 4.7 per cent K, 23.7 per cent Ca, 0.6 per

a wide variety of reasons; as large- or small-scale

cent P and trace amounts of Mg, Fe, Mn, Cu, Co and

units, as commercial or government sponsored ven-

Zn.

tures to produce export quality carcasses and as a

Increased attention is being paid to the potential of

means of trying to reduce overgrazing of com-

small amounts of highly digestible cellulose as a sup-

munal areas. Initial developments tended to follow

plement in the form of legume or browse material. Such

the large-scale pattern of North American feedlots,

material can stimulate cellulolytic bacteria and enable

but it is now recognized that small-scale projects

an improved utilization of a low quality diet. Browse

that demand more labour than capital are more *usually contains over 10 per cent CP/unit DM and*

sustainable.

can often have as high as 25 per cent CP/unit DM.

Certain circumstances are required before intensifi-

It thus forms a good supplement to poor-quality

cation becomes an economic strategy, as follows.

roughage.

Other forms of supplement in Nigeria include cot-

• Beef is one of the most expensive meats within the

tonseed cake, groundnut tops, cow pea stalks, ground-

country.

nut cake and also salt, chaff, bran, cut branches and cut

• Animals are economically available for feeding on

grass. In Sudan some livestock owners in the Gezira

a continuing basis.

area provide daily supplement mixtures containing

• Above average quality feeds are economically

cottonseed cake, groundnut cake, bran and molasses.

available on a continuing basis.

Where breweries are nearby, brewers' grains may also

• Adequate initial funding is available.

be available.

• Infrastructural factors such as transport, communi-

cations, husbandry and health services are available

Animals to supplement: Not all animals have the same

and adequate.

need for supplementation and optimum use of

• There is an absence of restrictive factors, e.g.

resources can be achieved by identifying an order of

butcher cartels or legal restrictions on export.

priority, e.g. weaned calves, late pregnancy/early

lactation cows, breeding heifers. Lowest priority will

A failure to satisfy these requirements has led to the

normally be given to growing steers.

limited success of many feedlots.

Fig. 6.7

Stall-fed fattening of Fulani cattle

in Nigeria.

Smallholder fattening

success in Kano State where work bulls after 2–3 years

are stall-fattened for 6–8 months and sold to butchers.

In Malawi a smallholder fattening project was started

as long ago as 1957 and has now expanded to other

parts of the country. It has proved to have many bene-

fits, as follows.

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employment opportunity.

2033 K Street, Washington.

The participating farmer must build a suitable stall

Food and Agricultural Organization (1998) Production Year-

book 52, pp. 186–8, 195–7, 212–14.

for one or two animals. Several farmers commonly

Hogg, B.W. (1991) Compensatory growth in ruminants. In

build their stalls together. Farmers receive a credit steer

Growth Regulation in Farm Animals (ed. by A.M. Pearson of 260–280 kg with the assistance of the extension serv-

& T.R. Dutson), pp. 103–34. Elsevier Applied Science,

ices. This is fed on maize stover, groundnut haulms and

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maize bran during the dry season and cut-and-carry

Macfarlane, J.S. & Worrall, K. (1970) Observations on the

Napier grass (Pennisetum purpureum) and/or Rhodes

occurrence of puberty in Bos indicus heifers. East African grass (Chloris gayana) during the rainy season. Average Agricultural and Forestry Journal, ***35****,*

409–10.

daily gain is about 0.5 kg and with approximately 200

Nicholson, M.J. & Butterworth, M.H. (1985) A Guide to

days feeding total gains of 100 kg are achieved pro-

Condition Scoring of Zebu Cattle, International Livestock ducing a final weight of 360–380 kg.

Centre for Africa, Addis Ababa, Ethiopia, pp. 3–30.

In Nigeria, stall feeding and fattening is also carried

Otsyina, R.M., von Kaufman, R.R., Mohamed Saleem, M.A.

& Suleiman, H. (1987) Manual on Fodder Bank Establish-

out and is a common method of cattle production in the

ment and Management, International Livestock Centre for subhumid zone and northern savannah areas (Fig. 6.7).

Africa, Addis Ababa, Ethiopia, pp. 8–12.

Farmers often keep up to six animals, usually young

Pullen, N.B. (1978) Condition scoring of White Fulani Cattle.

bulls, for 18–24 months before selling them to urban

Tropical Animal Health and Production, ***10****, 118–20.*

traders. This method of production has been the subject

Reynolds, L., Metz, T. & Kiptarus, J. (1996) Smallholder

of a major extension exercise by the National Livestock

dairy production in Kenya. World Animal Review ***87****, Projects Department in*

Nigeria, and has been of some

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Chapter 7

Ethnoveterinary Medicine

in the Tropics

R.D. Fielding

Introduction

McCorkle, 1989; Bizimana, 1994; IIRR, 1994), including

Definition and examples of nature of EVM

83

various internet sites. Some examples of EVM from

Why ethnoveterinary medicine?

83

these and other sources are presented below.

Advantages and disadvantages of EVM

84

The majority of ethnoveterinary practices are aimed

The way forward – validation?

84

at relatively chronic conditions such as internal and

Discussion

85

external parasites, digestive disorders such as inap-

Conclusions

86

petance, constipation, diarrhoea and bloat, wounds,

lameness, non-specific ‘fevers’ and ‘coughs and colds’.

In Ethiopia goatkeepers boil the leaves of the castor-

Introduction

oil plant (Ricinus communis) to provide a viscous liquid which they use to *control mange in their goats. The*

Over the last 30 to 40 years most 'top-down' rural devel-

active agent, ricin, is very poisonous for humans and

opment projects in the tropics have continued to have

provides an example of an EVM agent that must be

disappointing results. In response to this, and prompted

handled with care (Peacock, 1996).

largely by social scientists, there has been a growing

In many Mediterranean countries honey is used on

awareness that an appreciation of rural people's local

wounds to promote healing (personal observation). The

knowledge should be the starting point for discussing

mode of action is believed to be partly achieved

development interventions of any kind. This participa-

through an osmotic effect which draws fluid into the

tory 'bottom-up' approach is now being applied across

wound. This fluid serves to 'flush out' dirt and other

all areas of natural resource use in the tropics. As

contaminants and thus promotes healing.

regards the maintenance of health amongst the live-

There are many plants which appear to have some *stock resource it is Constance McCorkle, an anthropol-*

anthelmintic effect: Artemisia maritima, Caesalpinia ogist, and Evelyn Mathius-Mundy, a veterinarian, who

crista,

Melia azedarach,

Mallotus philippinensis,

have done most in the last 15 years or so to bring atten-

Chrysanthemum spp., Matteuccia orientalis, Carica tion to that local knowledge in the tropics which deals

papaya, Heracleum spp., Hedysarum coronarium, Aloe with animal disease treatment. This body of knowledge

barteri, Terminalia avicennioides and Diospyros mollis is now commonly referred to as ethnoveterinary medi-

(Hammond et al., 1997). Firing and bloodletting

cine (EVM). The objective of this chapter is to highlight

are widely used practices to treat problems such as

the key issues and developments in EVM in the tropics.

lameness and inflammation. These practices are most

commonly used by owners of horses and donkeys.

Definition and examples of

nature of EVM

Why ethnoveterinary medicine?

For the purposes of this chapter ethnoveterinary med-

In addition to the increasing appreciation of local

icine is defined simply as the traditional treatments and

knowledge as explained above there are several other

practices that livestock keepers are using now, other

reasons which have contributed to the recent growth in

than modern synthetic drugs. The majority of the treat-

interest in EVM at farm, local, national and interna-

ments are of plant origin. Some EVM involves magico-

tional levels.

religious practices. Although these latter practices can

Antibiotics, acaricides and anthelmintics can be

be very important to those who use them, they are not

dramatically effective when affordable and correctly

discussed here.

used. However, the rising cost of these medicines and

There is an increasing amount of literature listing

its consequences is now a major issue. If the cost of

and describing EVM practices (Mathius-Mundy &

a treatment is a significant proportion of the value *of the animal that is being treated then one or more*

per cent fewer Haemonchus contortus in the treated

things may happen:

group as compared to the control ($p < 0.05$).

• It is freely available or at a cost in proportion to the

• The animal is left untreated or a low cost EVM

value of the animal.

method is used.

• It is easily administered, usually topically or

• The seller of the chemical dilutes it to make

orally.

it cheaper and so that it will 'go further'. Monteiro

• EVM relieves the worry and concern of owners

et al. (1998) in Kenya found that of seven

of sick animals in that it makes it possible to do

anthelmintics marketed as containing levamisole,

something, effective or not, for their animals.

an effective anthelmintic agent, two contained

However, EVM is not without disadvantages and

none, whilst two others had levels of levamisole of

limitations:

11.8 per cent and 78.7 per cent of the amount stated

on the label.

• Particular methods are often geographically local-

• Livestock owners who buy costly drugs may also try

ized and the scope for their further dissemination is

to make them ‘go further’ by diluting them, by

limited.

underdosing or by not completing the full recom-

• Cures are variable in their effectiveness according

mended course of treatment. All abuses of drugs

to season, method of preparation, etc., and few if

are associated with incomplete cures and with the

any have been validated in the same way in which

promotion of organism resistance.

synthetic drugs must be validated.

• From a technical standpoint some are totally

Even when properly administered the long-term

ineffective.

regular use of drugs and chemicals such as

• EVM has little to offer against the acute viral

anthelmintics and acaricides leads to the loss of an *diseases of animals, other than treatments for the*

animal's natural resistance. If for whatever reason the

signs.

anthelmintics/acaricides are suddenly unavailable the

• EVM is not always practical on a large scale. A

animal is totally exposed to the worst effects of the par-

particular EVM method may require considerable

asites and organisms which these drugs are keeping

amounts of leaves, seeds or even roots. Identifying

under control. For this reason the routine use of acari-

a plant as certainly medicinal may lead to its total

cides, for example, has been questioned for some time

destruction. In Nepal people have been excluded

(Norval, 1983).

from some forests because of the excessive

Farmers in the tropics rarely have any awareness of

collection of medicinal plants, albeit they were for

the environmental damage and pollution that may be

use in human medicine.

caused by the incorrect disposal of chemicals and/or the

In the new millenium the major arguments for giving *associated packaging.*

greater attention to EVM include the following:

Globally there is a growing interest in ‘alternative’

and ‘sustainable’ approaches to disease treatment. In

• It is what livestock keepers use now and, by defini-

human medicine what were once regarded as ‘odd’,

tion therefore, should be the starting point for any

such as herbalism, acupuncture and homeopathy, are

animal health intervention.

now taken seriously. Veterinary medicine is currently

• It would be unwise to rely on only one strategy

evolving, in a similar way (see Chapter 65).

for disease control, i.e. modern drugs, when the

strategy has limitations, some of which have been

highlighted above.

• In the long term the ‘official’ recognition of EVM

Advantages and disadvantages

empowers those who practise it, with potential

of EVM

benefits for increased participation in other areas

of social and economic development.

The advantages of EVM are as follows:

• Livestock keepers are already familiar with it, it is

The way forward – validation?

what they use now.

• A significant part of it appears to ‘work’. For

Over the last 15 years or so there have been many

example, Bennet-Jenkins and Bryant (1996) tested

publications listing EVM medicines and practices, as

the anthelmintic effect of Eucalyptus grandis leaves

indicated above. However, there have been very few

with feral goats. On autopsy these authors found 91

trials and validations of EVM that stand up to rigorous

scientific scrutiny. There may be a bias in favour of

(6)

The remedy has been scientifically validated as

identifying treatment success with EVM, as has been

effective to treat the problem in the livestock

observed in human ethnomedicine (Roscoe, 1991).

species in question.

Thus it is now timely to bring to EVM the rigour of

Of some 330 treatments listed by IIRR (1994) only five

objective assessment.

are designated as '6', i.e. as being scientifically validated.

Hammond et al. (1997) have outlined one approach

Of these five, one is for a pig sedative using the leaves

for the identification and validation of anthelmintic

of Mimosa pudica, the other four are for upper respi-

plants used in EVM. In brief this methodology involves

ratory problems in poultry (leaves of Heliotropium

the following stages:

indicum, Spondias pinnata and garlic, Allium sativum)

• *A wide-ranging survey to identify all relevant*

and for internal parasites (garlic and the latex of

EVMs and the people involved.

papaya, Carica papaya).

• *Selection of the 'best bet' anthelmintic plants being*

Is validation of EVM important for the livestock

used against the most economically important

owners who use it? Possibly 'no' if they are using prac-

diseases.

tices that have been used 'successfully' for generations.

• Study of selected plants in terms of their use in

But possibly 'yes' if they have seen the effectiveness of

human medicine, given that many plants are used

modern drugs as indicated above. Are users of EVM

in both human and animal medicine.

experimenting with/validating EVM medicines and

• Preparation of the test medicines in the ways used

methods now in any way at all? Until relatively recently

by the livestock owners/healers.

the answer given by outsiders would have been 'no'.

• Testing for activity against indicator helminths.

But following on from the work of van Veldhuizen et al.

• Testing for toxic effects, probably on-station.

(1997) and others, it is now clear that much experi-

• Validation on-farm with livestock owners.

mentation is done by ordinary farmers in the tropics

although its extent remains to be fully documented.

If the results of the above are positive it is logical to

One example of an on-farm ethnoveterinary validation

proceed to more detailed identification of the active

with farmers has been provided in Peru within the

principles and of how their effects might be extended,
Project for the Validation of Technologies in Commu-
for example through improved storage.
nities (McCorkle & Bazalar, 1996). In this instance
It is relatively easy to list EVM practices and to
the validation exercise proved to be very positive and
review the literature in human and animal medicine.
beneficial for the community concerned.
However, as soon as any attempt is made to test EVM
If EVM is locally specific then validation probably
in a quantitative way major problems arise. The
has to be locally specific. In the past validation work has
ultimate one is cost, but this arises from the fact that
been something usually done on-station and in labora-
so many EVM practices are locally specific and highly
tories with the use of specialized equipment. The need
variable in their application and use.
for these has not gone away, but there are a number of
One response to the above problem is a qualitative
tools such as weigh-bands and body condition scoring
method of validation based on 'confidently used' EVM.

systems which serve to make validation on-farm more

IIRR (1994) produced a collection of EVM practices in

feasible. Van Wyk et al. (1997) have reported an eyelid Asia using a workshop brainstorming technique. The

colour system for measuring anaemia in sheep and

authors attempted to 'validate' practices on a scale of

relating this to worm burdens. This system could be

1–6 as follows:

used to help organize balanced groups of animals with

similar worm burdens for the purposes of testing the

(1)

Workshop participants agreed that the treatment

efficacy of, for example, anthelmintic plants. The

would be useful.

McMaster method for counting parasite eggs in animal

(2)

Treatment is widely used in a region or a country.

faeces is one that can be learnt relatively easily and

(Some remedies were also validated against prac-

used at farmer group level. Although facilitated farmer

tices from outside Asia.)

validation may seem ambitious it seems unlikely that

(3)

Workshop participants had first-hand knowledge

extensive validation of EVM in the tropics will be

of the remedy's use on-farm.

achieved in any other way.

(4)

Traditional healers are known to use the remedy.

(5)

The remedy is cited in the literature in one of two

ways: either it is used to treat the same problem

Discussion

in humans or another animal species or this plant

has proven pharmacological activity to treat the

If it is assumed that validation trials can be organized

problem in question (laboratory validation).

and carried out, there are two possible outcomes. One

is that the plant has no statistically significant effect on

Bizimana, N. (1994) Traditional Veterinary Practice in Africa.

the targeted organism. For example, on the basis of a

Deutsche Gesellschaft für Technische Zusammenarbeit

literature review, Hammond et al. (1997) suggested that (GTZ) Gmbh, Eschborn.

Mallotus philippensis, widely used in EVM in Asia,

Hammond, J.A., Fielding, D. & Bishop, S.C. (1997) Prospects could be effective as a broad spectrum anthelmintic.

for plant anthelmintics in tropical veterinary medicine.

Veterinary Research Communications, ***21****, 213–28.*

Following an actual validation of the dried powdered

IIRR (1994) Ethnoveterinary Medicine in Asia: An Informa-

fruit of this plant, termed kamala, Jost et al. (1996) con-tion Kit on Traditional Animal Health Care Practices. Inter-cluded that a particular sample of the dried fruit was

national Institute of Rural Reconstruction, Silang, Cavite,

ineffective against particular gastrointestinal nema-

Philippines.

todes in certain goats indigenous to Balochistan,

Jost, C.C., Sherman, D.M., Thomson, E.F. & Hesselton, R.M.

Pakistan. If a medicinal plant is found to be ineffective

(1996) Kamala *(Mallotus philippinensis*) fruit is ineffective in a validation it will be difficult to communicate the

as an anthelmintic against gastro-intestinal nematodes in

result to many livestock owners. There is unlikely to be

goats indigenous to Balochistan, Pakistan . *Small Ruminant* any campaign, or funding, to stop livestock owners

Research, **20**, 147–53.

using it. Furthermore, livestock owners may not believe

McCorkle, C.M. & Bazalar, H. (1996) Field trials in ethno-

veterinary research and development: lessons from the

the negative result, and in any case there may be some

Andes. In *Ethnoveterinary Research and Development*

medicinal effect albeit in different circumstances and at

(ed. by C.M. McCorkle, E. Mathias & T.W. Schillhorn van

a biological but statistically insignificant level.

Veen), pp. 264–82. Intermediate Technology Publications,

If a validation proves positive, what are the options?

London.

One obvious option is to encourage greater use of the

Mathius-Mundy, E. & McCorkle, C.M. (1989) *Ethnoveterinary* medicine in question through extension services and

Medicine: An Annotated Bibliography. Bibliographies in publications. Even so it will be difficult to make uni-Technology and Social Change, No 6. Technology and Social

versal recommendations as is possible with a synthetic

Change Program, Iowa State University, Ames, Iowa.

drug, because of the underlying variability in EVM as

Monteiro, A.M., Wanyangu, S.W., Kariuki, D.P., Bain, R.,

arising, for example, from species, seasonal and method

Jackson, F. & McKellar, Q.A. (1998) Pharmaceutical quality of preparation effects.

of anthelmintics sold in Kenya. *Veterinary Record*, **142**, 396–8.

Thus, whether or not validation is carried out and

Nichter, M. (1992) (ed.) *Anthropological Approaches to the* whether or not it is positive seems unlikely to have

Study of Ethnomedicine. Gordon and Breach Sciences, San much effect on the short-term use of ethnoveterinary

Antonio.

medicines by livestock owners outwith the specific

Norval, R.A.I. (1983) Arguments against intensive dipping.

locality in question, although this is not necessarily the

Zimbabwe Veterinary Journal, **14**, 19–25.

case for the long term.

Peacock, C.P. (1996) *Improving Goat Production in the Tropics*

– *A Manual for Development Workers*. Oxfam, Oxford.

Roscoe, P. (1991) *The Perils of 'Positivism': A Critique*

Conclusions

of the Image of 'Positivism' in Cultural Anthropology.

Unpublished manuscript, as cited by Nichter (1992).

The key issues highlighted above are as follows:

van Veldhuizen, L., Waters-Bayer, A., Ramirez, R., Johnson,

A. & Thompson, J. (eds) (1997) *Farmers' Research in*

• If poverty and/or drug costs continue to increase

Practice: Lessons from the Field. Intermediate Technology then so will the use of EVM.

Publications, London.

• Some EVM 'works' and is worth investigating/

van Wyk, J.A., Malan, F.S. & Bath, G.F. (1997) Rampant

validating objectively.

anthelmintic resistance in sheep in South Africa – what are

• The evolution of evidence-based EVM will be slow

the options? In *Managing Anthelmintic Resistance in*

Endoparasites (ed. by J. van Wyk & P.C. van Schalkwyk), and may require a new participative approach to

pp. 51–63. Workshop held at the 116th International Con-

validation.

ference of the World Association for the Advancement of

From the above points it can be further concluded that

Veterinary Parasitology, August 1997, Sun City, South

there is likely to be a continuing place for EVM in the

Africa.

tropics alongside modern methods of disease treatment

and according to circumstances.

Further reading

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International Journal of Parasitology, **26**, 937–47.

23.

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(17.11.99).

Intermediate Technology Development Group and Inter-

Wanyama, J. (1997) *Confidently used Ethnoveterinary Knowl-*

national Institute of Rural Reconstruction, Nairobi.

edge among Pastoralists of Samburu, Kenya. Intermediate Relevant internet site:

http://pc4.sisc.ucl.ac.be/prelude/

Technology, Nairobi.

prelude_Homepage.html (17.11.99).

Chapter 8

Heat Stress in Dairy Cattle

J.K. Shearer

Introduction

88

ondary concern and almost always suffers. The specific

Thermoregulation and the thermal comfort zone

88

thermoregulatory responses that impact performance

Body heat production

89

are a reduction in feed intake and nutrient absorption,

Heat gain from the environment

89

and a redirection of blood flow from internal organs to

Body heat loss

89

peripheral tissues. During the prepartum period, this

Effects of heat stress on performance

89

results in lower calf birthweight and reduced milk yield

Prepartum heat stress

89

in the subsequent lactation. Postpartum, hyperthermia

Peripartum heat stress

90

Postpartum heat stress

90

depresses dry matter intake, reduces milk yield and

Methods to reduce heat stress

90

decreases reproductive performance.

Natural shade

90

Methods to relieve heat stress include the provision

Artificial shade

90

of shade, forced air movement as with fans, and water

Cooling by reducing ambient air temperature

91

in the form of a fog, mist or sprinkle droplet. In some

Evaporative cooling pads and fans

92

areas of the world cooling of cows may be accomplished

High pressure foggers

92

by permitting access to ponds which are managed

Misters

92

for such purposes. Depending upon specific climatic

Enhancing the cow’s natural mechanisms of heat loss

92

conditions (i.e. hot dry or arid verses hot and humid)

Sprinklers and fans

92

these can be used in combination to assist cows in the

Sprayers in parlour exit lanes

93

achievement of acceptable heat balance.

Cooling ponds

93

Introduction

Thermoregulation and the thermal

comfort zone

Cattle, like all mammals and birds, are homeotherms.

Despite wide fluctuations in environmental tem-

For lactating dairy cattle, the most comfortable

perature they are capable of maintaining a relatively

environmental temperature range is between 5 and

constant body temperature. This ability to regulate or

25°C (41 and 77°F), otherwise known as the thermal

stabilize body temperature is essential to preserve the

comfort zone. Within this range of temperatures

multitude of biochemical reactions and physiological

optimal animal performance can be expected. Temper-

processes that occur with normal metabolism. As envi-

atures that range outside this zone may require an alter-

ronmental temperatures rise a series of thermoregula-

ation in the basal metabolic rate for the animal to

tory responses designed to stabilize body temperature

maintain normal body temperature. The lower critical

are initiated. These include physiological, anatomical

temperature is the point at which an animal will begin

and behavioural changes which exhibit themselves as to feel cold and must increase body heat production.

reduced feed intake, decreased activity, shade or wind

It varies with age, physiological status (lactating or

seeking, increased peripheral blood flow, sweating and

non-lactating), degree of insulation, level of milk pro-

panting.

duction and acclimatization. For example, the lower

During periods when ambient air temperature and

critical temperature for neonatal calves is reported to

humidity are particularly high, thermoregulatory

be 12.8°C (55°F). On the other hand, a mature cow in

activities may not be sufficient to maintain normal body

peak lactation may be comfortable at a temperature of

temperature. The result is a rise in body temperature

-25°C (-13°F). The upper critical temperature is the

and the induction of a series of thermoregulatory

point above which an animal begins to feel warm and

events whose objective is survival from a potentially

must begin to compensate. Unlike the variability

life-threatening crisis. Performance is naturally a sec-

described for lower critical temperature, the upper critical temperature limit remains constant at about

mechanisms. Between the temperatures of -17.8 and

25°C (77°F) regardless of age or physiological status.

10°C (0–50°F), 75 per cent or more of heat loss from

the body occurs by non-evaporative cooling (i.e. con-

duction, convection and radiation). However, at tem-

Body heat production

peratures of 29.5°C (85°F) and above, nearly 80 per cent

of heat is dissipated by evaporative cooling (i.e. the

Total body heat load is a combination of heat derived

evaporation of water from the skin and respiratory

from metabolism and that obtained from environ-

tract). In general, whenever temperatures exceed 21°C

mental sources. Internal body heat associated with

(70°F), evaporative cooling becomes the predominant

basal body functions (digestion and cellular biochemi-

mechanism of heat loss in cattle.

cal reactions) accounts for 35–70 per cent of total daily

Bos indicus (Zebu) cattle have larger and a greater heat production. In ruminants there is greater heat gain number of sweat glands than *Bos taurus* cattle, but associated with the digestion of roughages as compared actual sweating rates are only slightly higher. The evap- with concentrate feedstuffs. Other sources of body heat oration of water from the cow’s skin is a very effective include that associated with daily physical activity and cooling mechanism. It is enhanced by conditions which increased metabolic activity associated with lactational provide air movement which moves water vapour away performance. Finally, it is significant to note that the from the skin thereby increasing the vapour-pressure increased respiratory rates and panting associated gradient in the immediate air space surrounding the with evaporative cooling, while necessary to cool the animal.

cow, also account for an increase in daily maintenance The primary obstacle to evaporative cooling is requirements by 7–25 per cent.

high relative humidity. Humid air is more saturated with water vapour. Thus, the vapour-pressure gradient is reduced. In some environments this is exacerbated

Heat gain from the environment

still further by limited air movement. This results in

very low water evaporation rates and consequently

The primary sources of heat gain from the environment

minimal cooling. In hot and humid environments this

are solar radiation and high ambient air temperature.

condition may be overcome by a combination of sprin-

The amount of heat absorbed by an animal exposed to

kling the skin with water and forced air movement with

direct sunlight is related to coat colour. Black cows

fans. Fanning cools wetted cows by accelerating the

absorb over twice as much heat from the sun as white

water vaporization rate.

cows. This is complicated by virtue of the fact that

the flow of heat away from the cow's body is restricted

by high ambient air temperature which narrows the

Effects of heat stress on

thermal gradient between the cow's body and the

performance

surrounding air. Thus, solar radiation together with high ambient air temperature are important sources of

Prepartum heat stress

heat gain from the environment. Since little can be

done to reduce air temperature, efforts to provide

Elevated environmental temperatures during the last

shade should be a high priority.

trimester of gestation alter blood flow to the uterus and

maternal–fetal hormone concentrations. The result

is lower calf birthweight and reduced milk yield in

Body heat loss

the subsequent lactation. Approximately 60 per cent of

fetal growth occurs during the last 90 days of gestation.

The release of heat from any object to the environment

Chronic heat stress during late gestation leads to

is proportional to its exposed surface area. Further,

reduced blood flow to the uterus which retards placen-

the ratio of surface area to body mass decreases as

tal and fetal growth. As a consequence, placental mass

overall size increases. This means that large animals

is reduced and calf birthweights are lowered by as much

such as cows are at a disadvantage in losing excess as 6 to 8 per cent. Studies have also shown that milk

body heat. They are also at greater risk of becoming

yield is related to calf birthweight and lower calf birth-

overheated. Calves, on the other hand, have a greater

weights are associated with reduced milk production.

amount of surface area relative to body mass and,

Although the precise reasons for reduced milk yield are

therefore, are much better at dissipating heat than a

unknown, most researchers believe that hyperthermia

mature cow.

in late gestation interferes with normal hormonal

Avenues for the dissipation of heat in cows include

regulation of mammary development, lactogenesis and

both non-evaporative and evaporative cooling

milk yield.

Peripartum heat stress

Heat stress has a major impact on reproductive

performance. It lowers conception rates, reduces the

Cows calving during daylight hours in hot climates

length of the oestrous period and oestrous intensity, with direct exposure to solar radiation are particularly

modifies endocrine function, alters the oviductal and

subject to hyperthermia and heat stroke (p. 935). This

uterine environment and increases early embryonic

is particularly true for cows experiencing hypocal-

death by interrupting embryo development. The sea-

caemia at calving, when control of body temperature

sonal depression in reproductive performance that

by natural mechanisms is greatly diminished. Therefore

results is one of the most serious problems for the dairy

close monitoring of calving cows is essential in hot

and livestock industry of subtropical and tropical

climates.

regions throughout the entire world.

Heat stress at parturition also creates significant

consequences for calves. Once delivered, calves born

in stressful conditions are weaker and slower to suck

colostrum. Indeed, passive transfer of immunoglobulins

Methods to reduce heat stress (p. 975)

has a seasonal pattern in calves. Calves born during

the hotter summer months have higher rates of failure

Successful abatement of heat stress generally

of passive transfer whereas calves born during the

requires environmental modification. Critical compo-

more moderate times of the year tend to have better

nents include shade, water in the form of a fog, mist or

rates of passive transfer. At least one study suggests

sprinkling and air flow – either natural or by forced air

that an increase in serum corticosteroids in heat

movement with fans. The primary objectives are to

stressed neonates reduces permeability of the intestine

reduce direct solar radiation, lower air temperature,

to immunoglobulin absorption. Thus, it would appear

improve or assist air movement or in some cases increase

that both physical and physiological mechanisms are

the natural evaporative cooling from skin surfaces.

responsible for high rates of failure of passive transfer

in calves.

Natural shade

Trees are an excellent source of shade. They are

Postpartum heat stress

not only effective blockers of solar radiation but the

Reduced feed intake is a primary strategy for lowering evaporation of moisture from leaf surfaces cools the body heat production. The consequence is a reduction surrounding air without appreciably interfering with air in milk production of as much as 10 to 20 per cent circulation. In addition, animals acquire very little or more. Similar effects on constituent (milk fat and radiant heat load from the shade of a tree compared protein) yield are observed. Milk quality parameters with a metal roof. Therefore, trees are a highly desir- are also affected whereby somatic cell and bacterial able natural resource in the environment of the dairy counts tend to increase during periods of hot and cow. However, trees have a short life span in operations humid weather. Although specific data are limited, where they are not protected. In fact, most last only the observed increase in somatic cell counts suggests about one to two summers after the onset of cow expo- a greater susceptibility to infection due to decreased sure where stocking rates are high. As cows congregate host resistance or increased exposure to pathogens to seek protection from the summer sun they quickly

created by an environment more favourable for their

develop mud holes at the base of trees. This soon leads

propagation.

to death of the tree and loss of this natural shade source.

Improper ration formulation, intermittent feeding

In order to take advantage of natural shade, some effort

behaviour, a lack of cud chewing, elevated respiratory

must be made to ensure that trees are protected from

rates, excessive losses of saliva from drooling and an

damage by cows.

overall reduction in the buffering capacity may inter-

fere with the normal buffering of rumen contents. This

Artificial shade

is believed to be a significant contributor to rumen

acidosis (see p. 829), laminitis (see p. 420) and other

Solar radiation is a major factor in heat stress and

lameness conditions (see Chapter 31) that seem to be

increases heat gain by direct as well as indirect means.

particularly prevalent during periods of hot weather.

Blocking its effects through the use of properly

Feeding the lactating cow is particularly challenging

constructed shade structures alone increased milk

during periods of intense heat. The objective is to

production by 10–19 per cent in studies conducted in

maintain some level of performance and homeostasis

Florida. Options include permanent or portable shade

yet not add to the internal heat load or tendency toward

structures. In the following sections consideration

rumen acidosis.

will be given to design and maintenance factors.

Permanent shade structures

Structures wider than 12 m (40 feet) should have

eave heights of at least 5 m (16 feet) or more.

Major design parameters for permanent shade struc-

• There should be at least 15m (50 feet) of clearance

tures include:

between adjacent buildings or other obstructions.

• Orientation

• Gable roofs should have at least a 4:12 slope (6:12

• Floor space

is acceptable but difficult to work on) and a

• Height

continuous open ridge. Ridge caps if desired should

• Ventilation

have a minimum of 0.3 m (1 foot) of clearance

• Roof construction

between the cap and the roof peak.

• Feeding and water facilities

• Ridge openings should be a minimum of 0.3m (1

• Waste management system.

foot) wide plus 5 cm (2 inches) for each 3 m (10 feet)

of structure width over 6 m (20 feet).

The preferred orientation of a shade structure

• Painting metal roofs white and adding insulation

depends upon whether or not cows are confined to the

directly beneath the roofing will reflect and insu-

structure. Alignment of the long axis in an east–west

late from effects of solar radiation and will reduce

direction achieves the maximum amount of shade

thermal radiation on cows.

under the structure and is therefore the preferred orientation for confined animals. On the other hand,

Thermal radiation from the roof of shade structures

where cows are free to move with the shadow of the

can add significant heat load to cattle, particularly

structure a north–south orientation is better because

in low structures without a ridge opening. In these

this orientation will allow sunlight to dry out as much

types of structures thermal radiation can be reduced by

as 35–50 per cent of the area beneath the shade

cooling the roof with water, adding insulation or paint-

structure during both the morning and afternoon hours.

ing the roof with a reflective type of paint. However, it

This is particularly important for shade structures with

should be remembered that these additions to the

earthen floors.

structure do not cool air, reduce humidity or augment

Some prefer concrete slab floors. A reinforced con-

the natural evaporative cooling mechanisms of cows

crete slab at least 10 cm (4 inches) thick, with a smooth

beneath the shade structure. Furthermore, proper

finish and grooved for good footing, is recommended.

design of the shade structure (adequate eave height and

If a flush system is to be used the floor should be sloped

an open ridge) will naturally limit thermal radiation

1.5–2 per cent. Water availability, space and environ-

effects. When faced with the need to retrofit cooling

mental concerns are currently of interest in floor scrap-

into an ill-designed existing structure, the priorities

ing and removal of manure solids from the premises.

should be directed to cooling the cows rather than the

Various other waste handling facilities incorporate

roof. Roof cooling (beyond painting with a reflective

settling basins, liquid/solid separators, pumping and

paint), while beneficial, is a secondary consideration.

gravity-flow systems.

Guidelines regarding the size of shade structures

Portable shade structures

vary according to climatic conditions. Some recom-

mend 1.75–2.5 m2 (19–27 square feet) of floor space per

Portable shades offer some advantages over permanent

cow. However, for hot and humid environments, some

structures in their ability to be moved as required to

would recommend a floor space equivalent to 5.5–
cleaner and drier locations. However, protection from
6.0 m2 (60–65 square feet) per cow. Space requirements
solar radiation is less than that achieved in permanent
are doubled for hot and humid climates to provide an
structures. Shade cloth patterns come in various weaves
additional open area for improved air movement.
providing 30–90 per cent shade. One of the more com-
Natural air movement under a shade structure is
mon types is a woven polypropylene fabric which
affected by its height and width, the slope of the roof
provides 80 per cent shade. While longevity is consid-
and the presence of, or size of, the ridge opening.
erably less than that expected of permanent structures,
Air movement may occur naturally as breezes through
shade cloth if properly maintained (kept tight) can last
the open sides of structures or by thermal buoyancy,
5 years or longer.
in which air warmed by the presence of animals
and thermal radiation through the roof creates air
flow toward the ridge opening. A steady flow of air

Cooling by reducing ambient air

through a shade structure requires the following design

temperature

specifications:

• Shade structures of 12m (40 feet) or less in width

As temperatures rise above the upper critical tempera-

require a minimum eave height of 3.7 m (12 feet).

ture threshold of 25.5°C (78°F) the dairy cow begins

to increase heat loss via the respiratory tract and skin

litres (30–50 gallons)/cow per day). The primary

surface. However, despite the remarkable efficiency of

disadvantage is that they require more maintenance.

these thermoregulatory responses to dissipate heat, as

In-line water filters must be cleaned or checked daily

temperatures continue to rise these natural mechanisms

to prevent clogging of fogger nozzles.

are overwhelmed, leading to hyperthermia and reduced

performance. In these circumstances efforts to mini-

mize additional heat gain and supplement cooling be-

Misters

come necessary. Water and air movement become the
A mist droplet is larger than a fog droplet but cools air
agents by which the micro-environment is cooled and
by the same principle. These systems do not work
evaporative cooling by the cow is augmented.
well in windy conditions or in combination with fans in
humid environments. In warm humid environments
Evaporative cooling pads and fans
mist droplets are too large to evaporate fully before
settling to the ground. The consequence is wet bed-
Air temperatures can be lowered by air conditioning or
ding and wet feed. A further complication with misters
refrigeration, but the expense of such types of mechan-
is the formation of an insulating layer of air between
ical air cooling makes these impractical for cooling
the droplets of water on hair shafts and the cow's
dairy cows. A more economically feasible method to
skin. When this occurs it impedes natural evaporative
cool the micro-environment is the evaporative cooling
heat loss from the skin and can result in body heat
pad (corrugated cardboard or similar material) and fan

build-up.

system which uses the energy from air to evaporate

water. This process cools the air and raises its relative

humidity. Although these systems are most effective in

Enhancing the cow's natural

arid climates, they have been observed to reduce air

temperature in humid climates as well.

mechanisms of heat loss

Protecting the cow from solar radiation with shades and

High pressure foggers (see also Chapter 71)

reducing ambient air temperatures through the pro-

In recent years interest in high pressure foggers has

cess of water vaporization and controlled ventilation

grown. These systems offer effective cooling but with

are important considerations in cooling dairy cattle.

lower water use. Foggers disperse very fine droplets of

Various combinations of these techniques have proven

water which quickly evaporate, cooling the surrounding

to be particularly useful in arid climates. Cooling in hot

air and raising the relative humidity in the process. The

and humid climates, on the other hand, can be more typical design incorporates a ring of fogger nozzles

challenging. Instead of trying to lower ambient air

attached to the exhaust side of a fan. As fog droplets

temperature, another technique is to provide shade, wet

are emitted (200 psi) they are immediately dispersed

the skin and move air to enhance the cow's primary

into the fan's air stream where they soon evaporate. The

mechanism for the dissipation of heat – evaporative

temperature of the animals is reduced as they inspire

cooling from the skin.

the cooled air and it is blown over their bodies. Fogger

systems are most effective in areas of low humidity.

Sprinklers and fans

However, even where humidity is normally quite high,

daytime humidity is still low enough to allow effective

Sprinkling systems utilize a larger size water droplet

cooling with fogger systems. In areas where relative

that is able to wet the hair coat to the skin. Cooling

humidity increases to nearly 90 or 100 per cent in the

is accomplished as water evaporates from the hair

overnight hours foggers must be turned off. Once the and skin. In combination with forced air, sprinkling

air is saturated with moisture evaporation is reduced

substantially increases the loss of body heat over

and cooling stops. High pressure foggers should

that possible by sweating alone. Several studies have

be designed to operate during the less humid hours of

demonstrated upper body sprinkling followed

the day. Finally, they should be used only in open-

by forced-air ventilation to be an effective means

sided, ridge-vented, tall (greater than 3.7 m (12 feet))

to reduce body temperature, increase feed intake and

barns. Low barns with side walls restrict air flow and

boost milk yield. This combination has been applied to

fog droplet evaporation. This reduces cooling and

holding areas outside milking areas, shade structures,

makes for excessively wet conditions in the barn.

feed barns and free-stall barns with a high degree of

High pressure foggers are advantageous in the fact

success.

that they use far less water (13.5–23 litres (3–5 gallons)/

Sprinkler and fan systems require a properly sloped cow per day) compared with sprinkler systems (135–230

concrete floor with facilities to handle water run-off at

rates of somewhere between 230 and 450 litres (50 and

good reason. Experience has shown that free access

100 gallons) of water per animal per day depending

to streams and ponds may predispose to a number of

upon sprinkling rates. In early Florida studies water use

infectious diseases and some toxicities in dairy cattle.

amounted to 455 litres (120 gallons)/cow per day (sprin-

Most notable of these are leptospirosis (see pp. 734–7)

kling for 30 seconds every 5 minutes when ambient air

and mastitis (see Chapter 23) caused by a variety of

temperatures exceeded 26.5°C (80°F)). Later work has

organisms, particularly *Protheca* species (achlorophyllic shown that rates of 230 litres (50 gallons)/cow per day

algae). As a result, most advise that cows be fenced

or less will provide effective cooling. Consequently, in

away from streams and ponds. Cooling ponds, there-

addition to plans for water run-off and containment,

fore, represent a controversial method for the manage-some determination of the water supply is advised.

ment of heat stress. However, studies in the USA have

Sprinklers should be located above the cows, with

found that cooling ponds not only effectively reduce

nozzles directed such that they wet the cows but not

body temperature, but have no apparent adverse effect

the feed. The type of nozzle chosen depends upon the

on udder health.

volume of water and sprinkling rate desired. Generally,

The primary mode of heat loss in cooling ponds is

low pressure (10 psi), 180° spray nozzles, capable of

conduction, with a small amount lost by evaporative

delivering the equivalent of 1.25 mm (0.05 inches) of

cooling during the 5–10 minutes after exiting the pond.

rainfall per sprinkling cycle, are used. This sprinkling

Water temperature of the cooling ponds studied in the

rate assures that the cows will be wetted to the skin.

USA generally ranged from 24 to 30°C (75 to 86°F),

Nozzles are spaced approximately every 2.5 m (8 feet)

or occasionally higher. At this temperature there was

or as far apart as necessary to provide overlapping a favourable heat transfer gradient between the cow's

coverage.

body and the pond water.

Fans (0.5–1.0 hp) capable of air flow rates of 11 000

Major questions remain as to how cooling ponds

cfm or greater are recommended. Ninety centimetre

should be designed or maintained. Some operations

(36 inch) fans rated as such can be hung above the

that rely on ponds for cooling cows maintain them by

sprinklers every 9 m (30 feet) (every 1.2 m (40 feet) for

providing a constant inflow of water, with an overflow

120 cm (48 inch) fans). They should be tilted downward

at one end of the pond. They also drain, dredge and fill

at a 20–30° angle (from vertical) to direct the flow

them with new sand every 1 to 2 years. Although total

of air on to the cows. An air velocity of 120–185 m

bacterial content does not appear to be appreciably

(400–600 feet) per minute over the cow is desired. The

affected there is less build-up of organic material. There

system combines fans and sprinkling, with cows being

is some evidence that allowing cows access to stagnant sprinkled for 1–2 minutes at 15-minute intervals. Fans

or natural ponds may negatively affect milk quality and

should be run continuously. The entire system should

the incidence of mastitis. Cows from herds with man-

be thermostatically controlled to operate automatically

made ponds, which are maintained regularly, produce

when ambient air temperatures reach or exceed 26.5°C

milk with lower bacteria and somatic cell counts

(80°F).

compared with cows from herds which have no ponds

or natural ponds. Thus, one would conclude that the use

of ponds for heat stress management should be accom-

Sprayers in parlour exit lanes

panied by plans for pond maintenance.

Exit lane sprayers are available commercially and

designed to automatically spray water on to cows as

they pass through. Fan nozzles and timing of the spray

Further reading

are designed to spray only on to the cow's back and

sides. Fan spray nozzles must have a flow rate of at least

Beede, D.K. & Shearer, J.K. (1991) Heat stress, part IV:

36 litres (8 gallons) per minute at 40 psi. These systems

nutritional management of dairy cattle during hot weather.

would seem to have greatest appeal in operations

Agri-Practice, **12**, 5–13.

where cows travel some distance from the milking

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system can be made by simply locating an ordinary

tal management systems in hot humid environments.

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Chapter 9

Nutrition

J.M. Wilkinson

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Total mixed rations or complete diets

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Fermentation in the rumen

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Diet formulation

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Saliva

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Condition score

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Actual and potential digestion

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Optimizing digestion in the rumen

99

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Feed intake

100

Is feed intake under control?

100

Concentrates

100

The bovine animal, along with the other ruminants,

Roughages

101

depends very heavily on its symbiotic relationship

Rumen capacity

101

with the microbial population of the rumen. Thus any

Digestibility of forages

101

consideration of the nutrition of the bovine must be

Speed of digestion

101

focused on the rumen as the most important part of the

Grazed pasture

101

bovine digestive system. The fermentation in the rumen

Probable levels of intake

102

is dominated by the degradation of plant cell walls, of

Energy requirements

103

which the most abundant constituent is cellulose. This

Requirements and allowances

103

adaptation to plant cell wall digestion, in addition to cell

Partition of feed energy

104

content degradation places the bovine in an important

Efficiency of use of metabolizable energy

104

Energy requirements of growing cattle

104

strategic position relative to other animals.

Energy requirements of lactating cattle

105

Van Soest (1994) classified cattle feeding habit as

Protein requirements

106

being one of grazing fresh grass, rather than browsing

Microbial protein synthesis

107

trees and shrubs. Cattle have a greater need for water

Metabolizable protein

108

than other ruminants, possibly because they retain fibre

Requirements for metabolizable protein

110

for relatively long periods in the rumen. A high free-

Composition of feeds

111

water content, typically around 90 per cent, is essential

Cellulosic and non-cellulosic feeds

111

for optimal bacterial activity. In addition, there is less

Energy and protein in feeds

112

absorption of water in the large intestine and a higher

Physical form

113

water content in the faeces than with sheep and goats.

Feed preservation

114

The bovine is a relatively unselective eater compared

Drying

114

Ensiling

114

with the other ruminants. This may be a disadvantage

Primary and secondary fermentations

115

when tree and shrub leaves are abundant at a time

Typical analytical composition of silage

116

when pasture supply is scarce because of drought. But

Additives for silage

116

the bovine can and does browse. In situations of excess

Additives for hay and moist grain

117

food supply over consumption, selective eating occurs.

Feed processing

117

In temperate regions of the world, a constant supply

Physical processing of roughages

117

of feed throughout the year is achieved by preserving

Chemical processing of roughages

117

excess herbage growth as hay or as silage. This activity,

Processing of cereals

118

coupled with the production of root crops specifically

Feeding management

118

for use when grass growth is slow or non-existent, has

The importance of selective eating

118

transformed the annual cycle of production from one

Targets for sward surface height at pasture

118

Buffer feeding

119

totally dependent on grass growth to one which is not.

Frequency of feeding and ruminal acidosis

119

Thus beef cattle, for example, no longer lose weight in

Out-of-parlour feeders

119

the winter when grass is scarce, but are able to main-

Flat-rate feeding

120

tain or even increase in weight on a winter diet of hay,

silage or stored root crops. The development of the

crops by ensilage. Essentially, dietary carbohydrates,

human food and drink industry has released a wide

proteins and some fats are reduced to short-chain fatty

range of by-products, such as bran from the milling of

acids with the production of carbon dioxide, methane

grain for flour, and spent grains from the brewing of

and ATP.

beer and the production of spirits. These by-products,

The short-chain fatty acids produced in the digestive which are not edible by the human population, play a

tract are principally acetic, propionic and butyric acids,

vital role in the nutrition of the bovine when grazed

although occasionally lactic acid is also produced.

pasture grass is in short supply.

The most important bacteria involved in fermenta-

A remaining challenge in bovine nutrition is to

tion in the rumen are the cell-wall digesting or cellu-

achieve a similar constancy of feed supply to that of the

lolytic micro-organisms. The concentration of bacteria

temperate regions of the world, to bovine populations

in rumen fluid is about 1010 to 1011 bacteria/ml, with

in regions where drought is common, and where the

most being attached to particles of food. The predomi-

technology of feed preservation and by-product utiliza-

nant species of bacteria varies with the type of fermen-

tion is less well developed.

tation, which depends on the principal substrates in the

In this chapter, the fermentation in the rumen is

diet. Thus the major species of bacteria in the rumen

described, with particular emphasis on the kinetics of of animals given a diet of grass are those which digest

the process and its interaction with feed intake.

cellulose and hemicellulose, such as *Ruminococcus*

Requirements for energy and protein are then consid-

albus, *Ruminococcus flavefasciens* and *Bacteriodes* ered. The composition of feeds is outlined, together

succinogenes (see Table 9.1).

with technologies for feed preservation and feed pro-

Other species, such as *Streptococcus bovis*, ferment

cessing. Finally, the management of the feeding of

starch to acetic acid and ethanol. This species, along

the bovine is outlined in relation to maintaining stabil-

with other streptococci, can produce lactic acid and are

ity in the rumen, maximizing intake and meeting

more tolerant of acid conditions than other species

requirements for high levels of productivity.

of rumen bacteria. Acidosis can occur if the diet of

the animal is changed abruptly from cellulose to starch

or sucrose. The population of bacteria in the rumen

Fermentation in the rumen

changes from cellulolytic to amylolytic as the pH falls.

Lactic acid accumulates and accelerates the fall in pH.

The rumen accounts for more than half the total volume

Even a small fall in the pH of the rumen from pH 7 to

of the digestive tract of cattle. The animal relies very

pH 6 is reflected in a reduction in cellulose digestion

heavily on the reactions that occur in the rumen for its

and a change in the population of the bacteria towards

supply of major nutrients. Thus on a sole diet of grazed

the more acid tolerant species.

grass some 90 per cent of the animal's total energy

Proteins are degraded to a varying extent during the

and protein supply is derived directly from the

fermentation to their constituent amino acids. Some

rumen micro-organisms and the end-products of their

amino acids are used directly by bacteria and protozoa,

metabolism. Therefore, the importance of main-

but most are used as a source of energy and are broken

taining optimal conditions for fermentation cannot be

down further to ammonia and volatile fatty acids.

overstressed.

Ammonia is used as a substrate for the production of

The symbiotic relationship between the micro-

microbial protein, with the excess being absorbed into

organisms of the rumen and the host animal has been

the animal's portal blood and converted to urea in the

crucial to the survival of the bovine, since the animal itself liver. The extent to which proteins are degraded during

does not produce the enzymes to degrade the cellulose

the fermentation in the rumen depends on their

and hemicellulose in plant cell wall material. This task is

solubility, which is generally relatively high. However,

undertaken by the microbial population of the rumen.

solubility is lower in feeds which have been subjected

In the wild, surrounded by foliage and limited sup-

to heat treatment during processing. Thus the degrada-

plies of feeds containing starch or sugar, the bovine's

tion of protein in brewer's grains is only about 0.6, com-

fermentation of plant cell wall material secured not

pared to 0.9 for fresh herbage. Protein degradation also

only the supply of energy, but also a vital supply of

depends on the time the material spends in the rumen,

microbial protein. The ruminant has evolved a nutriand is lower for diets which pass rapidly through the

tional niche whereby it is independent of external

rumen (concentrates and feeds of small particle size)

sources of amino acids and B vitamins – a considerable

than for long forages which are digested slowly.

advantage when grass is the only feed available.

Protozoa and fungi are also involved in the fermen-

Fermentation in the rumen is the anaerobic process

tation process. These organisms can digest cellulose,

of microbial activity, which also occurs in the lower

starch, sugars and fats to produce acetic acid, butyric

digestive tract of animals and in the preservation of

acid, lactic acid, hydrogen and carbon dioxide.

Table 9.1

Common types of rumen micro-organisms and their action.

Species

Energy source

Fermentation

Requirements

products

Bacteria

Bacteroides

amylophilus

Starch

F, A, S

CO_2, NH_3, BrVFA

succinogenes

Cellulose

F, A, S

CO_2, NH_3, BrVFA,

SVFA, Vit.

Ruminococcus

albus

Cellulose, xylan

F, A, E, H_2, CO_2

BrVFA, CO_2, NH_3,

Vit.(A)

flavefaciens

Cellulose, xylan

F, A, S, H_2

Butyrivibrio

fibrosolvens

Xylan, starch

F, A, B, L, H_2, CO_2

BrVFA, A, CO_2,

NH_3, Vit.(A)

Lachnospira

multiparus

Pectin

F, A, L, E, H_2, CO_2, A, Vit.

Selenomonas

ruminantium

Lactate, starch

A, P, L, CO_2, H_2

A(CO_2)

Methanobacterium

ruminantium

Formate, H_2

Methane

A, BrVFA, Haem,

CO_2, NH_3

Protozoa

Holotrichs

Isotricha

Starch and sugars

A, B, L, H2

Dasytricha

Starch and sugars

A, B, L, H2

Entodiniomorphs

Entodinia

Starch

F, A, P, B, (L)

Epidinium

Starch, hemicell.

A, B, H2, (F, P, L)

Ophryoscolex

Starch

A, B, H2, (P)

Diplodinium

Eudiplodinium

H2, fatty acids

Polyplastron

Symbols: F, formate; A, acetate; P, propionate; B, butyrate; BrVFA, branched-chain VFA; E, ethanol; L, lactate; S, succinate; SVFA, straight-chain VFA; Vit., B vitamins.

The predominance of the weak acids acetic, propionic

tional circumstances the environment for fermentation

and butyric in the end-products of fermentations in the

remains relatively constant. However, digestive disor-

digestive tract highlights the importance of buffering

ders can arise to disrupt the equilibrium. Toxins, pro-

agents to maintain the pH of the environment close to

duced by undesirable bacteria and from moulds present

neutrality. Saliva, containing sodium and potassium

in foods, can damage the sensitive lining of the wall of the

bicarbonate and urea, is the most important buffering

rumen and reduce the absorption of nutrients. Sudden

agent in the rumen, and the amount of saliva produced

changes in diet can change the microbial population and

during eating and rumination is therefore crucial to the

result in the production of lactic acid in the rumen, as in

neutralization of the fermentation acids (see below).

the fermentation of crop material in the silo, with a con-

Long fibre is often included as a supplement to diets high sequent reduction in rumen pH. If the pH of the rumen

in concentrates to stimulate chewing and rumination.

falls below pH 5 and remains at a low level, there is a risk

The constant flow of saliva (p. 98) into and outflow of

of rumen stasis which can result in bloat because the

digesta from the rumen, and the absorption of digested

animal can no longer eructate the gases produced by the

nutrients into the portal blood, ensure that in most nutri-

fermentation.

Methane loss from the rumen is estimated to account

cellulose and cellulose to glucose and fructose. Starch

for about 8 per cent of the total gross energy eaten by

and pectins are also similarly degraded (Fig. 9.1). In the

the animal. Apart from the rumen fermentation,

case of plant cell wall material, this erosion continues

methane is also lost to the environment from hind gut

until lignified tissue is encountered. Lignin, which is

fermentations and together these fermentations con-

cross-linked to hemicellulose and cellulose, provides

stitute a significant contribution of methane to the structural strength to the plant and is also very resist-

global environment. Ways of reducing methanogenesis

ant to bacterial enzymic attack.

include chemical food additives (ionophores), and

The protozoa in the rumen mainly ferment starch and

changing the pattern of fermentation to increase the

sugar, but they also consume bacteria. The protozoa

proportion of propionate and to reduce the proportion

are thought to be active in assisting the bacterial

of acetate.

population in adapting to new feeds.

The end-products of bacterial digestion are short-

chain acids acetic, propionic and butyric (the volatile

Saliva

fatty acids, VFA), microbial cells (and their constituent

protein), and the gases methane and carbon dioxide.

Feeds are chewed during eating and also regurgitated

Methane comprises the major gaseous energy loss as

during rumination to allow very thorough mastication.

a result of fermentation. Gas is lost by eructation

Throughout these activities large quantities of saliva are whilst the VFA are mainly absorbed through the rumen

mixed with food. The effect of saliva is to buffer the

wall.

acids that are produced in the rumen as a result of the

Some common types of rumen micro-organisms and

fermentation. This buffering is vital to the maintenance

their actions are summarized in Table 9.1.

of the correct type of fermentation, and can even

prevent the collapse of normal rumen function in

extreme situations.

The principal buffering constituent of saliva is bicar-

Fermentation of different types of feed

bonate. It has been estimated that a dairy cow may

The fermentation of plant cell walls is optimal at

produce up to 3.5 kg of bicarbonate per day. Clearly, the

relatively high rumen pH (around pH 7.0) because the

need for adequate buffering is more important if the

bacteria responsible are sensitive to excess acidity.

diet is rapidly fermented than if it is only slowly fer-

Their growth is depressed if rumen pH falls below

mented. Further, if the diet is acidic, as in the case of about pH 6.2. The principal end-product of cellulose

silage, it is essential that salivary secretion is sufficient

fermentation is acetate, an important precursor of

to prevent a build-up of excessive acidity in the rumen

milk fat.

or in blood.

Starch and sugar are fermented to give propionic and

It follows that feeds which stimulate rumination are

butyric acids as the main end-products. The micro-

more useful to the maintenance of optimal conditions

organisms responsible for their fermentation are more

for fermentation in the rumen than those which do not.

tolerant of acidity than those which ferment cell wall.

Unfortunately many constituents of high-energy con-

Some species of starch-digesting bacteria (e.g. *Strepto-*

centrates, such as molasses and ground cereal grains, are

coccus bovis, *Selenomonas ruminantium*) produce lactic fermented rapidly in the rumen and do not stimulate

acid, a stronger acid than the VFA. Large amounts of

rumination. At the other extreme, hay and straw are

lactic acid can predispose the animal to rumen stasis chewed extensively to break down the fibre and their

and to acidosis (see p. 829).

rate of digestion is also relatively slow. Hence a com-

Protein is fermented to yield ammonia and VFA from

promise with respect to saliva production is required;

the carbon skeletons of amino acids. The ammonia may

fibre is required together with concentrated feed

be used by bacteria to synthesize new protein in their

sources in order that saliva output is maintained.

cells, but since bacterial growth is generally limited by

the energy available from carbohydrate digestion,

rather than from protein digestion, ammonia in excess

The actions of micro-organisms

of microbial requirements can easily be produced,

The major organisms responsible for digestion in the

especially on high-protein diets. Excess ammonia is

rumen are anaerobic bacteria and protozoa, although

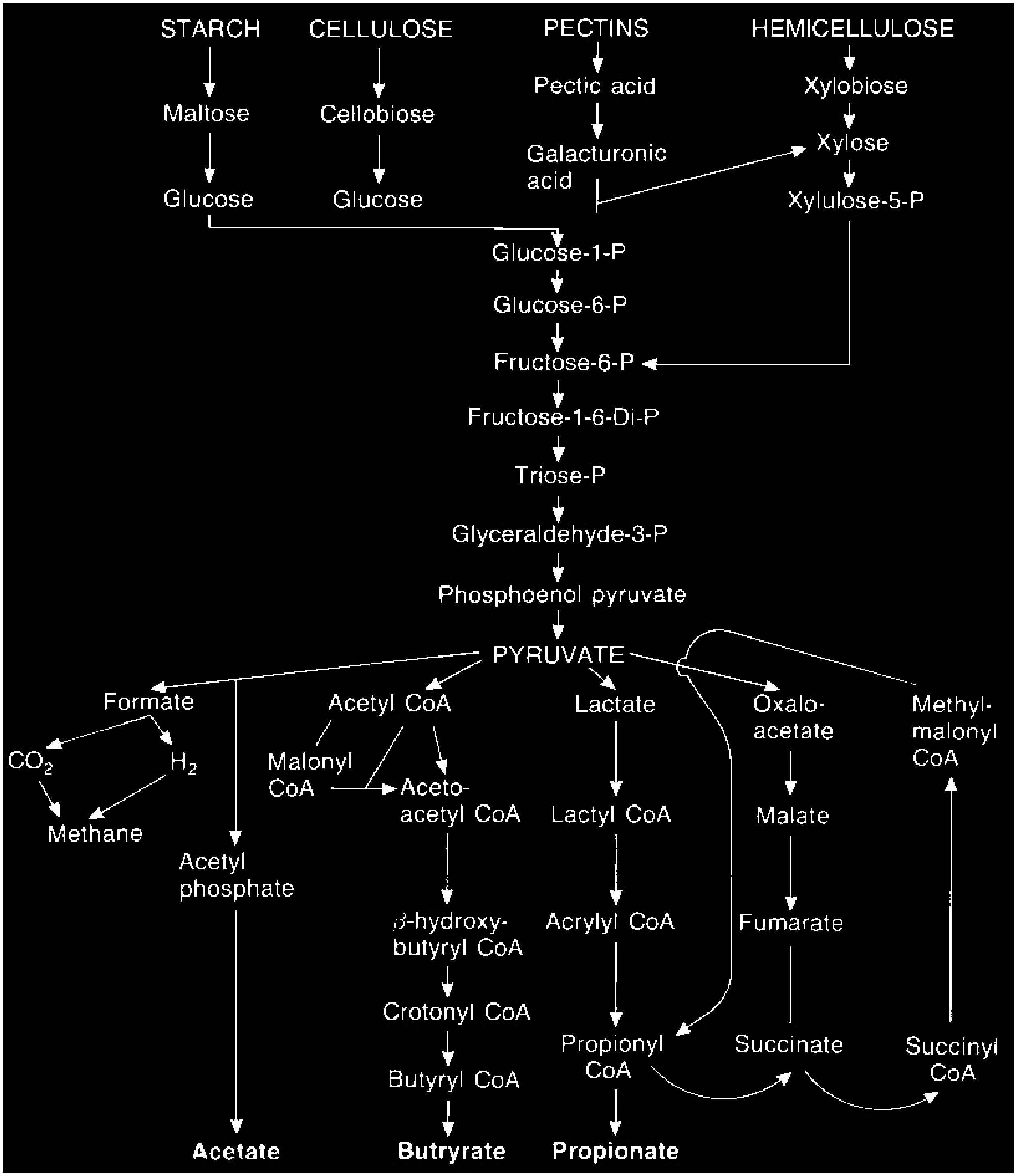
converted, at an energy cost, to urea in the liver and

anaerobic fungi are thought to be responsible for much

excreted in urine. A deficit of ammonia in the rumen

of the initial colonization of feed particles in the rumen.

slows down bacterial growth, reduces rate of digestion
The cellulolytic bacteria adhere to particles of fibrous
and depresses feed intake. Thus the rate of release of
feeds and secrete enzymes that gradually erode out the
ammonia should match as closely as possible the
digestible material. Their enzymes break down hemi-
release of energy (see Fig. 9.2).



STARCH
CELLULOSE
PECTINS
HEMICELLULOSE
Maltose
Cellobiose
Pectic acid
Xylobiose
Galacturonic acid
Xylose
Glucose
Glucose
Xylulose-5-P
Glucose-1-P
Glucose-6-P
Fructose-6-P
Fructose-1-6-Di-P
Triose-P
Glyceraldehyde-3-P
Phosphoenol pyruvate
PYRUVATE
Formate
Acetyl CoA
Lactate
Oxalo-acetate
Methyl-malonyl CoA
CO_2
H_2
Malonyl CoA
Aceto-acetyl CoA
Lactyl CoA
Malate
Methane
Acetyl phosphate
β-hydroxy-butyryl CoA
Acrylyl CoA
Fumarate
Crotonyl CoA
Propionyl CoA
Succinate
Succinyl CoA
Butyryl CoA
Acetate
Butyrate
Propionate

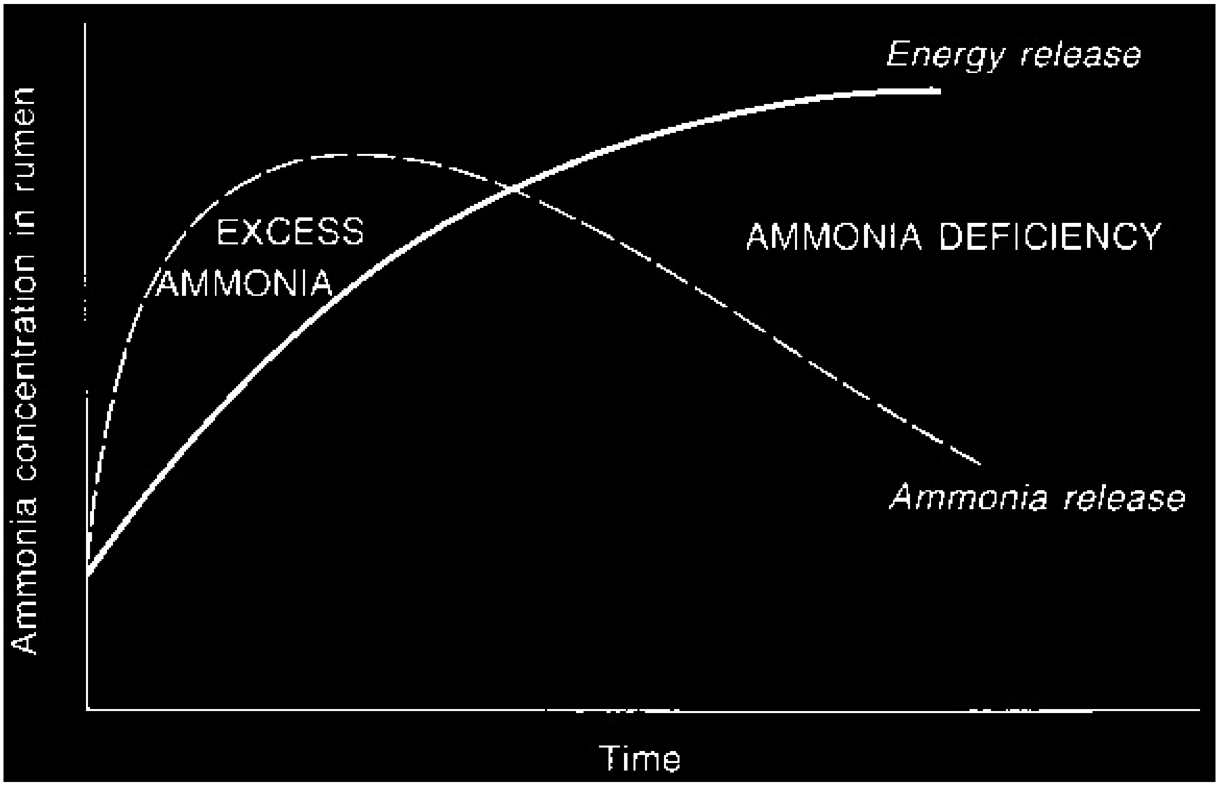


Fig. 9.1

Chemistry of rumen fermentation.

liable to pass on down the tract and out in the faeces. The rate of passage out of the rumen can influence the extent to which fibrous particles are actually digested. The faster the rate of passage, the lower the actual, relative to the potential, digestibility.

The same concept applies to protein, especially that fraction which is available for microbial fermentation in the rumen. A high-yielding dairy cow, given a high-quality diet with a fast rate of passage of feed through the

rumen, will have a relatively lower fibre digestibility than

a dry cow given less of the same diet, or a diet of lower

energy content. However, the protein in the diet of the

high-yielding cow will have a lower digestibility in the

Fig. 9.2

Typical patterns for the rates of release in the rumen of

rumen, yield less ammonia and provide more unde-

ammonia from the breakdown of protein, and of energy, following graded protein to the abomasum than that in the dry

a meal. The rate of ammonia release should match as closely as cow's diet (see Table 9.13). Paradoxically, the lower the

possible that of energy, either by reducing the amount of quickly actual, relative to potential, digestibility in the rumen,

degraded protein in the diet, or by increasing the quantity of the worse off the animal is with respect to energy, but the

readily-fermentable energy (e.g. starch or sugar) in the diet.

better off it is likely to be with respect to protein.

Actual and potential digestion

Optimizing digestion in the rumen

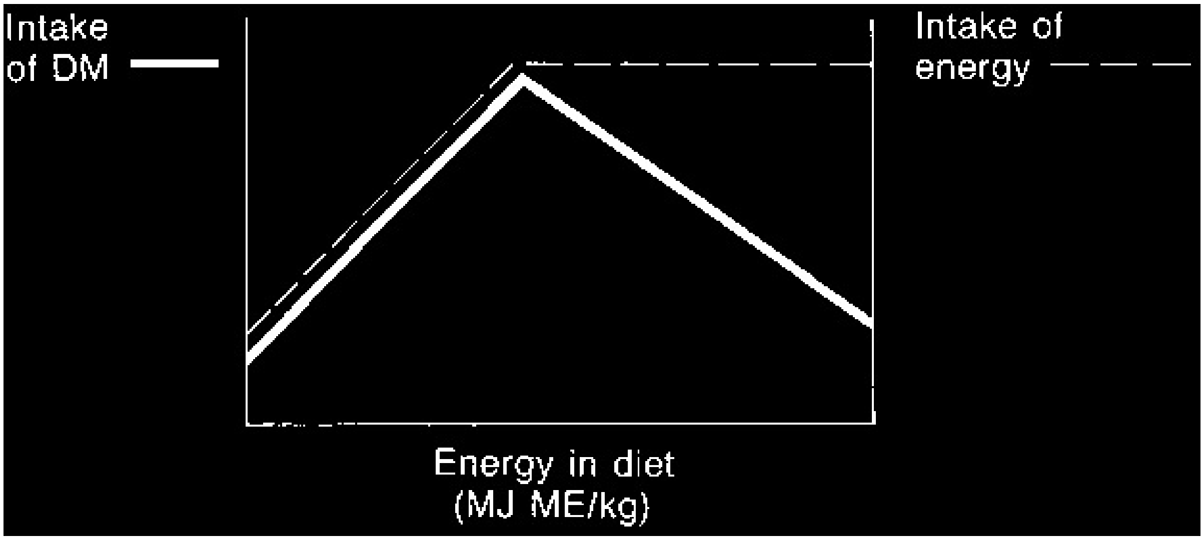
Fibre that has been reduced to a small enough particle

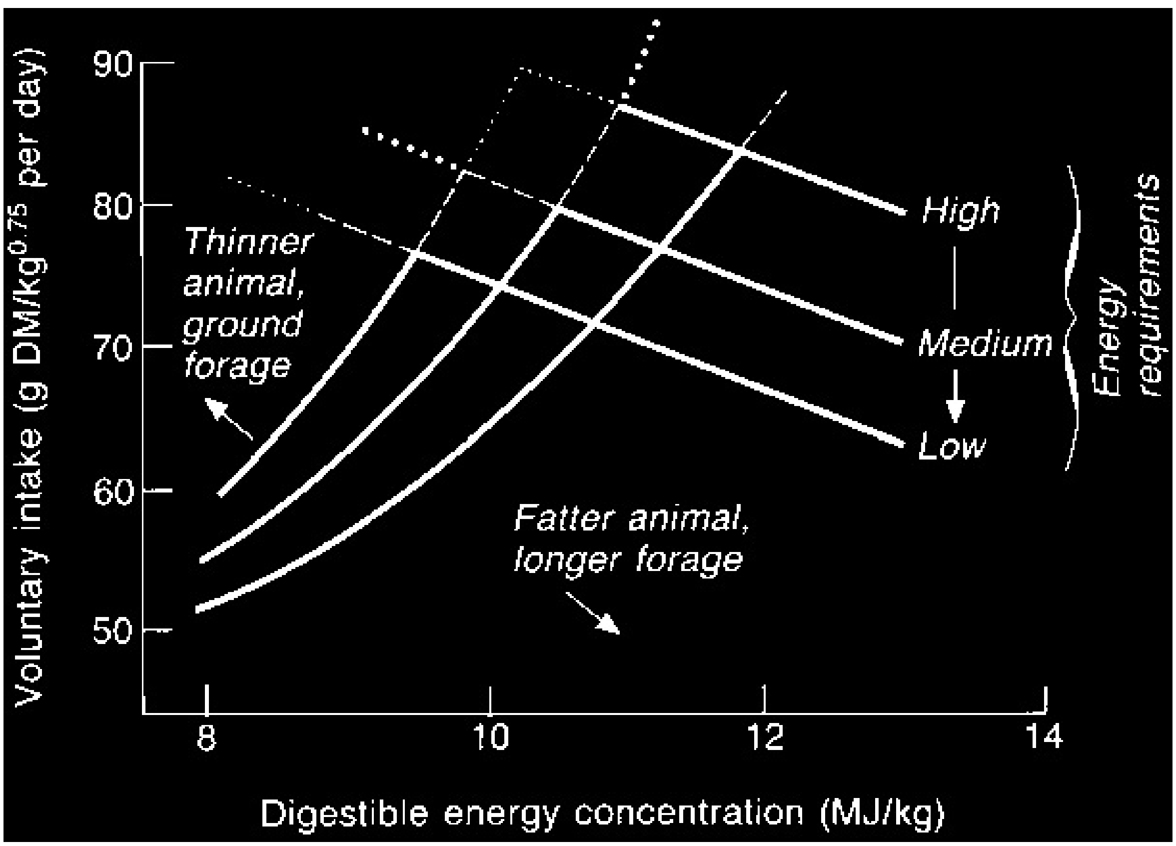
It follows from the above discussion that the following

size at which it can pass out of the rumen, and which principles need to be adopted in order to optimize the

has also resisted being digested by microbial activity, is

fermentation in the rumen:





• Cell wall is the principal source of digestible energy

in the diet of the bovine, and conditions in the

rumen should be optimal for its digestion.

• Sufficient saliva must be produced to maintain

rumen pH above pH 6.5, otherwise cell wall diges-

tion will be reduced.

• Adequate degradable protein must be supplied to

meet the requirements for microbial protein syn-

thesis (see section on protein requirements, p. 106).

• Supplementary energy in the form of starch or

Fig. 9.3

Simplified relationship between the energy content of

sugar must not interfere with the maintenance of

the diet and feed intake. As the energy content of the diet

the above conditions in the rumen (see section on

increases, dry matter intake will increase until it reaches a

feeding management, p. 118).

maximum. If energy content increases further, dry matter intake is reduced because metabolic factors, rather than the bulk, or When cell wall digestion is optimized, then feed intake

‘fill’, of the diet now control intake.

is likely to be maximal, at least with respect to fibrous

feeds (see below).

Feed intake

Most diets for cattle are offered in excess of the amount

the animal actually consumes, although there are situa-

tions where the amount of feed offered each day is

restricted intentionally. Two such situations are readily

apparent: the dry cow and the suckler cow in late lac-

tation. Both situations require that the animal does not

overeat and become excessively fat.

The concept of voluntary feed intake is discussed in

this section, that is, the amount of feed the animal will

eat when offered an excess supply so that about 10 to

15 per cent of the daily amount offered is refused.

Fig. 9.4

Composite diagram of the relationships between

intake and animal and feed factors in ruminants. At any given

energy content, intake is higher for cows that have a greater

Is feed intake under control?

requirement for energy (or potential milk production). Also, intake of dry matter is greater the thinner the cow, and the smaller the The fact that cattle can become overfat suggests that particle size of the feed. Source: Forbes (1983), reproduced with feed intake is under relatively imprecise control.

permission of CABI International.

Equally, sparse availability of range pastures or the

provision of very low quality roughages as the sole

feeds can lead to inadequate levels of feed intake and

chronic undernutrition. The animal can suffer from

lite such as acetate in blood), but the signals to cease

deprivation because it is unable to ingest, or digest,

eating may be physical (bulkiness of the food or restric-

enough nutrients daily to meet its requirements for

tion of rumen capacity by the fatness of the animal) or

maintenance of body weight. Nevertheless, there is evi-

metabolic (concentrations of absorbed nutrients in

dence that cattle eat to satisfy their demand for energy

blood), depending on the type of food. These concepts

to maintain weight and produce tissue growth or milk.

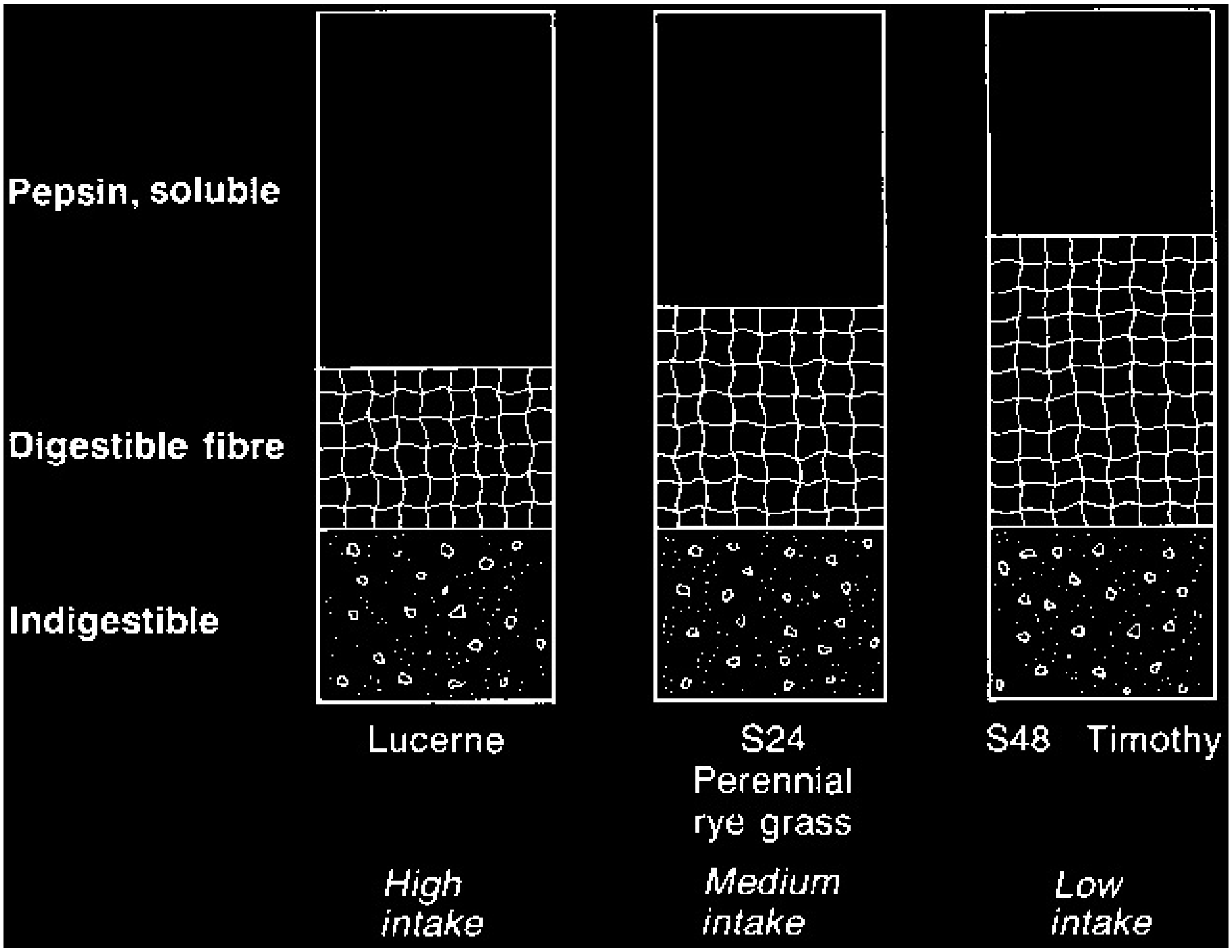
are discussed in more detail below.

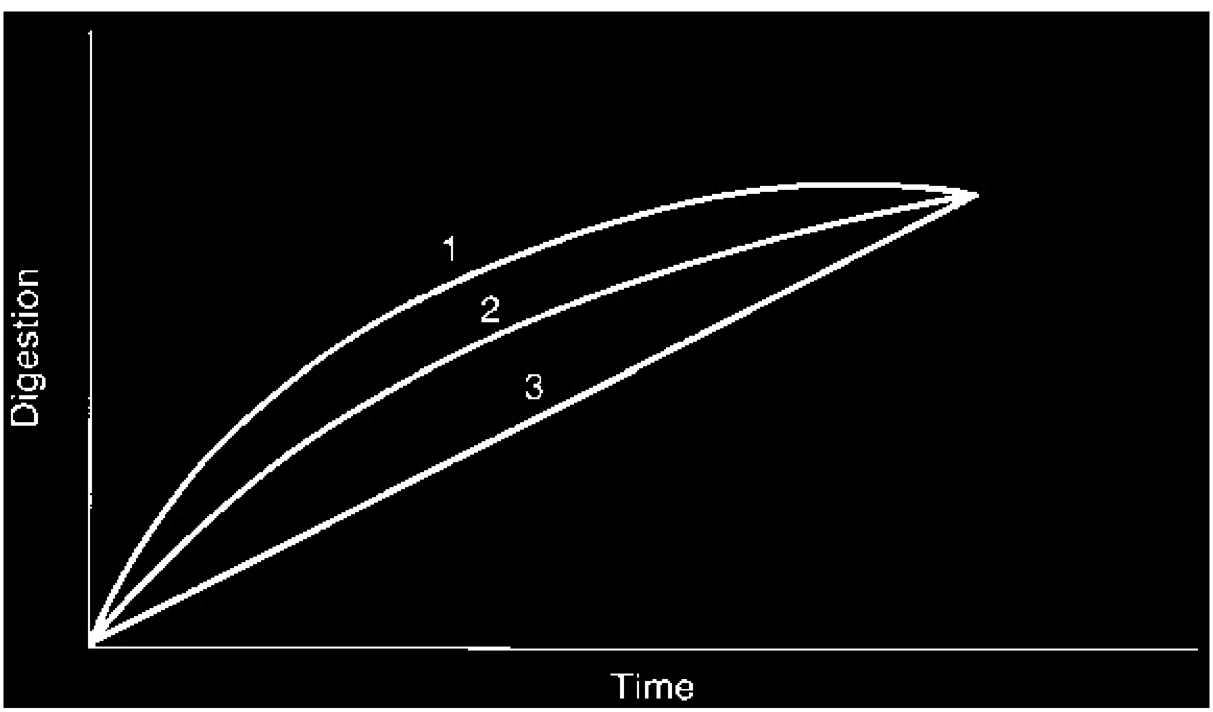
The generalized relationships between the energy

content of the diet and dry matter intake (Figs 9.3 and

Concentrates

9.4) suggest that signals received by the brain when
the animal’s energy needs are met in turn elicit the
With concentrates, satiety occurs long before the capac-
response to cease eating. Perhaps cattle eat as much as
ity of the rumen is reached. Intake is determined by the
possible whilst at the same time attempting to minimize
animal’s capacity to metabolize the nutrients absorbed
the total discomfort which may be caused physically or
following digestion. Enhanced rate of metabolism,
metabolically. Signals to commence eating may be
for example following the administration of soma-
metabolic (for example, the concentration of a metabo-
totrophin, is reflected in increased feed consumption of


Pepsin, soluble
Digestible fibre
Indigestible
Lucerne
S24
Perennial
rye grass
S48 Timothy
High
intake
Medium
intake
Low
intake


Digestion
1
2
3
Time

high-energy diets where physical limitations do not

apply (see below).

Roughages

With roughage feeds the volume of the rumen usually

restricts intake. Thus intake is proportional to the

volume of the rumen – the larger the rumen, the more

feed is consumed. Larger animals eat more than smaller

animals because their rumen volumes are greater.

Rumen capacity

Animals with large rumen capacities relative to their

total body weight eat more roughage than those with

relatively smaller rumen volumes. The implications are

Fig. 9.5

Variations in the ratio of material soluble in acid pepsin

that calves should be reared on diets that encourage

(cell contents) to digestible fibre (cell wall) in three forages of the rumen development, and cattle should be selected for

same digestibility, but differing in intake. Source: Osbourn (1967), large rumen capacities. Channel Island cattle (Jersey,

reproduced with permission of the British Grassland Society.

Guernsey) typically eat more food relative to their body weight than Holstein cattle because, although they

weigh much less, their rumen capacities are relatively

greater. Thinner cattle tend to eat relatively more than

fatter cattle (Fig. 9.4).

Digestibility of forages

Digestibility or energy concentration of forage feeds

exerts a large influence on feed intake (Fig. 9.5).

However,

the relationship between intake and

digestibility is much less evident for silages than for

dried forages, where the pattern of fermentation in the

silo, particularly the presence or absence of residual

Fig. 9.6

Three feeds with the same potential digestibility but

sugar and the pH value of the silage, can have an over-

different speeds of digestion. The animal will eat most of feed 1

riding influence on intake. Thus at the same digestibil-

and least of feed 3. Reproduced from Orskov (1998) with per-

ity drier silages of higher pH value and higher residual

mission of Chalcombe Publications.

sugar concentrations tend to be eaten in greater amounts than more extensively fermented silages, possibly because they provide more readily available form of cell contents, principally sugars and proteins, nutrients to the rumen microbial population.

and in this regard it is nearer to a concentrate in terms of its speed of digestion in the rumen.

Cell walls are generally fermented at a slower rate

Speed of digestion

than cell contents. The actual rate of cell wall digestion

Speed of digestion also has an important influence on

depends on initial particle size, the extent to which it is

intake, since it determines the length of time the feed

broken down by rumination, and the extent to which it

remains in the rumen. Legumes are digested at a faster

may be lignified. Three feeds with the same potential

rate than grasses of the same overall digestibility, partly

digestibility but different speeds of digestion are repre-

because they contain less cell wall than grasses (Fig.

sented in Fig. 9.6. The feed with the fastest speed of

9.5). Also, the structure of the cell walls of legumes

digestion will be eaten in the greatest amount by the enables bacteria to gain access more rapidly than with

animal.

grasses.

The cell contents of forages are fermented very

Grazed pasture

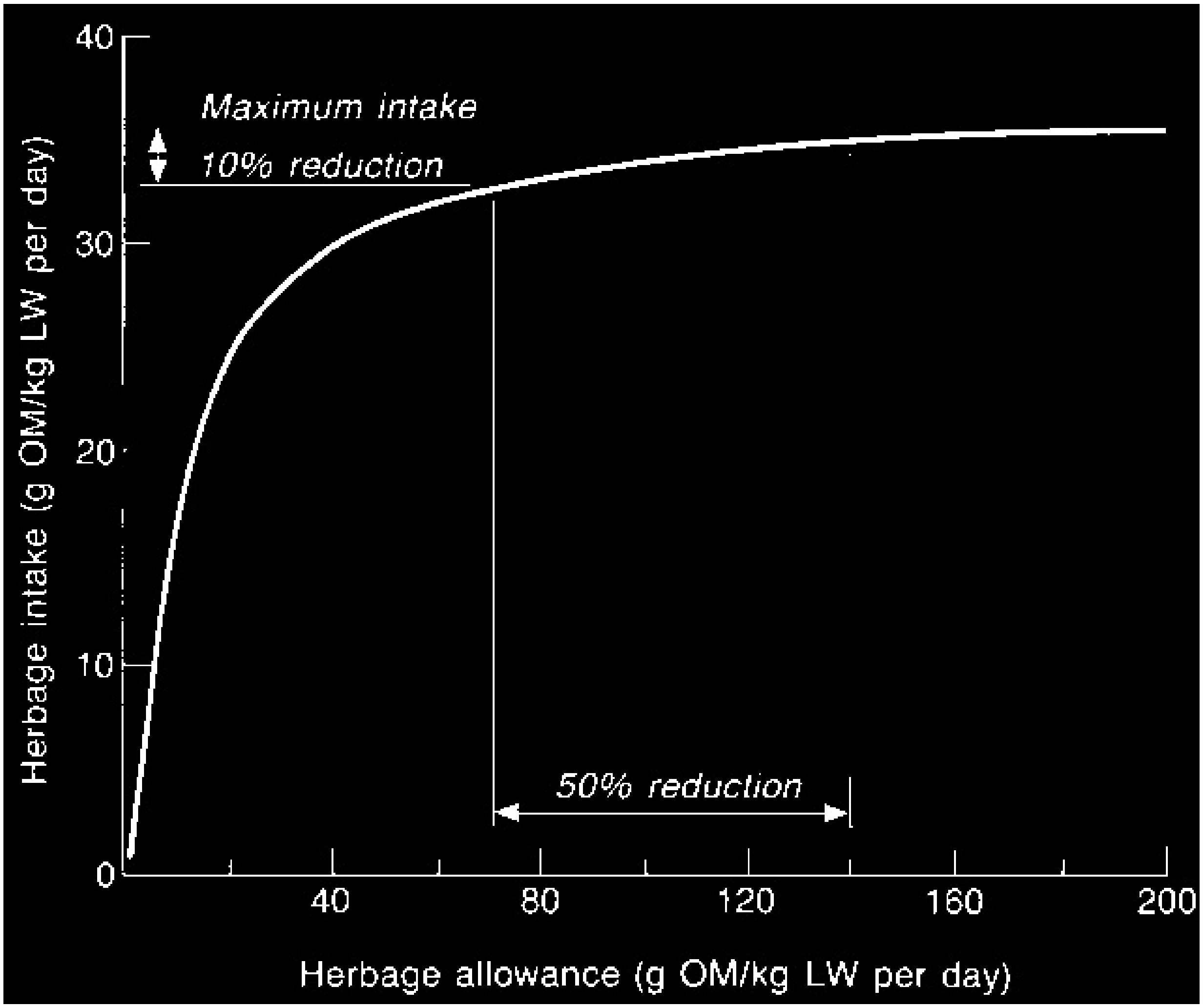
quickly in the rumen, provided they are released by

eating and by rumination. For example, young grass

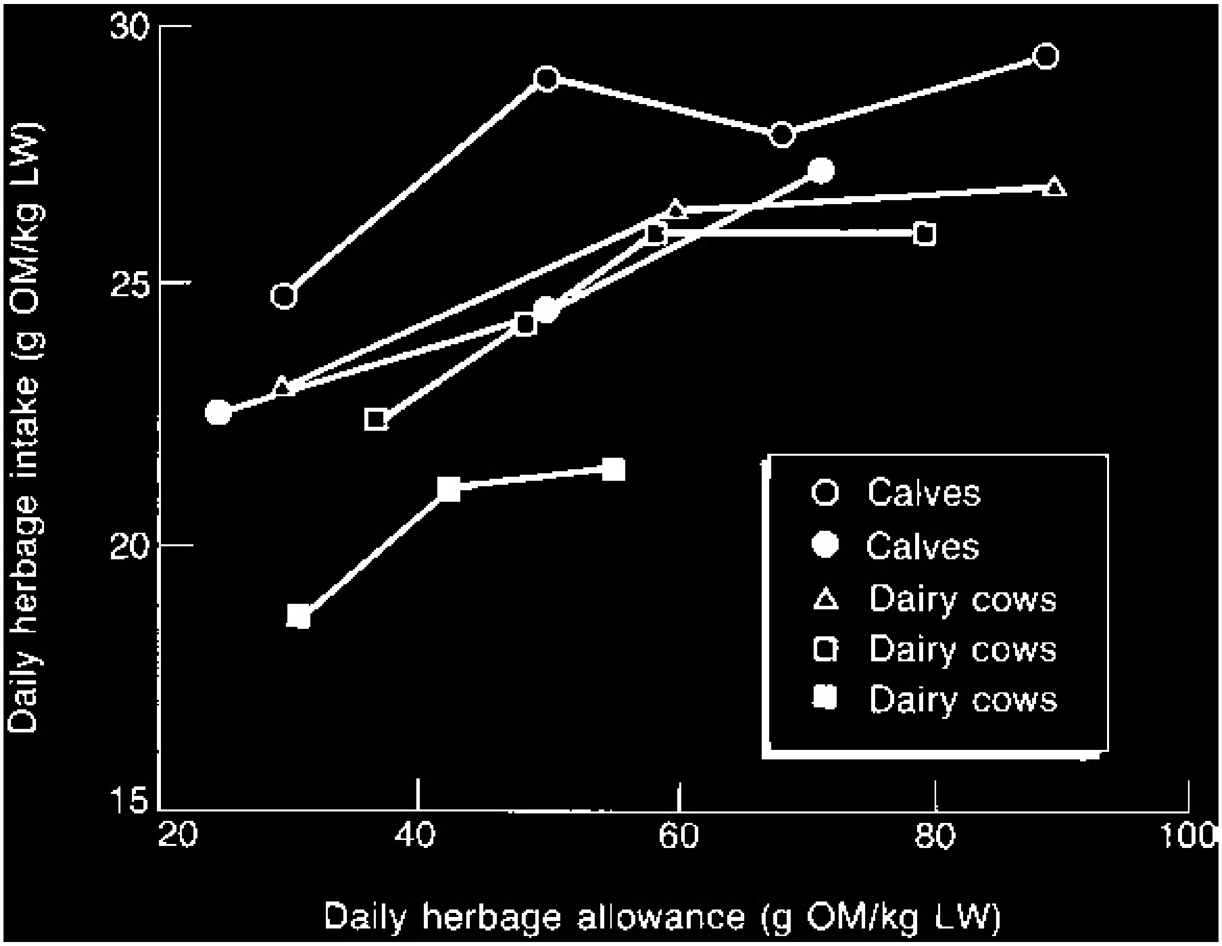
Unlike indoor feeding, grazing animals select what they

may contain up to 40 per cent of its dry matter in the

eat to a considerable extent, particularly when the



Maximum intake
10% reduction
50% reduction
Herbage intake (g OM/kg LW per day)
Herbage allowance (g OM/kg LW per day)
0
10
20
30
40
40
80
120
160
200



Daily herbage intake (g OM/kg LW)
30
25
20
15
20
40
60
80
100
Daily herbage allowance (g OM/kg LW)
Calves
Calves
Dairy cows
Dairy cows
Dairy cows

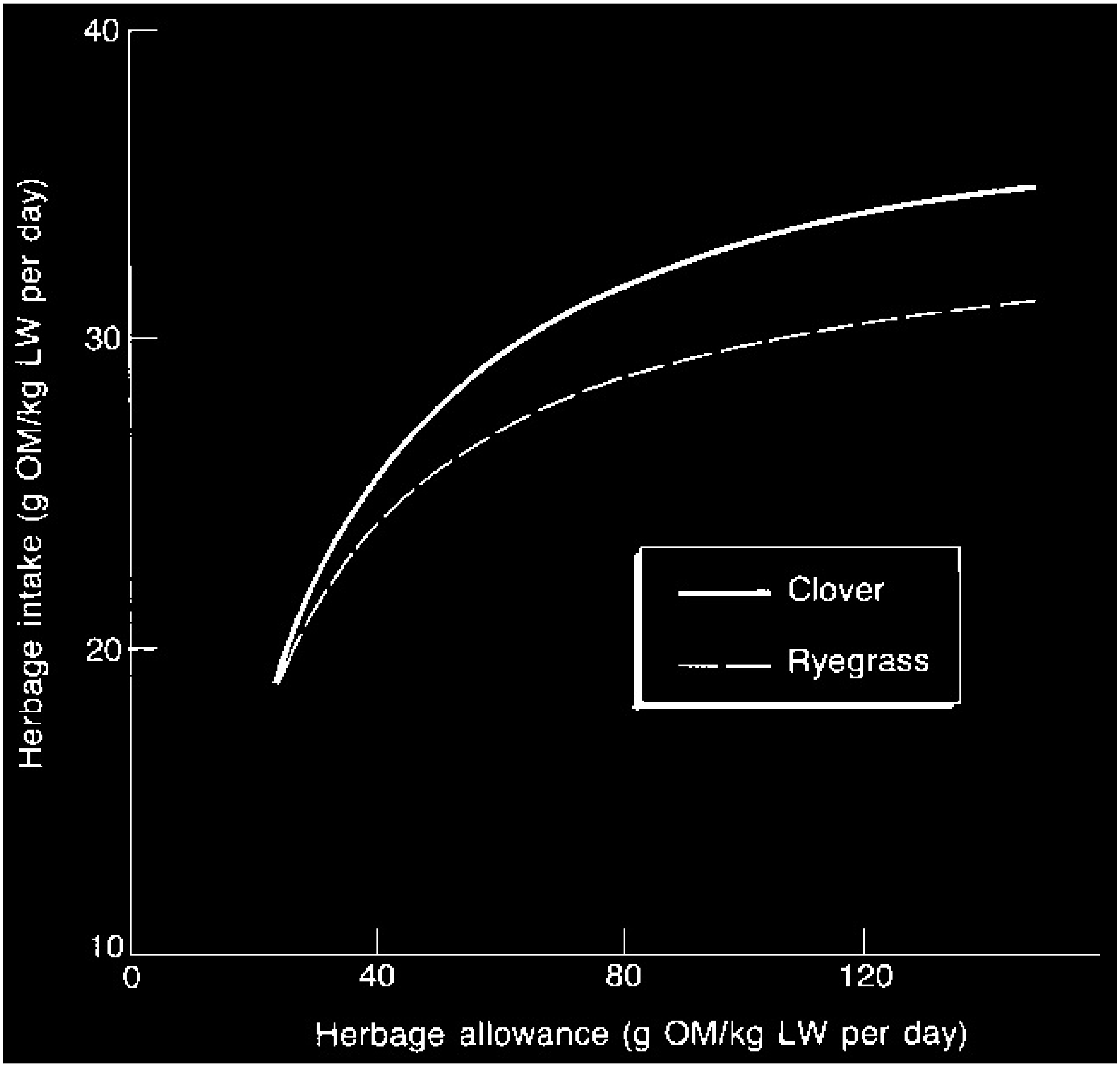


Fig. 9.7

Relationship between daily herbage allowance and

herbage intake in grazing lambs. Source: Hodgson (1975),

reproduced with permission of the British Grassland Society.

Fig. 9.9

Herbage intake of lambs grazing perennial ryegrass

and red clover. Source: Gibb & Treacher (1978), reproduced with permission of Cambridge University Press.

be expressed per kilogramme liveweight rather than

per hectare. It follows that stocking rate, a commonly

used but empirical and inflexible way of describing

herbage allowance, should not be expressed as num-

ber of animals per hectare, but as kilogrammes of

liveweight per hectare (see section on feeding manage-

ment, p. 118).

The relationship between herbage allowance and

intake holds for animals in different physiological

states, and for legumes as well as grasses (Fig. 9.9).

Studies of grazing behaviour and herbage intake by

animals grazed on adjacent monocultures of grass and

clover demonstrated that the grazing bovine has a

Fig. 9.8

Relationship between daily herbage allowance and

strong preference for clover. Clover comprised 70% of

herbage intake in cattle. (Data from different studies.) Source: total dry matter intake, and this preference was greater

Hodgson (1975), reproduced with permission of the British earlier in the day than during evening grazing, sug-

Grassland Society.

gesting that some discomfort may have been induced

following large meals of clover which the animal

herbage on offer is heterogeneous and is offered in

attempted to attenuate by preferentially eating grass in

excess of consumption. Thus a measure of the digestibil-

subsequent grazing meals.

ity of the herbage on offer is of little use as an indica-

tor of intake, since the animals are usually able to select

Probable levels of intake

material of higher digestibility than the average of that

on offer.

Estimated levels of voluntary dry matter intake for

Herbage intake under grazing is predominantly

growing and lactating cattle are shown in Tables 9.2 and

influenced by the amount on offer. To achieve

9.3. The relative intake of cows given the same diet

maximum intake, the amount on offer should exceed

throughout lactation, expressed as a percentage of the

that actually consumed by three to four times (Figs 9.7

mean for the whole lactation, is shown in Table 9.4. The

and 9.8).

important feature in Table 9.4 is the relatively low

Intake is usually expressed relative to liveweight, and

intake in the first month of lactation, when the demand

it follows that the amount of herbage on offer should

for nutrients for milk production is at its highest, and

Table 9.2

Estimated feed intake of growing cattle (kg DM/day). Reproduced from Allen (2001) with permission of Chalcombe Publications.

Well-preserved

Poorly-preserved

Big bale

Maize

Hay

Barley

Concentrate

grass silage

grass silage

silage

silage

straw

Metabolizable

11.0

10.0

10.5

11.0

9.0

6.5

12.5

energy

(MJ/kg DM)

Liveweight

Forage intake (kg DM/day)

(kg)

200

4.3

3.6

3.9

4.5

3.6

2.4

6.0

300

5.8

4.8

5.2

6.1

4.8

3.2

8.0

400

7.2

6.0

6.5

7.6

6.0

4.0

9.0

500

8.5

7.1

7.7

9.0

7.1

4.8

9.5

600

9.7

8.1

8.8

10.3

8.1

5.5

10.0

Reduction of forage DM intake/kg concentrate DM fed

0.5

0.4

0.5

0.6

0.3

0.2

–

Table 9.3

Probable dry matter intake of cows in mid and late lactation (kg/day). From Ministry of Agriculture, Fisheries and Food (MAFF, 1984).

Liveweight

Milk yield (*Y*) (kg/day)

(*W*) (kg)

5

10

15

20

25

30

35

40

350

9.3

9.8

10.3

10.8

11.3

11.8

400

10.5

11.0

11.5

12.0

12.5

13.0

450

11.8

12.3

12.8

13.3

13.8

14.3

14.8

500

13.0

13.5

14.0

14.5

15.0

15.5

16.0

550

14.3

14.8

15.3

15.8

16.3

16.8

17.3

17.8

600

15.5

16.0

16.5

17.0

17.5

18.0

18.5

19.0

650

16.8

17.3

17.8

18.3

18.8

19.3

19.8

20.3

700

18.0

18.5

19.0

19.5

20.0

20.5

21.0

21.5

Note: In the first 6 weeks of lactation, reduce these values by 2–3 kg DMI/day.

Based on DMI (kg/day) = 0.025 W + 0.1 Y.

the consequent deficiency in intake of nutrients which

Table 9.4

Relative intake of dairy cows fed on the same diet

results in the mobilization of nutrients from body

throughout lactation (daily intake per cent of mean intake for tissues.

complete lactation). From ARC (1980), reproduced with permis-

sion of CABI International.

Energy requirements

Month

Relative

Month

Relative

intake

intake

Requirements and allowances

1

81

6

108

The notion of requirements takes no account of the

2

98

7

101

variation between animals when kept in groups. Hence,

3

107

8

99

if a group is given enough feed to meet the mean

4

108

9

97

requirement for a given performance, a proportion of

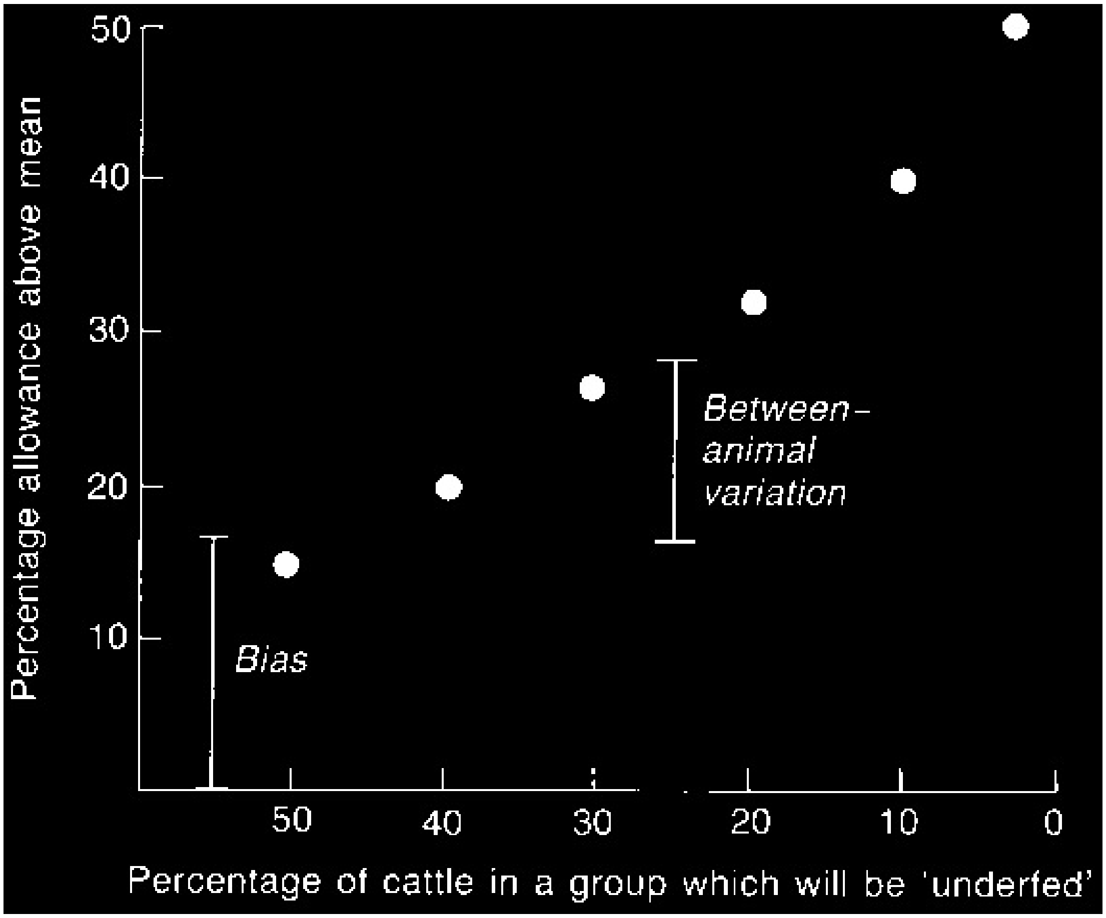
5

109

10

93

the group will be underfed and a proportion will be



Percentage allowance above mean
50
40
30
20
10
Between-
animal
variation
Bias
50
40
30
20
10
0
Percentage of cattle in a group which will be 'underfed'

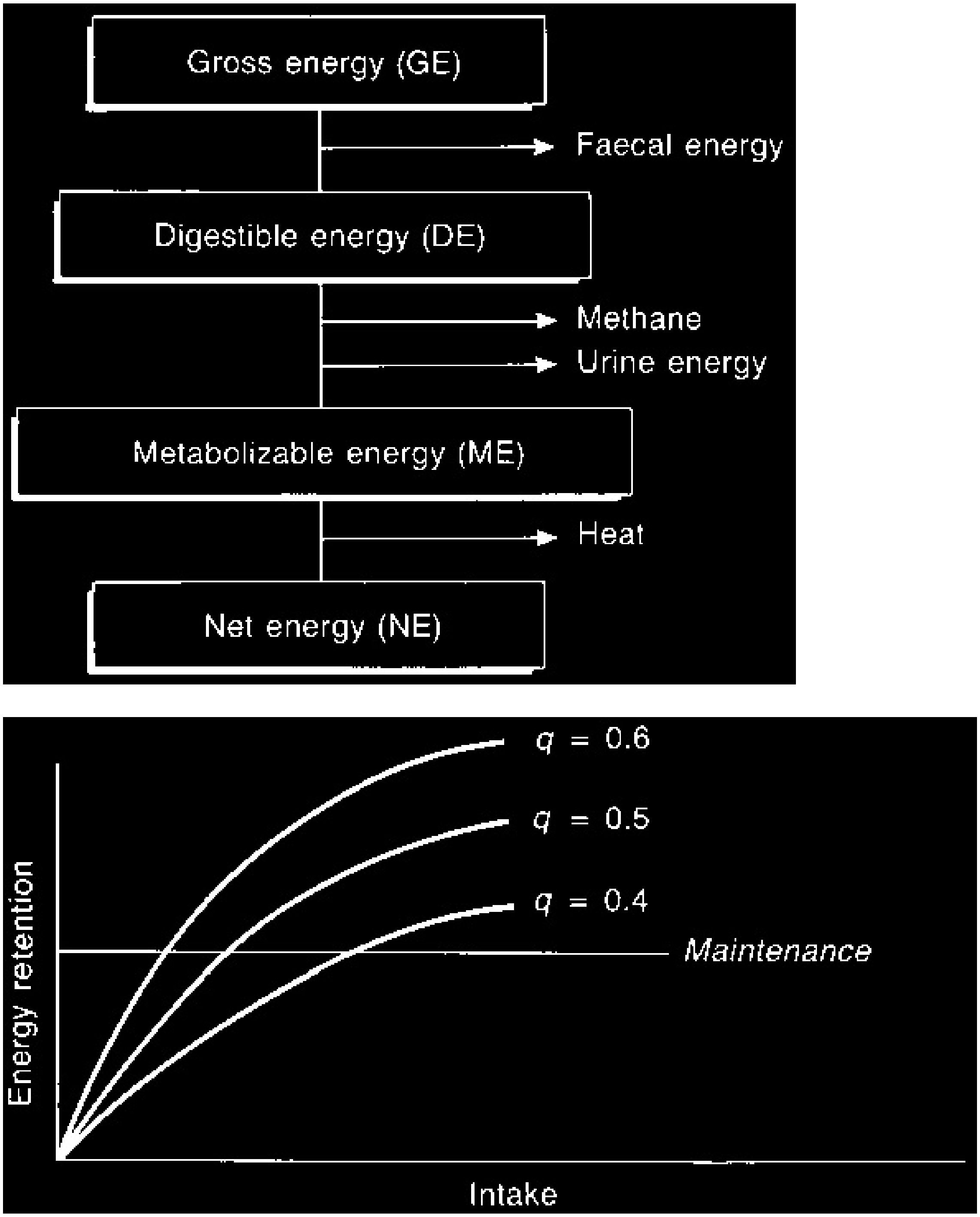


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Fig. 9.11

Partition of energy.

Fig. 9.10

Estimated allowances above mean requirements

(ARC, 1980) required to meet the ME needs of a defined pro-

portion of beef cattle in a group. Additional allowance due to bias in the estimate of requirements is shown separately from that

due to estimated between-animal variation. Source: *Energy*

Group Report (1988) Inter-Departmental Working Party.

overfed. Since underfeeding is considered to be the

more serious failure of the system, allowances are made

so that only a small proportion of the group remains

Fig. 9.12

Efficiency of use of ME for maintenance (k m) is rela-

underfed. If, as is the case with beef cattle, the metab-

tively high at 0.7. At twice the maintenance energy intake

(common level for growing animals) efficiency of use of ME for olizable energy system of assessing requirement overgrowth (k

predicts performance, an additional increment (15 per

g) = 0.3 to 0.5 for diets ranging from q = 0.4 to q = 0.6; k g declines further at higher levels of energy intake and correc-cent) is added on to account for this inaccuracy. The

tion must be made for the curvilinear decline.

result (Fig. 9.10) is that allowances may exceed require-

ments by some 30 per cent. ‘Requirements’ in practical feeding systems include a safety margin, although

in most cases this margin is only 5 per cent and is

lowest for feeds of low digestibility, such as straws, and

arbitrary.

highest for concentrates.

Partition of feed energy

Efficiency of use of metabolizable energy

The proportion of the gross energy (GE) of a feed that

The proportion of ME used for maintenance and pro-

is absorbed by the animal depends on its digestibility.

ductive functions, such as growth or lactation, depends

The amount remaining for metabolism (metabolizable

on the efficiency with which it is utilized by the animal

energy, ME) is the digested energy less energy lost as

(*k*). This depends on *q*, the level of feeding above main-methane or in urine. Further heat losses occur as a

tenance and on the productive purpose for which the

result of metabolism and the remaining energy (the

energy is to be used. Thus for growing cattle, *k* for

net energy) is that which is available to the animal for

maintenance (*k* m) varies as shown in Fig. 9.12.

maintenance of body weight, for weight gain or for milk

production. The partitioning is shown diagrammatically

Energy requirements of growing cattle

in Fig. 9.11.

In calculating energy requirements, the term ‘metab-

For growing cattle, a variable net energy system has

olizability’ (*q*) is used. This is an expression of ME/GE, been adopted to take account of the fact that *k* m varies where GE is usually about 18.4 MJ/kg dry matter (DM)

with *q*. The system involves assessing the animal pro-

for conventional feeds. The greater the work of diges-

duction level (APL), which depends on the weight of

tion, the higher the heat lost as a result of this work and

the animal and the desired level of weight gain, the net

the lower the *q* value of a feed. Thus *q* is generally energy allowance for the particular animal and level of

Table 9.5

Net energy allowances for maintenance and produc-

Table 9.7

Net energy values of feeds for maintenance and

tion NEmp in growing beef cattle (MJ/day). From MAFF (1975).

production in growing beef cattle. From MAFF (1975).

Liveweight

Liveweight gain (kg/day)

APL

Energy concentration in feed (MJ ME/kg DM)

(kg)

0.25

0.50

0.75

1.00

1.25

1.50

8

9

10

11

12

13

14

100

14.7

17.4

20.7

24.6

Net energy value (NE/kg DM)

200

21.6

25.0

29.0

33.9

39.9

300

28.6

32.6

37.3

43.1

50.2

1.00

5.8

6.5

7.2

7.9

8.6

9.4

10.1

400

35.5

40.1

45.6

52.3

65.8

77.0

1.10

5.2

6.0

6.8

7.6

8.3

9.1

9.9

500

42.4

47.7

53.9

61.5

70.9

82.9

1.15

5.1

5.8

6.6

7.4

8.2

9.0

9.8

1.20

4.9

5.7

6.5

7.3

8.1

8.9

9.8

1.30

4.6

5.4

6.3

7.1

7.9

8.8

9.7

1.40

4.4

5.2

6.1

6.9

7.9

8.8

9.7

Table 9.6

Values for animal production level (APL) in growing

1.50

4.2

5.1

5.9

6.8

7.7

8.6

9.5

beef cattle. From MAFF (1975).

1.75

3.9

4.8

5.6

6.5

7.4

8.4

9.3

2.00

3.8

4.6

5.4

6.3

7.3

8.2

9.2

Liveweight

Liveweight gain (kg/day)

2.25

3.6

4.4

5.3

6.2

7.1

8.1

9.1

(kg)

APL

0.25

0.50

0.75

1.00

1.25

1.50

Table 9.8

Example of feed requirements for a 300 kg steer

growing at 0.75 kg/day on silage (ME 10) and barley (ME 13).

100

1.19

1.40

1.66

1.98

200

1.15

1.33

1.54

1.79

2.11

1

Dry matter intake (DMI) (simplified), 0.02 *W* = 6 kg/day 300

1.13

1.29

1.47

1.70

1.97

2.33

2

Net energy for M + LWG (NEmp) (from Table 9.5),

400

1.12

1.26

1.43

1.64

1.90

2.22

37.3 MJ/day

500

1.11

1.25

1.41

1.60

1.84

2.15

3

Animal production level (from Tables 9.6), 1.46

NE + NE

4

Net energy values of feeds (from

m

p or

MEmp

gain, and the net energy value of a feed, which depends

Table 9.7)

on its ME content and the particular APL. The relevant

Silage ME 10 = 5.9 MJ/kg

Barley ME 13 = 8.6 MJ/kg

information is shown in Tables 9.5, 9.6 and 9.7. For two

5

Energy concentration in ration,

ingredient rations, a Pearson square is used to solve the

37 3

.

simultaneous equations to derive the amount of each

NE

DMI =

= 6 2

. MJ kg

mp

6

feed required in the diet (see example in Table 9.8).

6

Pearson Square to calculate ration:

Barley 8.6

0.3

0 3

. 2

/ 7

. ¥ 6 = 0 6

. 7 kg barley DM

Energy requirements of lactating cattle

6.2

As with growing cattle, the main determinant of the ME

Silage 5.9

2 4

.

2 4

. 2

/ 7

. ¥ 6 = 5 3

. 3 kg silage DM

requirement for maintenance is liveweight, but the ME

2 7

.

system for lactating cattle also recognizes that k_m varies **7**

Divide by DM, 0.67/0.85 = 0.8 kg fresh barley

with q (Fig. 9.13). A further important consideration is 5.33/0.25 = 21.3 kg fresh silage

the composition of the milk produced by the cow. The

higher the fat and protein concentration, the higher the

milk energy concentration and the greater the require-

ment for ME for milk production at any given dietary

The requirement for ME to support the growth of the

q value. However, in most practical feeding situations fetus during pregnancy increases progressively with

the q of diets for lactating dairy cows is unlikely to vary the duration of gestation. For the first half of gestation

significantly from about 0.7, because of the need to

the requirement is negligible, and in practice the energy

include high-energy forages and concentrates to meet

requirement of the fetus only assumes significance in

the total energy requirement. The values for ME

the last two months of pregnancy, i.e. in the dry period.

required for milk production in Table 9.9 relate to a q

The requirement for ME for pregnancy (Fig. 9.14)

value of 0.7 for simplicity. If the diet has a q value lower assumes a 40 kg calf at term. The requirement for

than 0.7, then the requirement should be increased

heavier calves, such as Charolais ¥ Holstein, is increased

accordingly (Table 9.9).

by direct linear scaling.

75

73

70

69

69

65

65

65

66

61

62

62

60

57

58

59

55

54

Ration quality

55

q = 0.50

50

52

q = 0.60

q = 0.70

Maintenance requirements (MJ ME/day)

45

40

Fig. 9.13

Metabolizable energy require-

500

550

600

650

700

ment for maintenance in lactating cattle.

Liveweight (kg)

Source: AFRC (1992).

Table 9.9

Metabolizable energy requirement (MJ/litre) for milk

world the energy expended in activity is considered

production. Reproduced from Chamberlain & Wilkinson, 1996

to be moderate and the above requirements relate to

with permission of Chalcombe Publications.

that situation. However, cattle are sometimes subjected

to extensive foraging under range and semi-arid

Milk fat (%

Milk protein (% per litre)

conditions, and account should be taken of the

per litre)

increased energy required for activity when assessing

3.00

3.20

3.40

3.60

requirements.

The total ME required is calculated as the sum of the

$q = 0.6$

3.00

4.39

4.47

4.54

4.62

above factors, but the overall efficiency of energy uti-

3.50

4.71

4.79

4.86

4.94

lization of the lactating animal declines with increasing

4.00

5.03

5.11

5.18

5.26

level of production, partly because of the faster rate of

4.50

5.35

5.43

5.50

5.58

passage of food through the digestive tract at higher

5.00

5.67

5.75

5.82

5.90

levels of voluntary intake and partly because the

processes of absorption and metabolism are less effi-

$q = 0.7$

cient at higher levels of output. The correction for ME

3.00

4.16

4.23

4.30

4.37

required depends on the animal production level

3.50

4.47

4.54

4.61

4.68

(APL), defined here as the total ME required divided

4.00

4.77

4.84

4.91

4.98

by the ME required for maintenance. Correction

4.50

5.07

5.14

5.21

5.28

factors for level of production are in Table 9.11.

5.00

5.38

5.45

5.52

5.59

q = gross energy/metabolizable energy.

Protein requirements

The net energy value of weight change is assumed to

Traditionally, protein requirements were expressed as

be relatively constant in the case of adult cattle, but the

digestible crude protein (DCP), that is, the proportion

impact of weight loss on the ME requirement varies

of the crude protein (CP or total nitrogen multiplied by

according to the presumed utilization of the body tissue

6.25) that is apparently digestible and therefore avail-

catabolized – milk production in early lactation and

able to the animal. It is now recognized that DCP is

growth of the fetus in the dry period. The ME value of

totally inadequate as a system for assessing the protein

weight change also varies with the q value of the diet requirements of ruminants.

(Table 9.10).

The concept of digestible crude protein ignored the

The energy requirement of the cow is also influenced

fact that a proportion of the digestible protein is by the amount of activity, especially walking, that the

degraded to ammonia by the action of the rumen micro-

animal undertakes daily. In most temperate areas of the

organisms. Some of this ammonia is synthesized into

50

45

44

40

35

30

25

22

20

15

11

10

5.5

Metabolizable energy requirement (MJ/day)

5

2.8

0.3

0.7

1.4

0

0

5

10

15

20

25

30

35

40

Fig. 9.14

Metabolizable energy require-

Week of pregnancy

ment for pregnancy. Source: AFRC (1992).

Table 9.10

Metabolizable energy value (MJ ME) of weight

Table 9.11

Correction factors for metabolizable energy require-changes in dairy cows given diets of different qualities (*q*).

ment according to the animal production level (APL). Repro-

Reproduced from Chamberlain & Wilkinson, 1996 with permis-

duced from Chamberlain & Wilkinson, 1996 with permission of sion of Chalcombe Publications.

Chalcombe Publications.

Live weight change (kg/day)

APL

Correction factor

q

-1.00

-0.50

0.50

1.00

0.7

0.99

1.0

1.00

Lactating cows

2.0

1.02

0.5

-23.3

-11.6

19.4

38.8

3.0

1.04

0.6

-22.0

-11.0

18.3

36.7

4.0

1.05

0.7

-20.8

-10.4

17.4

34.7

5.0

1.07

Dry, pregnant cows

0.4

-24.8

-12.4

34.5

69.0

APL = total ME/MEmaint

0.5

-24.8

-12.4

27.7

55.4

the animal's requirement (Table 9.12). Most classes

q = gross energy/metabolizable energy.

of ruminant livestock can fulfil their total requirement

for metabolizable protein (MP) from the supply of

microbial protein in the rumen; the rest is absorbed into

microbial true protein (MTP) alone. The exception is

the bloodstream, converted to urea in the liver and

the high-yielding dairy cow, where supplementary

excreted in the urine.

digestible undegraded feed protein is required to meet

There are many situations where the animal’s

the animal’s total requirement for metabolizable

requirements can be met entirely by microbial protein.

protein (see below). In this situation, there may also be

However, in some situations, particularly with high-

a requirement for supplementary essential amino acids

yielding dairy cows, the animal requires more protein

such as methionine and lysine.

than that supplied by the microbial cells and it is nec-

Much of the dietary protein eaten by the animal is

essary to supply additional dietary protein to the abo-

degraded in the rumen to ammonia by the microbial

masum that has not been broken down *en route* through

population and it is possible to include non-protein

the rumen.

nitrogen, such as urea, in diets which are deficient in

degradable protein. Such deficiencies might arise in

situations where the dietary ingredients, such as straw

Microbial protein synthesis

or maize silage, are low in total protein, or where the

Microbial protein is of high value to the ruminant in

degradability of the feed protein is relatively low, as a

that its balance of essential amino acids is very close to

result of heat-treatment during processing.

Table 9.12

Amino acid composition of bacterial protein and

FME is therefore the total metabolizable energy

animal proteins (g amino acid/100 g protein). From Van Soest

minus the gross energy content of the lipids and (in the

(1994).

case of fermented feeds like silages) the content of fer-

mentation acids. The yield of microbial crude protein

Amino acid

Microbial

Milk

Beef

(MCP) per MJ of FME, known as Y, depends on the

protein

APL because at lower APL the outflow rate from the

rumen is reduced and at the lower outflow rate bacte-

Isoleucine

5.8

5.6

5.1

ria and protozoa die before passing out of the rumen

Leucine

8.0

10.2

8.0

Lysine

9.2

8.2

9.1

and are digested by other rumen microbes. Their

Methionine

2.5

2.9

2.7

protein is recycled to produce new microbial protein.

Cysteine

1.4

1.0

1.3

However, this process requires energy so additional

Phenylalanine

5.3

5.4

4.5

FME is utilized with no net increase in yield of

Tyrosine

4.9

4.5

3.8

microbial protein.

Threonine

5.7

5.0

4.6

The limit to the total yield of MCP is either the

Tryptophan

1.5

1.4

1.3

supply of ERDP (g per day) from the diet itself, in

Valine

5.8

7.4

5.3

which case MCP production equals the supply of

Arginine

5.3

4.0

6.7

ERDP. Or, when the limit to the total yield of MCP is

Histidine

2.1

3.0

3.7

FME, the total amount of MCP produced is equal to

Alanine

6.8

3.8

6.4

the yield of MCP per MJ of FME (Y, which ranges from

Aspartic acid

11.9

8.5

9.6

Glutamic acid

12.4

23.0

17.3

8 g MCP/MJ FME at an APL of 1.0 to 11.5 at an APL

Glycine

5.4

2.2

5.6

of 4.0) multiplied by the total supply of FME in MJ

Proline

3.6

9.4

5.1

per day. The *lesser* of the two values is taken as the Serine

4.7

5.9

4.5

production of MCP in the rumen.

It is unusual to find a situation where the two limit-

ing factors to the production of MCP – ERDP and FME

– are equal and where the calculation of MCP produc-

The production of microbial protein in the rumen

tion by the two methods gives the same result. For

depends on the supply of degradable protein and the

example, most grass silages contain an excess of ERDP

supply of fermentable metabolizable energy (FME).

and a deficit of FME, whilst maize silage has a deficit of

The supply of degradable protein depends on the feed

ERDP relative to FME. The skill in formulating diets

source and also on the time the feed spends in the

is to achieve the correct overall balance between the

rumen. Rumen outflow rate depends on the APL. The

total supply of ERDP, the total supply of FME (see Figs

APL is therefore higher for high-producing animals

9.16 and 9.17 for examples of the ERDP and FME con-

than for low-producing animals. Degraded protein is not tents of different feeds) and their respective rates of

used with complete efficiency for microbial protein syn-

digestion in the rumen.

thesis because some of the quickly degraded fraction is

Having calculated the production of MCP, this value

lost as ammonia through the rumen wall and is con-

is then reduced to take account of the fact that about

verted to urea in the liver. The proportion of quickly

0.75 of MCP is true protein and that it is absorbed into

degraded protein (QDP) which is lost from the rumen is

the blood with an efficiency of about 0.85 (Fig. 9.15).

presumed to be 0.2, so that only 0.8 of the QDP is avail-

Thus microbial true protein supply is only about 0.64 of

able to the rumen microbial population. All the slowly

the MCP produced.

degraded protein (SDP) is potentially available to the

micro-organisms and, together with 0.8 of the QDP, is

the *effective* rumen degradable protein (ERDP) and is

Metabolizable protein

the amount of protein (or nitrogen) available for micro-

bial growth and metabolism. However, the amount of

The digestion and metabolism of dietary protein are

ERDP which the microbial population can utilize

shown in simplified form in Fig. 9.15. Dietary crude

depends on the amount of energy available, known as

protein (CP) (Total N ¥ 6.25) contains true protein,

the fermentable metabolizable energy or FME. Some

polypeptides, peptides and non-protein nitrogenous

sources of energy in foods are considered to be of low

compounds (NPN) such as amino acids, amines, amides

value to the microbes, particularly those which yield low

and ammonia. Urea, recycled to the rumen in saliva, is

levels of ATP during their digestion in the rumen. Thus

produced in the liver from ammonia which is in excess

the energy in lipids and in silage acids is discounted, and

to that used by the microbial population of the rumen

the energy in undegraded protein should also be dis-

to synthesize microbial protein (see above). The amino

counted (but is not) in the calculation of FME.

acid content of microbial true protein is very constant,

CP

RDP

UDP

QDP

SDP

ADIN

0.80

1.00

0.90

ERDP

FME

Y

DUP

MCP

0.64

Faeces

MP

Fig. 9.15

The metabolizable protein

1.00

0.59

1.00

0.85

0.68

0.26

system. Reproduced from Chamberlain &

Wilkinson (1996) with permission of Chal-

NP

NP

NP

NP

NP

NP

Maintenance Weight gain

Weight Loss

Pregnancy

Lactation

Wool

combe Publications.

and similar to the amino acid composition of tissue

Table 9.13

Example of differences in the proportion of

protein (beef) and also of milk (Table 9.12).

degraded and undegraded soyabean meal protein according to

The degradable fraction, or ERDP, which yields

class of livestock. Reproduced from Orskov, 1998 with permis-

microbial protein, is only part of the total supply of

sion of Chalcombe Publications.

protein to the animal (Fig. 9.15). The protein which is

Dairy cows

Growing cattle

Suckler cows

not degraded in the rumen is termed undegraded

dietary protein, of which a proportion, insoluble in

ERDP

DUP

ERDP

DUP

ERDP

DUP

acid detergent (ADIP or ADIN ¥ 6.25), is indigestible.

The remainder is known as the digestible undegraded

0.50

0.50

0.65

0.35

0.85

0.15

protein or DUP.

The extent of degradation depends not only on the

ERDP = effective rumen degradable protein.

inherent characteristics of the protein source, but also

DUP = digestible undegraded protein.

on the time the material is exposed to degradation in

the rumen, i.e. on outflow rate from the rumen. Thus

the same protein may have quite different values when

The higher the APL, the faster the rate of passage of

given to different types of cattle (Table 9.13).

feed through the rumen. Thus MP supply depends not

The supply of MP to the animal has two components

only on the feed itself but also on the type of animal to

(Fig. 9.15): MTP derived from the growth of bacteria

which the feed is being given. The requirement of the

and protozoa in the rumen (see the section on micro-

animal for MP depends on its level of productivity. The

bial protein above) and digested undegraded feed
major requirement for MP in adult female ruminants is
protein (DUP), which has passed intact through the
for the production of milk during lactation (see below),
rumen and has been digested in the abomasum together
but the animal also requires MP for maintenance and
with the microbial protein. The rate of production of
growth, including the growth of the fetus during preg-
microbial protein in the rumen depends on the supply
nancy, and for the production of wool. MP is released
of ERDP, the supply of FME to the rumen microbes
from the breakdown of muscle tissue during periods of
and the speed of flow of digesta out of the rumen. The
body weight loss. MP is presumed to be utilized with
supply of undegraded feed protein is also affected by
variable efficiencies (net protein, NP) depending on its
the speed of flow of digesta through the rumen (Table
use (Fig. 9.15), with an efficiency of 1.0 for maintenance
9.13). The speed with which feed particles pass through
and with variable efficiencies for pregnancy (0.85), lac-
the rumen depends mainly on the APL of the animal.

tation (0.68), growth (0.6) and wool (0.26).

Table 9.14

Metabolizable protein (MP) requirement for main-

Table 9.16

Metabolizable protein (MP) requirement for preg-

tenance. Reproduced from Chamberlain & Wilkinson, 1996 with nancy. Reproduced from Chamberlain & Wilkinson, 1996 with

permission of Chalcombe Publications.

permission of Chalcombe Publications.

Live weight (kg)

MP requirement for

Week of gestation

MP requirement (g/day)

maintenance (g/day)

5

1

400

216

10

3

450

236

15

8

500

256

20

17

550

275

25

34

600

293

30

64

650

312

35

114

700

329

40

191

750

347

Table 9.17

Metabolizable protein (MP) allowances for weight

change in dairy cows. Reproduced from Chamberlain & WilkinTable 9.15

Metabolizable protein (MP) requirement for milk

son, 1996 with permission of Chalcombe Publications.

production. Reproduced from Chamberlain & Wilkinson, 1996

with permission of Chalcombe Publications.

Live weight change (kg/day)

MP requirement (g/day)

Milk yield

Milk protein (% per litre)

-1.0

-131

(litres/day)

-0.5

-66

3.00

3.20

3.40

3.60

0

0

0.5

122

MP requirement (g/day)

1.0

245

10

427

456

484

513

20

855

912

969

1026

30

1282

1368

1453

1539

The protein requirement of the bovine animal is

40

1710

1823

1937

2051

generally considered in terms of the main activities of

50

2137

2279

2422

2564

the body – the maintenance of essential functions, lacta-

tion, pregnancy and weight change. The requirements

of cattle of different liveweights for metabolizable

protein for maintenance are shown in Table 9.14.

The requirement for MP for lactation is quantita-

Requirements for metabolizable protein

tively the most important and varies with milk yield and

The requirement of the animal for MP depends on the

also, though to a much lesser degree, with the protein

amount of protein produced in tissue growth or in milk.

concentration in the milk. Values for the requirement

The young calf has a high rate of lean tissue growth

for MP for milk production are shown in Table 9.15.

relative to its feed intake. Hence the concentration of

The requirement for MP to support fetal growth in

protein in its diet needs to be relatively high. The

pregnancy is very low in the early stages and only

cow yields more milk and eats less feed in early lactation

becomes of significance in the final two months of gesta-

than in mid-lactation. At this time the energy output in

tion (Table 9.16). Allowances for MP for weight loss and

the milk is higher than that consumed in the feed

the requirement for weight gain are shown in Table 9.17.

because the cow is using stored reserves, mostly body

The total requirement for MP is calculated as the sum

fat. However, fat from body reserves yields no metabo-
of the requirements for the appropriate bodily func-
lizable protein and as a result she requires more protein
tions. Thus, for a dairy cow weighing 600 kg liveweight,
per unit of feed in early lactation than later on.
yielding 20 litres of milk of 3.2% protein, in her
If sufficient energy is provided to maintain the
fifteenth week of pregnancy and gaining 0.5 kg
animal, then microbial protein produced from ERDP is
liveweight/day the total requirement is 293 g for main-
likely to be sufficient to meet the maintenance require-
tenance (Table 9.14) + 912 g for milk production (Table
ment for MP. On the other hand, if the animal is
9.15) + 8 g for pregnancy (Table 9.16) + 122 g for weight
restricted to a submaintenance level of feeding, then it
gain (Table 9.17) = 1335 g MP/day.
will lose not only body fat but also protein from muscle
In some situations the total protein requirement is
tissue.
expressed as a recommended concentration of crude

Table 9.18

Recommended concentrations of crude protein in diets for cattle.

Dairy cows

Beef suckler cows

Growing beef cattle

Milk yield

Dietary

Milk yield

Dietary

Liveweight

Dietary crude

(litres/day)

crude protein

(litres/day)

crude protein

(kg)

protein (g/kg

(g/kg dry

(g/kg dry

dry matter)

matter)

matter)

ME of total diet

(MJ/kg DM)

11.0

12.0

0

135–145

0

120

100

180

210

10

145–155

5

150

200

140

150

20

155–165

10

150

>200

130

140

30

165–175

40

175–180

50

180–190

protein in the total diet dry matter. This may appear to

Table 9.19

Classification of feeds. From MAFF (1986b) and

be an oversimplification, but where the degradability

Lonsdale (1989).

characteristics of the protein in some dietary ingredi-

Mainly cellulosic

Mainly non-cellulosic

ents are not known, or where there is uncertainty about

(NDF > 500 g/kg DM)

(NDF < 500 g/kg DM)

the actual animal production level, then diets should be

formulated according to the recommended concentra-

Straw

Kale

tions of crude protein in Table 9.18.

Hay

Very young grass

Tests of the MP system with dairy cows have revealed

Grass (except very young

Maize silage

that the system works reasonably well at low to medium

grass)

Fodder beet, root crops

levels of milk yield (20 to 30 litres/day), but that at higher Silage (except maize)

Cereal grains

levels of production the MP required is underestimated.

Brewers' grains

Molasses

This implies that the efficiency of utilization of MP for

Malt distillers' draff

Molassed sugar beet pulp

milk production is not constant at 0.68 (see section on

Pectin-extracted fruit

Maize gluten feed

metabolizable protein), but that it decreases at increased

Coffee grounds

Soyabean meal

Unmolassed sugar beet pulp

Fat

levels of output. The values for MP requirement for lac-

Bran

Cottonseed cake

tation in Table 9.15 have been adjusted upwards to take

Wheat feed

Distillers' dark grains

account of the decrease in efficiency of utilization of MP

Citrus pulp

for milk production above a milk yield of 25 litres/day.

Legume seeds

Other systems of assessing protein supply and require-

ments, for example the French PDI system, also take account of the relatively greater requirement for MP of

different types of bacteria and at different rates (see

the high-yielding cow.

section on fermentation in the rumen, p. 96). Cellulosic

feeds are fermented at a slower rate, occupy more

Composition of feeds

space in the rumen and are usually eaten in smaller

quantities (i.e. at a slower rate) than non-cellulosic

feeds.

Cellulosic and non-cellulosic feeds

When formulating diets it is useful to recognize the

Feeds for cattle are best described in terms of the

different fermentation patterns of the two types of feed

major components that undergo fermentation in the

and their different rates of intake by the animal. With

rumen. In other words, the conventional division into

productive cattle it is important to avoid too much of

concentrates and roughages is only a crude way of

one type, or intake may be depressed – by acidosis if

distinguishing between feeds that contain mainly

too much non-cellulosic material is eaten, or by a slow non-cellulosic (starch, sugar and protein) or cellulosic

fermentation in the rumen and slow outflow rate if too

(plant cell wall) material.

much cellulosic material is eaten.

The division into cellulosic and non-cellulosic feeds

Feeds are classified into those which are mainly cel-

is relevant because the two fractions are fermented by

lulosic and those which are mainly non-cellulosic, as

Table 9.20

Classification of raw materials according to their energy and protein contents. The degradability of the protein is also indicated*. Reproduced from Lonsdale (1989) with permission of Chalcombe Publications.

Protein

Metabolizable energy content (MJ/kg DM)

content

(g/kg DM)

High > **12.0**

Medium 9.0–12.0

Low < **9.0**

High

Maize gluten meal (prairie meal) (B)

Rapeseed meal (B)

Cotton cake (undec.) (B)

> **200**

Groundnut cake (A)

Sunflower seed meal (B)

Sunflower seed meal (undec.) (B)

Soyabean meal (B)

Cottonseed cake (B)

Safflower meal expeller (A)

Sesame meal (B)

Safflower meal (A)

Soya beans (whole processed) (C)

Malt culms (B)

Condensed corn steep liquor

Brussels sprout packhouse waste (A)

Lupins (sweet) (B)

Malt residual pellets (B)

Pot ale syrup (A)

Brewers’ grains (B)

Linseed meal (B)

Palm kernel meal (extr.) (B)

Spent wash syrups (A)

US corn distillers’ dark grains (C)

Beans (field) (C)

Wheat distillers’ dark grains (C)

Malt distillers’ dark grains (C)

Peas (B)

Delactosed whey syrup (A)

Copra expeller (B)

Maize gluten feed (B)

Medium

Maize germ meal (B)

Wheat bran (B)

Rice bran (C)

120–200

Whey (A)

Dried forages (grass, lucerne) (B)

Shea nut meal (D)

Triticale (A)

Wheatfeed (A)

Rape meal (D)

Wheat (A)

Low

Barley (A)

Pectin extracted fruit (B)

Oatfeed (C)

< **120**

Oats (A)

Apple pomace (B)

Sugar beet pulp (molassed, dried,

pressed, ensiled) (B)

Potatoes (A)

Maize grain (B)

Carrots (A)

Citrus pulp (B)

Molasses (A)

Manioc (B)

* Degradability: category A = 0.71–0.90, B = 0.51–0.70, C = 0.31–0.50, D = <0.31.

shown in Table 9.19. Some forage feeds, which would at

first sight be considered cellulosic, are not. High-quality

grass, for example, typically contains less than half of

The two most important nutrients are energy and pro-

the DM as cell wall or neutral detergent fibre (NDF)

tein. Other nutrients, particularly minerals, can limit

(MAFF, 1992); maize silage also contains less cell

efficiency of feed use, but in practice if a wide range of

wall than cell contents, because of its high grain content;

feeds is included in the diet the risk of mineral imbalance

typically 250 to 300 g of the DM of maize silage is starch.

is low. Most farmers add proprietary mineral supple-

Fodder beet contains 650 g sugar per kg DM, but it is

ments to the diets of their cattle. However, particular

contained within cell walls and is released in the rumen

deficiency situations do arise due to inadequate man-

for fermentation at a slower rate than, say, the sugar

agement, for example hypomagnesaemia (see Chapter

from molasses.

46).

150

Good grass

Good silage

100

Average silage

Poor silage

Average grass

Maize silage

Fodder beet

ERDP (g/kg DM)

50

Hay

Barley straw

Wheat straw

Fig. 9.16

Typical concentrations of ERDP

and FME in selected forage crops. Repro-

duced from Chamberlain & Wilkinson

0

4

5

6

7

8

9

10

11

12

(1996) with permission of Chalcombe

FME (MJ/kg DM)

Publications.

300

Rapeseed

Fishmeal

250

Soyabean

200

150

Maize gluten

ERDP (g/kg DM)

Brewers grains

Wheat

100

Barley

Palm kernel

Molasses

50

Fig. 9.17

Typical concentrations of ERDP

and FME in selected concentrates. Repro-

duced from Chamberlain & Wilkinson

0

6

8

10

12

14

(1996) with permission of Chalcombe

FME (MJ/kg DM)

Publications.

A simple classification of feeds is one which takes into

ERDP relative to FME, whilst fishmeal, rapeseed meal,

account the concentrations of ME, FME, ERDP and

soyabean meal and maize gluten feed typically contain

DUP (see sections above for definitions of terms), as in

an excess of ERDP relative to their concentrations of

Table 9.20. A fuller description of the composition of

FME.

feeds is given in the UK Ministry of Agriculture, Fish-

eries and Food's book *Feed Composition* (MAFF, 1992).

Physical form

An alternative way of considering feed sources is in

terms of the balance between ERDP and FME, shown

There are three easily recognizable categories for the

in Figs 9.16 and 9.17 for selected forages and concen-

physical form of feeds: (i) liquids, (ii) moist solids and

trates, respectively. Maize silage, fodder beet, hay, straw,

(iii) dry solids. Examples of each category are shown in

molasses and cereal grains are typically deficient in

Table 9.21.

Table 9.21

Examples of the physical forms of raw material feeds. Reproduced from Stark & Lonsdale (1989) with permission of Chalcombe Publications.

Liquid

Moist solid

Dry solid

Condensed corn steep liquor

Apple pomace

Bran (wheat and rice)

Delactosed whey syrup

Brewers’ grains

Cereal grains

Fresh whey

Brussels sprout

Citrus pulp

Molasses

packhouse waste

Distillers’ dark grains

Pot ale syrup

Carrot rejects

Dried grass and lucerne

Maize gluten feed*

Legume seeds

Pectin-extracted fruit

Maize germ meal

Potatoes

Maize gluten feed*

Sugar beet pulp*

Maize gluten meal

Malt culms

Malt residual pellets

Oatfeed

Oilseed residues

Sugar beet pulp*

Wheatfeed

Whole oilseeds

* Available as either a moist or dry solid.

Liquids range from very low DM materials such as

temperatures, low levels of acidity (pH 6 to 8), oxygen

whey, which has handling characteristics similar to

and water. Hence preservation may be achieved by

water, to viscous liquids such as molasses, which has a

cooling (preferably freezing), by acidification, by exclu-

typical DM content of 750 g/kg fresh weight. With the

sion or removal of oxygen, or by drying.

exception of whey, most liquid feeds have been con-

densed prior to shipment, in an attempt to reduce

haulage costs.

Drying

Moist solids comprise those which contain fer-

Drying is the most effective form of feed preservation.

mentable sugars (e.g. fresh grass, molassed sugar beet

It is also the most costly and therefore tends to be used

pulp) and are usually stored as silage (see section on

with the more valuable feeds (e.g. cereals) and with

feed preservation, see below), and those which are low

feeds that are prone to deterioration (e.g. citrus pulp).

in fermentable components (e.g. apple pomace), and

The DM content of cereals is normally increased by

which benefit from the addition of a preservative.

drying to 850 to 870 g/kg prior to storage. Hay is dried

Dry solids are a common form of feed and include

in the field to about 800 g DM/kg fresh weight, unless it

cereal grains and by-products from the flour milling

is to be dried artificially in the barn, when it may be har-

industry, hay, straw and residues from oil seed extrac-

vested in a moist state at between 650 and 750 g DM/kg.

tion. The DM content of dry solids is usually in the

Drying in the barn proceeds until the safe DM content, range 830 to 930 g/kg fresh weight. Higher moisture

more than 800 g/kg, has been reached and the crop

contents increase the risk of spoilage during storage

shows little sign of heating and moulding.

and for this reason most manufacturers of dry feeds aim

to approach 900 g DM/kg fresh weight if possible. Hay

is usually stored at an initial DM content of around

Ensiling

800 g/kg, but final DM content is typically 850 g/kg

fresh weight.

The process of ensilage involves the fermentation of

plant water-soluble carbohydrate (WSC) monomers

(simple sugars, mainly fructose and glucose) to organic

Feed preservation

acids, principally lactic acid. The acidity thus produced

effectively ‘pickles’ the crop or feed in a stable state in

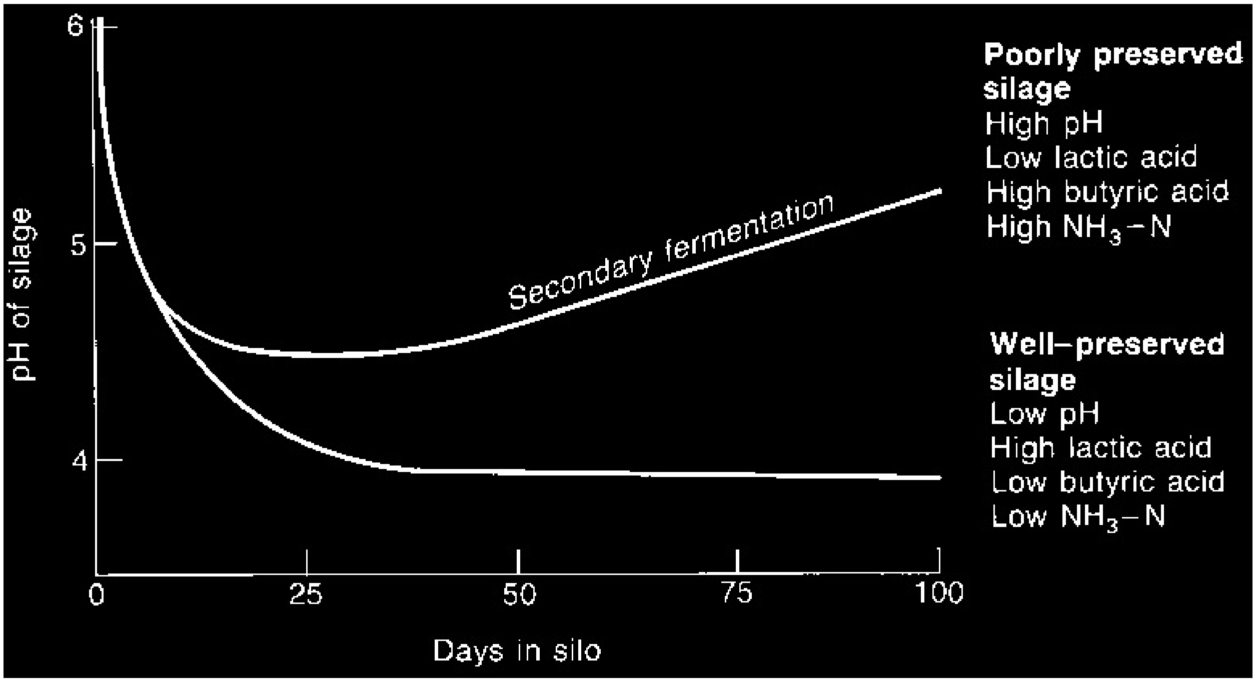
The principle of preservation is to prevent the devel-

the absence of air.

opment of spoilage organisms such as the putrefying

Fermentation is an anaerobic process. The crop must

bacteria and moulds. These organisms prefer warm be completely sealed from the air to facilitate the growth



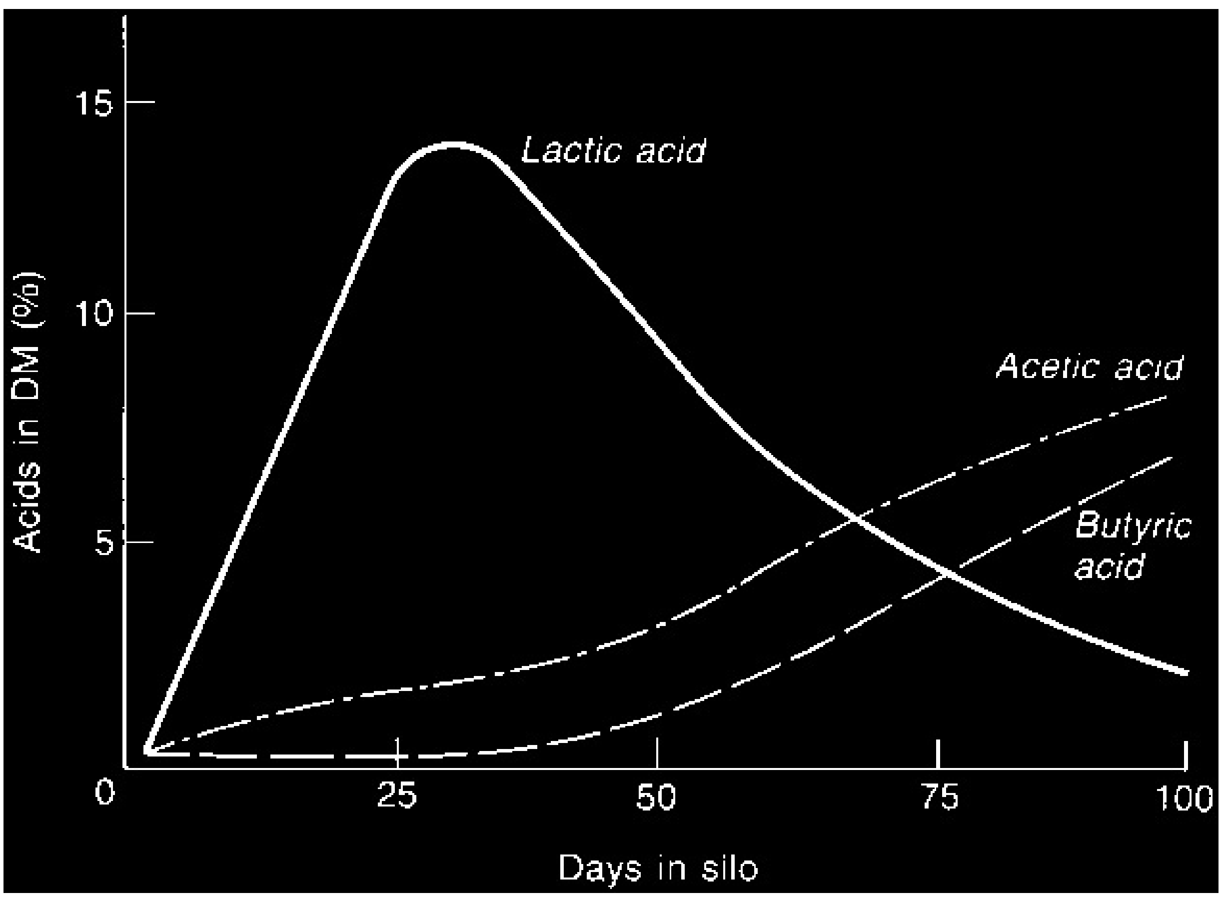


Fig. 9.18

Patterns of fermentation and changes
in the pH value of silage as a result of secondary
fermentation.

of the desirable anaerobic bacteria that are present on the crop in the field in relatively small numbers. As much air as possible should be removed from the crop at the time of ensiling, so that residual oxygen is exhausted as rapidly as possible. This is achieved by first chopping the crop as it is harvested from the field, by consolidating it once the crop is in the silo and finally by sealing it completely using a plastic sheet.

Primary and secondary fermentations

It is important to distinguish between primary and secondary fermentations, and to recognize that both are quite distinct from the process of aerobic spoilage that

Fig. 9.19

Typical changes in the content of fermentation acids

occurs on exposure of silage to the air at the time of

in silage as a result of secondary fermentation.

feed-out.

Primary fermentation essentially comprises the con-

version of sugars or WSC, mainly fructose and glucose,

to lactic and other acids as the result of the metabolism

of bacteria. This process can be rapid and completed in

nant product. Acidity increases as the conversion of

a few days.

sugars to acids continues.

Secondary fermentation, which sometimes follows

Primary fermentation proceeds until either the

the primary fermentation, involves the degradation of

supply of fermentable substrate is exhausted or the

lactic and other acids, with the formation of evil-

amount of free water (i.e. that not associated with

smelling acids like butyric acid. The process can also be

products of fermentation) is reduced to a sufficiently

accompanied by the complete degradation of nitroge-

low level to restrict bacterial activity. A stable low pH

nous compounds to ammonia. The main organisms

is reached. The silage contains lactic acid as the main

involved in secondary fermentation are the obligate fermentation acid and the amount of protein com-

anaerobic clostridial bacteria.

pletely degraded to ammonia is small (see Fig. 9.18).

At the point of entry to the silo the pH of the fresh

However, if the supply of sugar in the crop is low,

crop is usually about 6.0. The crop is still alive, but it is

or its resistance to acidification or buffering capacity is

consuming the products of photosynthesis (sugars) by

relatively high, secondary fermentation may occur

respiration and producing carbon dioxide, water and

during the storage period. In this situation the silage

heat. In addition, aerobic bacteria such as the Enter-

is unstable. Wet crops of low sugar content are par-

obacteriaceae (coliforms) consume sugars to produce

ticularly prone to secondary fermentation. Typical

acetic acid and degrade protein to ammonia.

changes in the content of fermentation acids in silage

As the supply of oxygen is exhausted, the primary

as a result of secondary fermentation are shown in

fermentation dominates, with lactic acid the predomi-

Fig. 9.19.

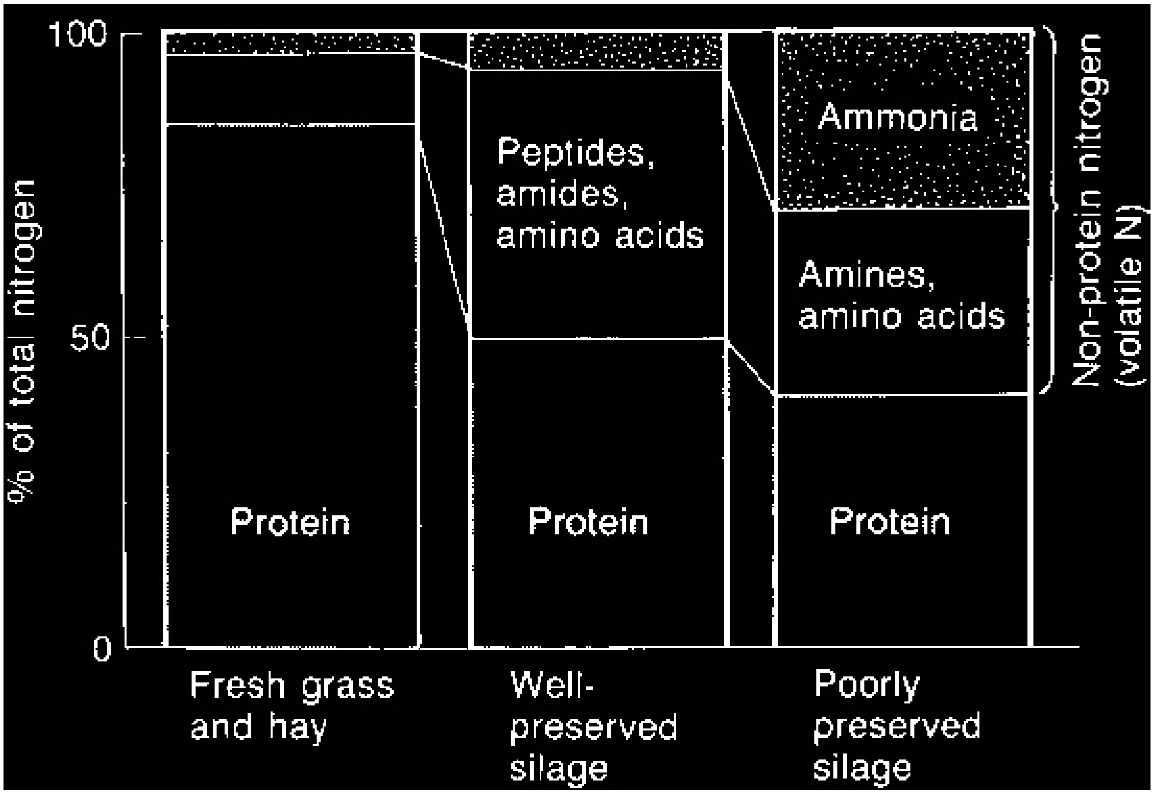


Table 9.22

Crops ranked in order of their ‘ensilability’. Repro-

Typical analytical composition of silage

duced from Wilkinson (1990) with permission of Chalcombe

Publications.

Typical values for the composition of grass and maize

silages made in bunker silos under European conditions

Good

Maize

are shown in Table 9.23. The most notable differences

Whole crop cereals

between grass and maize silage are in crude protein and

Italian and hybrid ryegrass

NDF, which are higher for grass than maize, and in

Perennial ryegrass

starch which is very low in grass silage. Poorly-

Brome grass

preserved grass silages normally contain elevated levels

Timothy/meadow fescue

of ash, fibre, acetic acid, butyric acid and ammonia–N,

Permanent pasture

whilst energy values are depressed compared to well-

Cocksfoot

preserved material. Amino acid–N is reduced as a pro-

Arable silage containing legumes

portion of the total non-protein nitrogen, indicating

Grass/clover

Red clover

greater degradation to amines, amides and ammonia.

Poor

Lucerne

Wilted grass silages generally undergo less extensive

fermentations and consequently have higher pH values

than wetter silages, residual (i.e. unfermented) WSC,

lower concentrations of fermentation acids and less

ammonia–N (Table 9.23).

Additives for silage

The main objective in applying an additive at the time

of harvest is to prevent the multiplication of clostridia.

The lactic acid bacteria are more tolerant of acid con-

ditions than are the clostridia, so traditionally their

growth has been inhibited by direct acidification of the

crop with an organic acid such as formic, or an inorganic

acid such as sulphuric. The former is relatively more

expensive, but it does have a specific antimicrobial

action against clostridia, whilst sulphuric acid acts solely

Fig. 9.20

The nitrogenous components of fresh grass, well-

through its effect in reducing pH. Some products com-

preserved silage and poorly preserved silage. Source: Wilkinson prise mixtures of acids and synergistic properties are

(1985).

claimed for them.

If the pH of the crop can be reduced from 6.0 to

Some crops, because they have a relatively low

about 4.5 by acidification at the time of harvest then the

content of WSC or have relatively high buffering

risk of clostridial growth is greatly reduced.

capacities, are more prone than others to secondary

An alternative approach is to accelerate the produc-

fermentations – their ‘ensilability’ is relatively low.

tion of lactic acid by the direct inoculation of the crop

Crops are ranked in order of their ensilability in Table

at harvest. Provided sufficient live bacteria are added

9.22. Maize combines adequate WSC with low buffer-

(ideally l million colony forming units/g fresh crop) and

ing capacity, whilst the converse is true for the legumes,

provided the content of fermentable sugar in the crop

lucerne in particular.

is sufficient for their growth then good preservation

Wilting in good weather prior to harvest has the

quality should be assured. Problems can arise with

effect of concentrating the sugars in the crop, and this

inoculants if there is insufficient sugar, either because
is beneficial in terms of reducing the risk of secondary
the crop itself is deficient or because the crop is too wet
fermentation.
at the time of ensiling. The most common species of
Silages that have undergone secondary fermentation
bacteria in inoculants is *Lactobacillus plantarum*.
are poorly preserved, but paradoxically they tend to be
Enzyme additives, containing hemicellulase and cel-
relatively stable on exposure to air. A major conse-
lulase, are another type of additive; the object in this
quence of clostridial activity is an increase in the pro-
case is to generate extra sugar from cell wall compo-
portion of nitrogen present as ammonia in the silage
nents to ensure sufficient acidification during primary
(Fig. 9.20). Digestibility and energy value are also
fermentation so that clostridia are inhibited.
reduced due to secondary fermentation; hence losses of
Products are now available which contain both lactic
nutrients are elevated in poorly preserved silages.
acid bacteria and enzymes. It is essential, however, to

Table 9.23

Typical composition of grass and maize silage stored in bunker silos.

Grass silage

Maize

silage

Direct-cut

Wilted

Poorly Well

preserved

preserved

pH

5.5

3.8

4.5

4.0

DM (g/kg fresh

160

180

360

300

weight)

Ash (g/kg DM)

110

80

90

55

Crude protein

160

160

150

90

(g/kg DM)

NDF (g/kg DM)

650

550

550

450

WSC (g/kg DM)

0

0

50

85

Starch (g/kg DM)

0

0

0

250

Lactic acid (g/kg DM)

50

150

65

100

Acetic acid (g/kg DM)

25

20

35

45

Butyric acid (g/kg DM)

35

0

0

0

DOMD (g/kg DM)

675

700

700

720

ME (MJ/kg DM)

10.8

11.2

11.2

11.5

NH3-N (g/kg total N)

300

75

40

30

Amino acid–N (g/kg

405

700

750

650

total soluble N)

establish that the active ingredients in these biological

With fibrous feeds such as straw, intake is often

additives really are active, and have not been destroyed

limited by the speed with which long particles are

by processing, packaging or storage.

reduced in size by chewing so that they can pass out

of the rumen. Grinding removes this restriction to

intake, but a consequence is that particles pass out of

Additives for hay and moist grain

the rumen before they are fully digested. The net result

The risk of development of moulds and mycotoxins in

is that although dry matter intake is increased,

moist hay and moist grain may be reduced by adding

digestibility is reduced and nutrient intake is little

an effective preservative at the time of storage. Propi-

changed.

onic acid and salts of propionic acid such as ammonium

Chopping long forages also reduces the opportunity

bis-propanoate, added at 15 kg active ingredient per

for the animal to select the best quality material on

tonne of fresh crop at the time of harvest, are effective offer. However, if straw is to be used in a complete diet,

in reducing mould development in both hay and grain

coarse chopping is a useful way of incorporating the

and also in big bale silage, where moulding due to

feed uniformly into the total mixture.

incomplete sealing is a common problem.

Long fibre with an average particle length of at least

150 mm is essential for milk fat synthesis and for the

maintenance of rumen function on high-concentrate

Feed processing

diets. It is therefore important to bear in mind that

physical processing of roughages can diminish their

Physical processing of roughages

value with respect to milk quality and the health status

of the rumen.

Traditionally, feeds like hays and straws were chopped

or ground prior to feeding. There is now increasing

evidence to indicate that although these procedures

Chemical processing of roughages

may be convenient for the processor, they are less than

ideal from the point of view of the nutrition of the

The use of alkalis, such as sodium hydroxide, for

animal.

upgrading straw is not new, but recently additional

benefits from the use of the technique have been

ing should be as small as possible: it is sufficient to crack

recognized.

the seed coat. Crimping is better than rolling, but treat-

Essentially, the technique involves adding sodium

ment with sodium hydroxide, which has the effect of

hydroxide to straw at about 50 kg per tonne fresh

breaking the seed coat by swelling it, is probably the

weight. The alkali degrades and swells the plant cell

best method from the animal's point of view. In addi-

wall material, with a consequent increase in digestibil-

tion to slowing down the rate of digestion of the starch

ity and intake. The benefits are valuable where straw is

in the grain, the residual alkali buffers acidity in the

plentiful and where it comprises a high proportion of

rumen.

the total diet, for example in the case of beef suckler cows.

The residual alkalinity in straw treated with sodium

Feeding management

hydroxide can help to reduce the risk of ruminal aci-

dosis in high-yielding dairy cows given diets containing

Successful nutrition of the bovine not only requires an

large proportions of concentrates and/or highly acid

understanding of the principles of nutrient require-

silages. In these situations, where fibre is needed to

ment, nutrient supply and animal response; it also

maintain milk fat content but the overall energy

involves appropriate management of feed resources.

content is required to be high at the same time, the

This includes presenting the correct amount of feed to

provision of a source of long fibre of enhanced

the animal for the appropriate period of time, formu-

digestibility is also valuable.

lating diets from available resources that meet require-

Ammonia (usually added in aqueous form at 30 kg

ments, taking into account the condition of the animal

NH_3 per tonne fresh weight) is a useful alternative and the desired direction and rate of change in weight

alkali to sodium hydroxide. It has the advantage of also

and condition and budgeting ahead so that rapid

contributing nitrogen, a valuable feature if the diet is

changes in diet are avoided and performance targets

deficient in rumen degradable nitrogen, but a disad-

are achieved.

vantage if silage of high protein content is the major

forage in the diet.

The importance of selective eating

Urea may also be used to upgrade straw, but both the

moisture content of the straw and ambient tempera-

The need to maintain stability in the rumen has led to

ture need to be relatively high for the technique to be

the presentation of feeds to the animal over a large pro-

successful.

portion of the day. This is particularly so with forages

The effect of an increase in digestibility of straw on

and straws, where rate of intake is relatively slow. It is

intake can be considerable. Thus a 10 per cent improve-

also important that the animal has access to feed for ment in digestibility can lead to a 50 per cent increase

most if not all the time when selectivity is desirable.

in dry matter intake. Since the feed consumed is more

At pasture, maximum intake is only achieved when

digestible, the increase in ME intake is even greater.

herbage is offered in substantial excess (Figs 9.7 to 9.9).

In general, the amount of herbage on offer should be

three to four times the amount eaten in order to achieve

Processing of cereals

maximum potential voluntary intake (see section on

Grinding of cereals was traditionally considered essen-

grazed pasture, p. 101).

tial to achieve complete digestion by cattle. A trade-off

was accepted between rapid digestion in the rumen and

Targets for sward surface height

possible acidosis on the one hand and poor digestibil-

at pasture

ity with undigested grains appearing in the faeces on the

other. It is now accepted that the passage of a few undi-

A simple guide to the amount of herbage on offer is the

gested grains has no measurable effect on digestibility, sward surface height of the grazed pasture. Regular

but that forage digestibility can be reduced when grain

measurement of sward height or sward mass is a useful

is overprocessed.

tactical aid to pasture management. Targets for sward

The need for cereal processing depends on the size

height for growing, lactating and dry cows are shown in

of the reticulo-omasal orifice. In the case of sheep and

Table 9.24.

calves less than 150 kg liveweight, it is difficult for whole

It is important to measure sward height in grazed

barley and whole oat grains to pass through the orifice,

areas, since herbage that is rejected due to contamina-

whilst it is easy in larger cattle. Thus whole grains may

tion by faeces, urine or treading is unlikely to be eaten

be given to young calves, but some processing is neces-

until the height of herbage in grazed areas is well below

sary for older cattle. If possible, the extent of process-

that at which intake is restricted below maximum.

Table 9.24

Target sward surface heights (cm) for rotational and continuous grazing.

Spring

Early summer

Late summer

Autumn

Lactating cows and

growing cattle

Rotational grazing

Pregrazing

10–15

12–16

14–18

10–15

Postgrazing

6–7

7–8

8–9

6–7

Continuous grazing

6–7

7–8

8–9

6–7

Dry cowsa

4–5

4–5

4–5

4–5

a Postgrazing, rotational and continuous grazing.

Buffer feeding

Traditionally, dairy cows were given concentrates,

usually in the form of milled compounded feeds, in the

The concept of buffer feeding was developed as a

parlour at milking and forages *ad libitum* for the rest of way of reducing losses in output from grazed pasture,

the day. With ever-increasing milk yields per cow, the

especially when herbage allowance was apparently

pressure on the available time in the parlour meant that

adequate but intake less than maximal due to poor

the cow had difficulty consuming a large feed of com-

weather, inadequate grass growth, short day length or

pounds during the milking period. Further, the rapid reduced time of access to pasture.

fermentation of the two relatively large meals (some-

The buffer feed should be less acceptable than the

times as much as 5 kg/meal) meant that rumen pH

herbage on offer at pasture, otherwise the buffer acts as

decreased, fibre digestion slowed down and forage

a substitute rather than a supplement for grazed grass.

intake was reduced as a result (see Fig. 9.21). Accord-

Typically, silage or hay are used as buffer feeds, offered

ingly, a mid-day feed of compounds or of by-products

ad libitum at the farm buildings to dairy cows after each such as dried sugar beet pulp was introduced to reduce

milking or placed in the grazing field for other classes

the quantity of compound to be fed through the

of stock.

parlour.

Sodium bicarbonate may be a suitable ingredient of

Frequency of feeding and ruminal acidosis

the diet when the cow is suffering from acidosis.

However, the problem with bicarbonate is that it is

It is significant that when cereal concentrates are relatively unpalatable and large quantities are required

offered *ad libitum* the animal eats a little at a time. Thus to have a significant effect. Thus the addition of 100 to

the general practice in feedlots, and in areas of the

150 g/cow per day is insignificant by comparison with

world where milk is produced from high-concentrate

the 3 kilogrammes of bicarbonate produced in saliva

diets, is to allow the animals 24-hour access to all feeds

daily. It is better therefore to include feeds, like hay or

(both concentrate and roughage) to avoid ruminal aci-

straw, to stimulate rumination and salivation.

dosis, otherwise known as ‘feedlot bloat’. This condition

is caused by the rapid fermentation of starches and

sugars, and can occur as the result of infrequent inges-

Out-of-parlour feeders

tion of large feeds of concentrates. It can also occur as

the result of inadequate long fibre to maintain rumina-

The advent of computerized cow identification has

tion and saliva production. Essentially, the condition is

enabled cows to be rationed accurately in the parlour

due to the dominance in the rumen fermentation of according to yield, and it was a relatively logical step to

lactic acid producing bacteria (p. 829). Ruminal stasis

introduce out-of-parlour feeders to allow the higher-

can occur at low rumen pH (less than pH 5.5) and the

yielding individuals to eat compounds and concentrates

inability of the animal to eructate leads to the accumu-

during the rest of the day. The nutritional advantages

lation of gas and the resultant bloat (p. 832).

were that higher levels of compounds could be given

Cattle given concentrates *ad libitum* should therefore to those cows that 'deserved' to receive them, and in a

also be allowed access to long forage or a source of

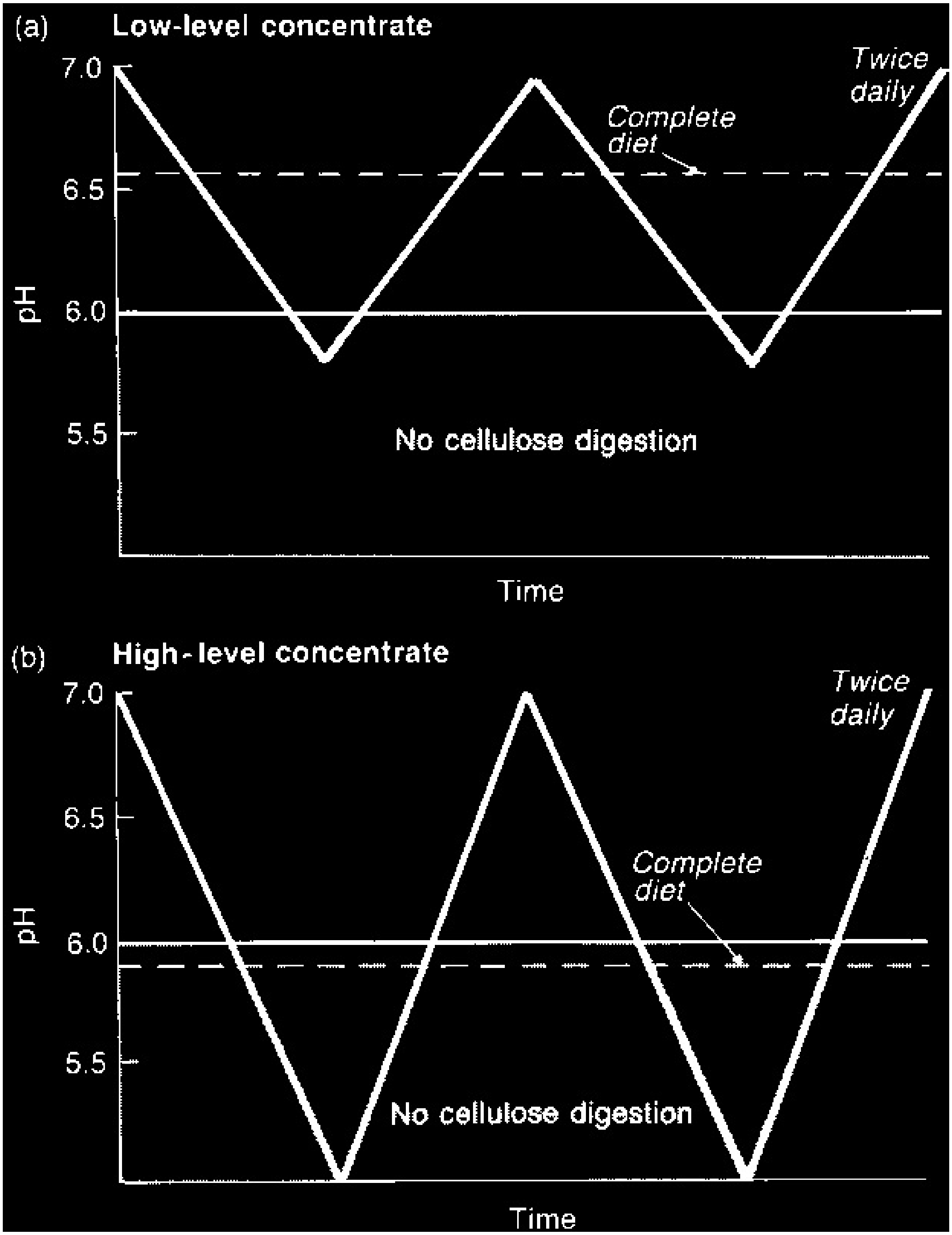
relatively large number of meals per day. Feeders could

roughage such as straw, at about 15 per cent of the total

be programmed to deliver equal proportions of the

diet dry matter.

total day's allocation in up to 12 feeds per day; cows not



In practice, higher-yielding cows in the herd eat more silage and it is important that the silage is on offer

ad libitum otherwise these animals are underfed. Peak lactation yields tend to be lower than in herds given

concentrates to yield, but the rate of decline in yield

post-peak tends also to be slower than in herds fed to

yield, giving a flatter lactation curve for flat-rate

feeding.

Total mixed rations or complete diets

The main principle of complete diet feeding is that the

animal receives an intimate mix of slowly and rapidly

fermented feeds, thus balancing the inflow to the rumen

of feeds with widely differing rates of fermentation and

(it is hoped) thereby maintaining stable conditions in

the rumen.

However, with high proportions of concentrates in

the mix, the level of acidity in the rumen may be so high

that fibre digestion is permanently depressed (Fig.

9.21). In this situation, the proportion of propionate in

the rumen volatile fatty acids is elevated and as a result

cows tend to gain in weight and produce milk of rela-

tively low fat content. Overfat cows with fatty livers were a feature of early mismanagement of herds given

Fig. 9.21

It is important to prevent the pH of the rumen from

complete diets.

falling below 6.0 for long periods of time, otherwise cellulose Thus, provided cows in late lactation and dry cows are

digestion will be greatly reduced. The problem is less at low

not given the same high-energy mix as higher-yielding

levels of concentrate feeding (a) than at high levels (b). Repro-animals, complete diets offer a logical approach to

duced from Orskov (1998) with permission of Chalcombe

feeding management. By-products can be incorporated

Publications.

into complete diets with greater ease than in other

feeding systems. Higher voluntary feed intakes are

usually achieved than with separate feeding, and milk

taking their feeds were readily identifiable and could be

compositional quality is often improved as a result of

checked for disease immediately.

the higher energy status of the animal and improved

fibre digestion in the rumen. On the other hand, the

investment in mixer-wagons can be considerable and

Flat-rate feeding

there is little evidence of improved overall efficiency of

The introduction in Europe of milk quotas placed a

feed utilization by animals given total mixed rations

limit on output, and the emphasis switched to simplify-

compared to the same diet in separate feeds of forages

ing the day-to-day feeding management of the dairy

and concentrates.

herd, especially in those herds where the input of con-

centrate was moderate and where the supply of grass-

Diet formulation

land for grazing and silage was adequate and reliable

throughout the growing season.

Diets are formulated to meet calculated requirements

The principle of flat-rate feeding is that all cows

for major nutrients (see sections on energy and protein

receive the same amount of concentrate, irrespective of

requirements, pages 103, 106), taking account also of the

their actual or potential milk production, together with

needs of the animal for macro- and microelements.

silage *ad libitum*. The system works best when there is Recent research in the

USA indicates that formulations

a compact calving pattern, with most cows at the same

for lactation should also take account of dry matter

stage of lactation, and when the input of concentrates

content and the content of NDF (cell wall) in the total

is relatively low. Silage quality should be relatively high

diet. The dry matter content of the whole diet should

and if necessary the level of concentrate should be

be between 500 and 650 g/kg fresh weight for maximum

reduced when the herd is in late lactation to prevent

intake, whilst the content of NDF should be be-

cows becoming overfat.

tween 350 and 450 g/kg DM for maximal output of milk

Table 9.25

Target condition scores for beef suckler cows.

Table 9.27

Feed budget for suckler cows (t fresh weight/cow

Reproduced from Fuller (1988) with permission of Chalcombe

and calf per annum). Silage and other feeds 25 per cent DM.

Publications.

Grazing

Stage of

Target condition score

Hill pastures and semi-arid lowlands: 0.5–1.0 cows/ha

reproductive

Upland pastures: 1.2–1.8 cows/ha

cycle

Autumn-calving Spring-calving

Lowland temperate pastures: 1.5–2.1 cows/ha

cows

cows

Winter feeding

Autumn calving

Spring calving

At calving

3

2.5

At mating

2.5

2

Lowland herds

Mid-pregnancy

2

3

Concentrates

0.4

0.2

Silage

3.5

2.5

Straw

1.0

0.8

Other feeds

0.3

0.4

Table 9.26

Feed budget for a dairy herd of 100 cows, average

(wet byproducts)

milk yield 6500 l/cow, calving September to November.

Upland herds

Concentrates

0.4

0.2

Feed

Budget

Silage

4.7

4.5

Straw

0.6

0.5

Grazing

Other feeds

0.2

0.4

Spring

5 cows per hectare

Hill herds: as for upland herds except silage 5.5 t /head to

Early summer

3.5 cows per hectare

allow for longer winter period

Late summer and autumn

2.5 cows per hectare

Silage

10 tonnes fresh weight per

cow at 10.5 MJ ME/kg DM

Table 9.28

Feed budgets for growing beef cattle.

Concentrates

When cows are housed

1.4 tonnes per cow

Grazing

When cows are grazing

0.1 tonnes per cow

Target liveweight (t /ha) at 250 kg N/ha

May

2.2

June

2.0

July

1.7

fat. Constraints in diet formulation programmes now

August

1.6

include dry matter and NDF in addition to conven-

September

1.4

tional prediction equations for voluntary intake and

October

1.4

nutrient requirements.

Average

1.7

Increase by 4 kg for each extra kg of N

Condition score

Silage and concentrates (t /head)

Silage

Concentrates

Condition scoring cows is relatively easy; there is no

(25% DM, 10.5 ME)

fleece to hide the animal's fatness (or thinness). The

Overwintered

essential areas for physical examination are: (i) the

store cattle

transverse processes of the lumbar vertebrae at the top

and finishing

of the loin, halfway between the last rib, (ii) the hip

suckled calves

3

0.3

bone and (iii) the tail head (see Chapter 2, Fig. 2.1).

18-month beef

5

0.9

Scoring should ideally be carried out by feeling the

Silage beef

6

0.8

(15–16 months)

extent of subcutaneous fat cover at the tail head and at

Cereal beef

*

1.6

the lumbar area. With practice, visual scoring is possi-

(11–12 months)

ble taking into account the visibility of the ribs and the
amount of fat at the tail head. Cows in condition score
* 0.2 t straw/head to maintain rumen function.
1 have no fat at the tail head and their ribs are promi-
nent. The ribs are visible in condition score 2 but not in
condition score 3 and above. As condition score rises
Regular condition scoring helps to identify overthin
above 2, the amount of fat visible at the tail head
cows that require preferential treatment (extra feed)
increases.
and overfat cows, especially those in late pregnancy,
Target condition scores for cows at different stages of
that are at risk of dystokia at calving. Scoring in early
the production cycle are shown in Table 9.25.
lactation to monitor the effectiveness of nutrient inputs

to achieve weight gain at mating is an essential part of
Gibb, M.J. & Treacher, T.T. (1978) The effect of herbage
successful rebreeding. Economies may also be made in
allowance on herbage intake and performance of ewes
high-energy feeds at times when the whole herd is

and their twin lambs grazing perennial ryegrass. *Journal of* scored as being slightly overfat.

Agricultural Science, Cambridge, **90**, 139–47.

Hodgson, J. (1975) The influence of grazing pressure and

stocking rate on herbage intake and performance. In

Feed budgeting

Pasture Utilisation by the Grazing Animal (ed. by J.

Hodgson & D.K. Jackson), Occasional Symposium No. 8,

Feed budgeting is the extension of daily diet formula-

British Grassland Society, pp. 93–103.

tion to annual feed planning. Future levels of output are

Lonsdale, C.R. (1989) *Straights: Raw Materials for Animal* set and a feeding policy is developed which takes into

Feed Compounders and Farmers. Chalcombe Publications,

account the home-produced feeds available, or likely to

Lincoln, pp. 1–87.

become available during the year, and the type and

Ministry of Agriculture, Fisheries and Food (1975) *Energy*

quantity of purchased feeds required to meet the target

Allowances and Feeding Systems for Ruminants. Technical level of output. A buying strategy is developed to meet

Bulletin 33. HMSO, London, pp. 1–79.

the projected requirements.

Ministry of Agriculture, Fisheries and Food (1984) *Energy*

Simplified examples of feed budgets for grazing and

Allowances and Feeding Systems for Ruminants. Technical Bulletin 433. HMSO, London, pp. 1–85.

winter feeding are shown in Tables 9.26 to 9.28 for dairy

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sional Symposium No. 3, British Grassland Society, pp.

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Chapter 10

Alternative Forages

M. Tame and the late P.S. Jarvis

Introduction

123

minerals for maintenance and production for lactating

Forage maize (corn)

123

and fattening animals. Knowledge is incomplete, and

Fodder beet

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the art of feeding stock relates to adjusting feeds, intro-

Swedes

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ducing different ingredients and measuring and observ-

Stubble turnips (leaves and roots)

125

ing the results.

Kale

125

The figures shown in Table 10.1 act as a starting point

Forage rape

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in the compilation of dairy cow rations, particularly as

Lucerne

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Red clover

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feeds can vary in analysis. Alternative forages will need

White clover

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to fit the criteria laid down for each animal's produc-

Peas

129

tion. However some forages, such as maize and lucerne,

Sainfoin

129

are DMI enhancers and so they can be perfectly satis-

Lupins

129

factory at lower energy densities in winter rations.

Rye

129

Dairy heifers, calving at two years old, need to grow

Triticale

130

at 0.7–0.8 kg/head daily to attain a satisfactory calving

Whole crop silage: whole wheat

130

weight, and beef animals in the final stages of fattening

Whole crop cereal with peas

130

require growth rates in excess of 1 kg/head daily.

Wet byproducts used in dairy cow rations

Total farm profitability determines whether or not

alternative forages feature in a farming system. Factors

to be considered include soil type, labour availability,

Introduction

working and fixed capital requirements, value for

money, yield variability, rotational considerations and

The main forage crops in the UK and many other

feeding facilities. The majority feature in winter rations,

countries for cattle are conserved grass in the form of

but kale and stubble turnips are often grazed in the

hay or silage, otherwise straw. Economic and nutritional

summer and early autumn, while lucerne and red clover

considerations have led to a quest for alternative

are versatile protein sources in the summer. They can

forages.

be grazed (with caution because of bloat) or conserved

Feeding dairy cows, dairy heifers, suckler cows and

as silage. Red clover is usually in a grass ley mixture,

beef animals is a mixture of science and art. Any ration

but lucerne is generally grown as a pure stand.

needs to be balanced for energy, protein, minerals,

A brief description will be given of some of the crops

vitamins and water, to meet the required production

available together with their use and integration into

objectives. Energy sources will include starches, sugars

cattle rations.

and digestible fibre, whilst protein will be of rumen

degradable and digestible undegradable protein and

Forage maize (corn)

will contain a wide range of amino acids. The ration

must be palatable, digestible, appetizing and free from

The typical analysis of forage maize silage per kg dry

dirt, stones, harmful bacteria and moulds. Some feeds

matter (DM) is:

are enhancers of dry matter intake (DMI), whilst others

substitute for existing ingredients in the ration. Thus

DM = 28 per cent, metabolizable energy (ME) = 10.8 MJ,

brewers' grains, sodium hydroxide-treated straw, maize,

digestible crude protein (DCP) = 70 g, neutral deter-

etc., are enhancers of DMI whereas, for example, barley

gent fibre (NDF) = 360 g, modified acid detergent fibre and wheat substitute for each other.

(MADF) = 215 g

The UK Ministry of Agriculture, Fisheries and Food

Minerals: Ca = 3.9 g, P = 1.8 g, Na = 0.2 g, Mg = 2.4 g

and the Agricultural and Food Research Council have

Yield on National Institute of Agricultural Botany

published standards for energy, protein and the major

(NIAB) plots = 12.0 t DM/ha

Table 10.1

Winter ration criteria for Friesian/Holstein dairy

maize gluten, 2.5 kg rapeseed meal, 1.5 kg soya bean

cows.

meal and 0.3 kg mineral/vitamin supplement. As the

DM of maize silage increases, so does the DMI.

Milk yield (kg/day)

Maize silage can be introduced to young cattle at

under three months old, but additional protein, vita-

35

25

18

Dry

mins and minerals are necessary. Typically, a 300 kg

heifer growing at 0.65 kg/day requires 5.1 kg DM of

Minimum DM (%)

38

33

26

22

maize silage, 0.2 kg 50 per cent vegetable protein and

Energy density

12.0

11.4

10.8

9.5

Minimum MADF fibre (%)

15

18

22

25

one per cent non-protein nitrogen (urea) added to

Approximate DMI

20.9

17.1

14.7

9.3

maize silage; 1 kg of a 34 per cent protein/mineral/

vitamin supplement would also be suitable.

Note: protein guidelines are 400 g DCP for maintenance and 60–65 g Bull beef animals have higher intakes of maize than

DCP/kg milk, with sufficient undegradable as well as degradable grass silage. A beast weighing 300 kg needs 6 kg DM of

protein in the ration.

maize silage plus 1.5 kg of a 34 per cent protein/mineral/

For Jersey cows with milk yields of 25, 18, 13 and 9 kg respectively, vitamin concentrate supplement to gain 1 kg/day. This

the protein requirements are 350 g DCP for maintenance and 70–75 g DCP/kg of milk.

quantity of supplement is kept constant over a range of

weights so that the crude protein of the complete ration

declines as the animal matures.

Maize silage is best stored in long, narrow clamps to

Maize fits well into a grass silage system and can be

limit the amount of heating and hence spoilage when self-fed or forage-box fed. It can be fed as a green crop

the clamp is opened. Most maize is grown in the south-

prior to harvest, and used as a buffer feed in spring for

ern counties of Britain but as more early-maturing

cows at pasture.

varieties are being bred, the frontiers are being pushed

further north.

The true value of maize (corn) is often underesti-

Fodder beet

mated by conventional equations. Maize silage costs

less to produce than grass silage, and is complementary

The typical analysis of fodder beet per kg DM is:

to it. In a dull, wet summer, the ME can be under 10

DM = 18.3 per cent, ME = 11.9 MJ, DCP = 34 g,

but is still as good as most grass silages made in similar

NDF = 127 g, MADF = 83 g

weather. Generally, it is a high-energy, low-protein con-

Minerals: Ca = 3.9 g, P = 1.8 g, Na = 2.4 g, Mg = 1.4 g

served forage that has limited fibre and is low in min-

Yield on NIAB plots = 14.2 t DM/ha (excluding the

erals, particularly calcium, phosphorus, sodium, copper, value of fodder beet tops (leaves), which can add up

zinc, iodine and manganese. The greater the proportion

to 30 per cent to the DM)

of maize in the ration, the more deficiencies need to be

corrected.

Ensiled tops are higher in protein minerals (espe-

A typical ration for a dairy cow yielding 25 kg milk

cially phosphorus) and fibre and can complement the

might include 32 kg grass silage, 14 kg maize silage, 1 kg

diet, but are difficult to harvest and utilize efficiently.

soya bean meal, 5.5 kg maize gluten and 0.15 kg high

Fresh tops can contain harmful oxalic acid and lead to

phosphorus minerals. Research work, particularly by

calcium problems but the problem is reduced with

Phipps (pers. comm.), has shown that by including at

wilting. Thus they can cause scouring and milk fever in

least 25 per cent of the silage as maize increases

freshly calved cows.

forage DMI, lowers the cost and increases milk pro-

Fodder beet is used primarily as a low-cost concen-

duction and hence the weight of fat and protein. The

trate replacer for dairy cows, at a maximum of 4–4.5 kg
response is greater with 63 per cent digestibility (‘D’
DM (22–25 kg fresh weight). As a high-energy source, it
value) silage compared with 68 D grass silage. With a
will need to be balanced by additional degradable and
ration based on 40 : 60 grass : maize silage and 6 kg con-
undegradable protein. In limited cases, it can be used as
centrates, DMI and milk yield were increased by 2.8 and
part of the maintenance ration but additional protein,
2.9 kg respectively compared with grass silage and 6 kg
fibre (as hay or straw) and minerals will be required.
concentrates. Maize silage combines well with lucerne
For a dairy cow yielding 25 kg milk, with 40 kg grass
silage, but needs an addition of 1–2 kg straw to provide
silage producing more than maintenance, 15 kg of
fibre.
fodder beet, 4 kg maize gluten and 2.25 kg of a propri-
Maize silage can be used as the sole source of forage
etary 20 per cent protein, high-energy concentrate
for dairy cows. An example ration for a cow producing
complete the ration. A mix of other dry concentrates

25 kg milk would be 27 kg maize silage, 3.5 kg caustic

such as barley and soya bean meal can replace maize

treated straw, 2 kg molasses, 2 kg sugar beet pulp, 3 kg

gluten.

Harvested fodder beet can be fed from a hopper or

Swedes

behind an electric fence provided that sufficient feed

space is available to avoid uneven intakes between

The typical analysis of swedes per kg DM is:

cows in the herd. It is more commonly fed as part of

a complete diet in a forage wagon, but the beet must

DM = 10.5 per cent, ME = 13.1 MJ, DCP = 64 g,

be free from dirt and preferably finely chopped or

NDF = 140 g, MADF = 114 g

shredded to integrate in the ration.

Minerals: Ca = 3.5 g, P = 2.6 g, Na = 1.5 g, Mg = 1.1 g

Strip-grazing beet in the field produces a multitude

Yield on NIAB plots = 7 t DM/ha

of problems: poisoning from tops (even when topped

The crop is generally grown in the cooler west and

this can be via secondary growth in the spring), waste
north of Britain. Fungal problems such as powdery
of feed and foot troubles (see Chapter 31).
mildew and club-root can limit crop yields.
When used as a concentrate replacer, fodder beet
Swedes have a low protein and high energy content,
enhances the butterfat and protein percentages in the
but a relatively low yield of DM. They are used
milk, but observations suggest that it depletes the com-
primarily for beef and sheep as well as for human
positional quality when used as part of the maintenance
consumption.
ration.
Swedes could be utilized by dairy cows on a similar
A combination of fodder beet and soya bean meal
DM basis to fodder beet, but are more costly to
can add to DMI and hence milk yield and quality, par-
produce. Despite their low DM (10.5 per cent) they are
ticularly replacing a 10.8 ME grass silage. The grass
likely to be DMI enhancers. Similarly, they can be fed
silage uptake has been shown to decrease from 9.6 to

to dairy heifers by incorporation in straw-based rations.

7.0 kg DM/cow per day. When fodder beet was added

The low DM of swedes could assist consumption, but

to a poorer silage and with no soyabean meal, compo-

chopping or slicing is advantageous. Swedes may be

sitional quality was not improved. As well as lowering

grazed *in situ*, especially by sheep.

the ration cost, fodder beet partially acts as a concen-

trate replacer.

Fodder beet should be finely chopped or shredded in

Stubble turnips (leaves and roots)

the rations for dairy heifers over one year old when

they are changing their teeth. For these animals average

The typical analysis of stubble turnips per kg DM is:

grass silage up to 2 kg DM (11 kg fresh weight) of fodder

DM = 8.0 per cent, ME = 11.6 MJ, DCP = 130 g

beet can be fed in place of sugar beet pulp to ensure

Figures for fibre levels and minerals are not available

good growth rates and conception. Using a straw-based

Yield on NIAB plots = 3.8 DM/ha (relates to the tops

ration, a 300 kg heifer growing at 0.8 kg/day could and that portion of the root that is above ground)

receive 3 kg straw, 14 kg fodder beet, 1.2 kg barley and

1 kg soya bean meal. If ammonia or urea-treated straw

These quick-growing turnips are a very useful catch

is used, 11 kg fodder beet and 1 kg barley could produce

crop being sown in the spring as a prelude to a grass

the desired results. Alternatively, 2 kg DM from both

reseed in the autumn or after winter barley in July as a

fodder beet and brewers' grains with *ad libitum* straw break crop.

should produce a palatable and productive ration.

Stubble turnips are grazed by dairy cows *in situ*

Amounts will, of course, be increased as the animals

behind an electric fence in midsummer and autumn,

grow.

particularly where grass production is limited. In the

Gleadthorpe Experimental Husbandry Farm (1984,

summer, stubble turnips and *ad libitum* ammonia-

1985) developed a fodder beet system that utilised its

treated straw complement grass, while in the early

low cost when compared with concentrates for Friesian

autumn the same combination can substitute for a

¥ Hereford heifers and steers. Crushed beet was intro-
limited amount of silage on free-draining soils. Stubble
duced when the animals weighed 200 kg. Both fishmeal
turnips can also be fed to sheep and suckler cows, but
and soyabean meal have been used as the protein
are little used for dairy heifers and beef animals
sources with minerals and straw also added if necessary.
because they are unlikely to be constrained by an elec-
In many cases, fodder beet requires much additional
tric fence. The cost per unit of energy is similar to
capital for sowing, harvesting, storing, cleaning and
grazed grass. Fungal problems such as powdery mildew
chopping the beet, but it can be grown in most areas of
and alternaria leaf spot can limit crop yields.
the UK and other temperate areas. In a wet autumn on
heavy soils, harvesting can be difficult, but it is a rela-
tively cheap source of energy. Mangels, which have a

Kale

DM of 10–15 per cent, are in the main similar to fodder
beet for feeding but crop yield is less.

The typical analysis for kale per kg DM is:

DM = 13.6 per cent, ME = 12.6 MJ, DCP = 119 g,

DM = 29 per cent, ME = 9.5 MJ, DCP = 134 g,

NDF = 208 g, MADF = 161 g

NDF = 464 g, MADF = 357 g

Minerals: Ca = 12.1 g, P = 3.5 g, Na = 1.2 g, Mg = 1.4 g

Minerals: it is claimed to be high in minerals, except

(varieties differ in analysis)

sodium, and to have good buffering capacity in the

Yield on NIAB plots = 8.6 t DM/ha

rumen. Ca = 17.6 g, P = 3.0 g, Mg = 1.8 g

Yield on NIAB plots = 14.7 t DM /ha

Kale can be grown in most areas of the UK but yields

can be adversely affected by dry weather.

Lucerne (alfalfa) is now the most important forage

Protein and minerals are contained in the leaves and

crop on a worldwide basis. While some 1 million ha are

carbohydrates and fibre occur in the stem. Thus, the

suitable for the crop in the UK, only around 22 000 ha

proportion of leaf to stem influences the feed value of

are cultivated. The crop grows best in areas where the kale.

night temperature remains above 10°C and where

Kale is a low DM, high-protein feed that is high in

daytime temperature is in the range 15–25°C. It is an

calcium, but low in phosphorus, copper, manganese and

erect, deep-rooting and hence very drought tolerant

iodine. Goitrogens can interfere with iodine use in the

crop which is well suited to cutting. The exceptionally

dairy cow (see pp. 257, 586). Excessive amounts of kale

deep rooting habit requires a well-fissured alkaline

can lead to haemolytic anaemia (see p. 941).

subsoil. The soils also need to be free draining as the

In the past, kale was strip-grazed in the autumn and

plant is not tolerant of a high water table. Top soil pH

up to midwinter and, together with hay, provided the

should be maintained at 6.2 or higher, preferably above

maintenance portion of the dairy cows' ration. The

6.5 as root nodulation does not occur at pH levels

practice has been largely curtailed as herds moved

below 6.2. Lucerne is not a competitive crop (Sheldrick

towards autumn calving, and a continuity of feed during *et al.* , 1995).

the winter season became necessary. In addition, foot

The advantages of lucerne are its reduced fertilizer

troubles were very common and udders needed addi-

requirement (it fixes very high levels of nitrogen); its

tional washing. Currently, kale is grazed *in situ* in the persistence (it will stand regular cutting for up to 5

summer and early autumn in a similar fashion to

years); its drought resistance; its high protein level (up

stubble turnips with ammonia-treated straw. It tends to

to 24% protein at tight bud stage); its high digestibility;

be fed to mid- and late-lactation cows and should not

the slow fall in D value; its low level of lignification and

exceed 30 per cent of the ration. In practice, 3–4 kg

its high levels of calcium and vitamins A and E

DM/head per day are consumed together with 1–2 kg of

(Koivisto, 1999, pers. comm.).

ammonia-treated straw. Kale can be cut and carted to

Its disadvantages are that in the small seedling stage

all classes of stock, and may be strip-grazed by sheep in

it is frost susceptible. It is not tolerant of wet conditions winter.

requiring a free draining soil. It is susceptible to stem

eelworm and sitona weevil and some varieties are sus-

Forage rape

ceptible to verticillium wilt. In some conditions downy

mildew and various leaf spots may occur.

The typical analysis of forage rape per kg DM is:

All seed should be checked to ensure that it has been fumigated against stem eelworm and all seed should be

DM = 14 per cent, ME = 9.5 MJ, DCP = 144 g

inoculated with *Rhizobium meliloti* in areas where it

(no fibre figures are available)

has not been grown in the last few years. A seed rate of

Minerals: Ca = 9.3 g, P = 4.2 g, Na = 2.3 g, Mg = 2.1 g

20–25 kg/ha is recommended, except in particularly

Yield on NIAB plots = 5.4 t DM/ha

favourable areas where the rate may be reduced to

Rape can be grown in most areas of the UK. Forage

15–20 kg/ha. The target seedling density should be 425

rape can be used as a catch crop like stubble turnips and

plants per square metre, although a mature stand may kale but is lower yielding than the latter and higher

only have 120–150 plants per square metre. The crop

yielding than the former. The principles of feeding and

should be sown between late April and the first week

the reservations on use of forage rape are similar to

in August. Lucerne should not be sown with grass as the

kale. Forage rape can cause taints in milk and should

latter is too competitive.

be introduced into the ration slowly. It can be grazed *in*

Another disadvantage is its low yield in the establish-

situ from July to December, or be zero-grazed.

ment year, although this can be overcome by undersow-

ing it into a spring cereal crop or a semi-leafless pea crop.

After establishing the nurse crop and controlling weeds

Lucerne

the lucerne should be broadcast and either rolled or

raked in. Alternatively the two crops can be drilled at the

The typical analysis of lucerne silage per kg DM is:

same time, although this makes weed control more diffi-

cult. If there is adequate late summer/early autumn rain-has spearheaded a revival of interest in the last five

fall the crop can be established in late summer, no later

years.

than mid-August, after a winter cereal crop.

Red clover yields well on a range of soils with a pH

Decaying lucerne roots exude chemicals known as

of 6 or higher and adequate soil moisture. Summer rain-

medicarpins which inhibit germination of lucerne so it

fall is also a prerequisite for good yields. Water-logged

is not possible to ‘stitch in’ seed to fill areas where the

soils, on the other hand, should be avoided and heavy

crop has died out.

soils subject to structural damage from smearing and

Fertilizer requirements are relatively low as there is

the use of heavy machinery will shorten the life of the

no requirement for nitrogen after establishment. The

crop. Unlike white clover, red clover does not produce

main requirements are for phosphate and particularly

stolons (runners) and has a single crown to the plant

potash.

that is susceptible to damage.

Lucerne is ideally suited to a cutting regime. The crop
As a general rule red clover is sown with Italian
should be allowed to flower before the first cut and
rye grass and with the more modern varieties a fairly
should then be cut at intervals of 35–40 days, with the
aggressive rye grass is required as the clover tends to
last cut being made in September to allow at least 6
take over in the second year. Seed rates are usually
weeks for recovery before the first frost. After the first
around 3 kg/ha with a target plant density of 200/m2.
frosts the crop will normally stop growing, at which time
It is important that the red clover seed is fumigated
it is safe either to cut or lightly graze the crop. The ideal
against stem eelworm. Modern varieties will usually
cutting time is mid-bud stage.
give two heavy cuts, with a third lighter cut over the first
Dry matter yields from a well-established crop of
two years. There is a significant decline in productivity
lucerne under ideal conditions could be as high as 14
in year three, although the new variety Milvus is
tonnes dry matter/ha, although average yields will be

claimed to give good production over a three-year

10–12 tonnes dry matter/ha. The first cut is normally

period. Growing red clover with Italian rye grass

expected to contribute about 35 per cent of the total,

will not only give a heavier crop, by up to 30 per

with the second, third and fourth cuts contributing 35,

cent annually, but also raise overall digestibility.

20 and 10 per cent, respectively.

Annual yields of dry matter are usually in the range

Ensiling lucerne is more difficult than grass silage as

9–12 tonnes/ha for pure stands and 11–13 tonnes/ha

the sugar levels are much lower and for ensiling to be

when grown with companion grasses. Yields in organic

successful it is strongly recommended that the crop is

systems will be almost, if not as high as in conventional

wilted to 30 per cent dry matter. If the dry matter prior

systems because of the high levels of nitrogen fixed.

to ensiling is much higher than this there is a very real

Red clover can fix up to 245 kg nitrogen/ha (Lampkin,

danger that losses will be high as a result of leaf shatter.

1990).

Lucerne is not usually grazed because of the risk of
Red clover is sensitive to soil potash levels as large
bloat, although there are instances where it has been
amounts are removed from the field under cutting.
grazed successfully. This requires a slow introduction
Potash level can be improved by the appropriate use of
and all the usual precautions to avoid tympany.
slurries to which it responds well. If high protein levels
Because of its ability to fix large amounts of nitrogen
are to be achieved in the first cut the use of some arti-
and its very deep and extensive root system lucerne is
ficial nitrogen may be necessary as nitrogen fixation by
well suited to organic systems, although its inclusion in
clovers is temperature dependent and in cold and wet
a rotation will extend it considerably.
seasons little nitrogen may be fixed before the first cut
is made. The protein level in the first cut material is
often very low in organic systems where the use of arti-

Red clover

ficial nitrogen is not permitted. However, it has usually
increased to around 18–20 per cent by the time the

The typical analysis for red clover silage per kg DM is:

second cut is made.

The low levels of sugar in clover can lead to poor fer-

DM = 22 per cent, ME = 9.8 MJ, DCP = 135 g

mentation in ensiled crops of pure red clover. Ensiling

Figures are not available for the fibre levels and mineral

grass/red clover is often more successful because of the

content, but like lucerne, red clover has high intake

sugar contributed from the grass. The quality of the fer-

characteristics and the ME is likely to be close to

mentation is also likely to be improved by wilting the

10 MJ/kg DM

crop to approximately 30 per cent dry matter whenever

Yield on NIAB plots = 13.5 t DM for first harvest year,

possible, but care should be taken not to exceed this as

and 11.1 t/ha for the second harvest year

leaf loss due to shattering occurs above this level. If the

The use of red clover declined dramatically to the late

material has to be ensiled at a significantly lower dry

1990s. However, the recent interest in organic farming

matter the use of an inoculant is recommended.

Weed control can be a problem as red clover is

Production levels from grass/white clover swards are

sensitive to many of the herbicides currently available.

lower than from grass/red clover swards and are likely

Control of weeds in organic systems is often achieved

to be of the order of 6 tonnes of dry matter/ha with no

by undersowing into a spring cereal nurse crop, a tech-

artificial nitrogen input to 7.6 tonnes/ha with 200 kg

nique which could also be used in conventional systems.

artificial nitrogen/ha. However, at this level the clover

A gap of at least four and preferably five years should

content of the second cut will be suppressed (Sheldrick

be allowed between red clover crops to reduce the risk

et al. , 1995). These same authors state that under ideal of pests and diseases, particularly stem eelworm and

conditions herbage yields equivalent to those from

Verticillium.

grass swards receiving in excess of 300 kg nitrogen/ha

The risk of bloat in cattle is reputedly higher with red

have been recorded. It is recommended that no more clover swards than white clover swards and as a result

than 50 kg of nitrogen/ha is used. In organic systems

red clover is grazed less frequently (p. 833). However,

where the use of artificial nitrogen is not permitted it

with careful management it can be avoided. The red

should be noted that the protein content of the first cut

clover should be introduced slowly and once introduced

is often very low, particularly in cold and wet seasons

it should be a consistent component of the diet. The risk

when it is typically between 10 and 12 per cent (Weller

is highest in cold wet weather and when the animals are

& Cooper, 2001; Tame, pers. obs.).

particularly hungry. Lambs in particular grow very well

The proportion of grass to clover can be managed to

on grass/red clover swards and increased growth rates

some extent by alternating cutting with grazing. The

can also be achieved with young stock and beef cattle

growth of the white clover is light sensitive; allowing the

(Thomas *et al*., 1982).

sward to grow will mean that eventually the clover will

Because of its ability to fix large amounts of nitrogen, be shaded out as the grass grows taller. This is particu-

red clover is an important part of the fertility building

larly so in autumn and early spring when the tempera-

cycle in organic systems.

tures are low enough to suppress clover growth but not

grass growth. The clover content can be increased by an

intensive grazing and/or cutting regime, although the

White clover

proportion of clover increases naturally through the

season (Weller & Cooper, 2001). Ensiling grass/white

In the last few years interest in white clover has

clover is less difficult than grass/red clover because of

increased significantly and it is increasingly being used

the generally lower clover content and higher sugar

in grazing swards. Again, interest has been fuelled by

level contributed by the grass, but even so wilting to

the increasing interest in organic husbandry.

around 30 per cent dry matter is again recommended.

Varieties tend to be classified according to leaf size,

At dry matter levels much higher than this leaf shatter

with the smaller leafed varieties being more suited to will be a problem.

sheep grazing and the larger leafed varieties being

Weed control can be a problem in newly established

more suited to cattle grazing and/or conservation. More

swards, particularly with annual weeds such as chick-

recently, varieties have been introduced which are more

weed. This can be controlled by the careful use of an

cold tolerant, resulting in earlier growth and nitrogen

appropriate herbicide, although most will have some

fixation. Soil pH should again be 6 or higher for good

adverse effect on the clover. In organic systems suc-

germination and growth, and on some soils this may

cessful control is achieved by the use of mechanical

mean the regular application of lime to maintain this pH.

control or by undersowing into a nurse crop of spring

White clover is much longer-lived than red clover

cereals.

and will typically be expected to survive for six years

Grass/white clover swards are used principally for

or more under good management. Typical seed mix-

grazing and it is worth noting that milk production will tures will contain between 1 and 2 kg/ha in a total

be 1–1.5 litres/cow higher from a grass/clover sward

mix of 12 kg/ha (the total seed rate may need to be

than from an all-grass sward.

higher in adverse conditions, e.g. low rainfall and

Care needs to be taken in the autumn to ensure that

light soils). White clover seed is very small and germi-

late grazing by sheep does not damage the stolons of

nates more successfully if broadcast on to the surface

the clover as such damage may result in a loss of clover

rather than being drilled into the seedbed. Grass vari-

in the following spring.

eties need to be chosen with care to avoid either the

White clover also plays an important part in soil

grass or the clover becoming the dominant species.

fertility building in organic systems because of its

Work in this area has been done by the Kingshay

ability to fix nitrogen even though it fixes less than red

Trust, from whom recommendations are available to its

clover, 150 kg/ha under good conditions (Lampkin,

members.

1990).

Peas

effect of reducing the rate of protein breakdown in

the rumen.

The typical analysis for pea silage per kg DM is:

Again sanfoin is well suited to organic systems

although, like lucerne, its inclusion in a rotation will

DM = 25.9 per cent, ME = 8.8 MJ, DCP = 146 g,

extend the length of the rotation considerably.

NDF = 517 g, MADF = 384 g

Minerals: Ca = 12.7 g, P = 4.4 g, Na = 0.4 g, Mg = 2.0 g

Yield (estimated) = 7 t DM/ha

Lupins

Pea silage can be a byproduct from the production of

vining peas and may be more like straw. Peas can also

Interest in this crop has been growing in recent years

be grown on their own, but need some physical support

particularly as large areas are grown in continental

and are usually sown in conjunction with spring barley

Europe, 60 000 ha in northern Germany alone, and on the basis of 40 : 60 peas : barley by seed weight.

particularly in Australia, 1 million ha. While the crop

Newman & Luffman (1984) have produced the arable

is normally grown as a grain crop it can also be har-

silage mixture (barley was cut at the cheesy stage) with

vested as a forage crop. When cut at ten to twelve weeks

a DM of 43.2 per cent, ME of 10.2 MJ and DCP of

post-emergence it gives a high yield of good quality

147 g. They observed that the silage yield at 10 t DM/ha

forage. Crude protein levels may be as high as 20 per

was very palatable. Depending on the stage of lactation,

cent, with a good energy level and up to 20–25 per cent

when fed to 200 dairy cows in Somerset, it produced

starch.

rises in DMI between 10 and 20 per cent over grass

Recommended types are the white, apically domi-

silage. (Dry matter intake of grass silage tends to be in

nant varieties or the yellow branched varieties. The

the range of 7–10 kg depending on the quality and quan-

crop is tolerant of a wide range of soil types provided

tity of the silage.) The arable silage mixture can also be that the pH is within the range 5–7. The crop should be

fed to dairy heifers and beef animals. Peas are not an

sown from mid-March to mid-April. The seed rate will

easy crop to establish and whole crop cereal silage may

depend on type and the seed should be inoculated.

be preferred.

Weeds need to be controlled in the early stages of the

crop. Yields as high as 10 tonnes of dry matter/ha have

been reported, although it is too early to know whether

Sainfoin

this is typical under UK conditions.

Lupins seem to be particularly well suited to organic

systems because of the high level of nitrogen fixation

A typical analysis for sainfoin silage per kg DM is:

and the fact that the crop is in the ground for such a

DM = 24 per cent, ME = 8.4 MJ, DCP = 124 g

short time means it fits well into rotations.

Figures for fibre and minerals are not available

Yield (estimated) = 7.5 t DM/ha

Sanfoin is a little grown crop although there has been

Rye

some revival of interest in the last few years. A research

programme is currently under way at the Royal

The typical analysis for grazed rye per kg DM is:

Agricultural College at Cirencester (Lane & Koivisto,

DM = 23 per cent, ME = 9.5 MJ, DCP = 88 g

1999). In most aspects the requirements, establishment

Figures are not yet available for fibre and mineral

and management of sanfoin are very similar to those for

content

lucerne.

Yield (estimated) = 7.7 t DM/ha

The main differences are that the most commonly

available varieties of sanfoin are significantly less pro-

Rye is grown on its own or in a mixture with Italian

ductive than lucerne with fewer cuts. However, some

ryegrass to produce an early bite in the spring on light

recent varieties that will soon be available from

land with a low pH. It is usually strip-grazed by dairy

Eastern Europe, notably Hungary, may well be almost

cows once daily and its feed value often decreases

as productive as lucerne. Another difference which rapidly. Zero-grazing is possible. Any surplus can be

has significant practical and nutritional implications is

conserved as big bale silage and used for any class of

that sanfoin has a relatively high tannin level which

stock. In some areas it is followed by forage maize and

means that there is no risk of bloat from grazing it.

could be drilled after an early maturing variety of

Indeed, very high growth rates have been achieved in

maize in the autumn. Many dairy farmers prefer buffer

lambs grazing sanfoin (Koivisto, pers. comm.). It is also

feeding of silage in late spring or other combinations of

likely that the tannin content of sanfoin may have the

feed as an alternative to growing small areas of rye.

Triticale

35–40 per cent (Kristensen, 1995). Winter barley should

be harvested slightly earlier at four to five weeks post

Feed analysis figures are not available for triticale,

ear emergence and at a dry matter of 30–35 per cent.

which is a hybrid of wheat and rye. Triticale can perform

However, in the UK the suggestion is that winter wheat a similar function to rye, and is said to have lower DM

can be harvested at up to 45 per cent dry matter (MDC,

yields than rye in the earlier part of the season, but its

1995). Yields for winter wheat are 10–12 tonnes dry

digestibility stays at a higher level than rye as the crop

matter/ha with conventional systems and 6–10 tonnes

matures. Feeding value is likely to be similar to whole

in organic systems depending on where it is placed

crop silage. If cut in mid June, it can have a DM of

in the rotation and whether it is undersown with

25 per cent and an ME of 9.6 MJ. Both sugar and fibre

grass/clover. If the dry matter is much higher than

levels are higher than grass.

50 per cent it is likely that grain will be excreted,

undigested, the amount increasing with higher dry

matter.

Whole crop cereal is well suited to use as a buffer

Whole crop silage: whole wheat

feed to supplement grazing in the summer, particularly

in organic systems where its starch and low protein

A typical analysis for whole wheat silage (Newman, content can be used to balance the very high levels of

pers. comm.) per kg DM is:

degradable protein in the grass/clover swards from mid-

summer onwards. Indeed, whole crop cereal silages fit

DM = 50 per cent, ME = 10.7 MJ,

very well into organic systems as a whole as the early

crude protein = 9 per cent, NDF = 400 g, pH = 8

harvest allows a grass/clover ley to be established in

Yield (estimated range) = 7–10 t DM/ha

August. It also allows a degree of flexibility in the

There has been a considerable increase in interest in

system as it can be taken either for grain or for forage

whole crop cereal silage over the last decade both in

depending on the season.

fermented and in urea-treated form.

The addition of whole crop cereal silage to the diets

of both cattle and dairy cows results in a significant

Whole crop cereal with peas

increase in dry matter intake, particularly with the urea-

treated form. However, there are some very significant

The major disadvantage with whole crop cereal silages differences between the two forms.

is that they are low in protein. This can be overcome to

The fermented form of whole crop has the advantage

a greater or lesser extent by growing whole crop cereals

that it has a much higher digestibility and results in a

as a bi-crop with peas. The target should be for at least

larger increase in milk output and a small increase in

40 per cent peas in the crop. The peas should be a short-

milk quality, mainly in butterfat. The disadvantage is

strawed, coloured, flowered variety. Sowing rate will

that it is lower in protein and is aerobically unstable,

depend on the proportion of peas required, but with a

although this latter disadvantage can be overcome to

50 : 50 mix the seed rates would be around 125 kg/ha

some extent by adequate chopping, good consolidation

wheat and 270 kg/ha peas depending on variety and

and good clamp management.

seed size.

Urea-treated whole crop has the advantages that

The crop should be harvested at 14–15 weeks post

there is a large increase in dry matter intake, it is aerosowing when the cereal grain is at the doughy stage and

bically stable and the added urea results in a higher

the pea seed is at the yellow wrinkled stage. The protein

nitrogen content. However, the disadvantage is that the

and starch are optimized at this stage (Adesogan, pers.

digestibility, particularly of the starch, appears to be

comm.). When harvested at this stage the silage should

much lower and the large increase in dry matter intake

have a crude protein content of 16–18 per cent, with

is reflected in only a small increase in milk output and

40 per cent peas in the mix. If higher crude protein

quality (Sutton *et al.* , 1997). As a result urea treatment levels are required the proportion of peas should be

of whole crop cereal silage is not recommended.

increased. In the same study digestibility is reported to

The objective should be to grow the crop as for a

be higher than grass silage when fed to sheep. A further

good grain yield with winter wheat being sown at a rate

trial showed that the total intake, milk yield and milk

of 150–200 kg/ha and spring wheat at up to 240 kg/ha. If

composition of cows fed whole crop/pea silage was a spring crop is to be undersown the seed rate should

higher than or comparable with cows fed first-cut/

be roughly half the figure just given. There will of

ryegrass silage and 4 kg more concentrate. As with fer-

course be a yield penalty with the lower sowing rate.

mented whole crop, the silage needs to be very well con-

Winter wheat should be harvested at between five and

solidated in the clamp and clamp management at

six weeks after ear emergence and at a dry matter of

feed-out must be very good.

Table 10.2

Analysis of byproducts fed to dairy cattle.

Food	DM	ME	DCP	NDF	MADF	Ca	P

Na

Mg

(%)

(MJ)

(g)

(g)

(g)

(g)

(g)

(g)

(g)

Brewers' grains

22.0

11.7

189

572

219

3.3

4.1

0.1

1.5

Cabbage

10.6

13.7

181

586

140

7.2

4.5

1.2

1.5

Carrots

13.0

12.8

62

–a

–

5.9

3.4

0.8

1.8

Parsnips

15.0

13.3

67

–

–

–

–

–

–

Potatoes

20.4

13.3

80

73

39

0.4

2.0

0.2

1.0

Pressed sugar beet pulp

25.4

12.3

60

557

259

9.0

1.1

0.6

2.0

Apples

13.6

12.2

–

111

101

0.5

0.9

0.1

0.3

Apple pomace

23.0

8.7

–

503

375

1.7

1.4

0.2

0.6

a –, no reliable information available.

Yields under a conventional system should be

Kristensen, V.F. (1995) The production and feeding of whole

around 11–12 tonnes dry matter/ha, while under

crop cereals in Denmark. In *Whole-Crop Cereals* (ed. by organic management it should be 7–10 tonnes of dry

B.A. Stark & J.M. Wilkinson). Chalcombe Publications,

matter/ha.

Lincoln, pp. 21–38.

Lampkin, N. (1990) Crop nutrition. In *Organic Farming*.

Farming Press, p. 84.

Wet byproducts used in dairy

Milk Development Council (MDC) (1995) *Making the Most*

of Whole Crop Cereals. MDC.

cow rations

Newman, G. & Luffman, B.J. (1984) Lucerne, red clover and

forge peas: management, utilization and incorporation into

The products shown in Table 10.2 can be incorporated

feed systems. In *Occasional Symposium of the British*

in winter rations for dairy cows and other stock. They

Grassland Society (ed. by D.S. Thompson), pp. 147–51.

are likely to be fed with straw and other ingredients for

Sheldrick, R.D., Newman, G. & Roberts, D.J. (1995) White

other cattle, and to supplement grass silage and act as

clover. In *Legumes for Milk and Meat*. Chalcombe Publications, Lincoln, p. 27.

a concentrate replacer for dairy cows.

Sutton, D.J., Abdalla, A.L., Phipps, R.H., Cammell, S.B. & Vegetable waste, e.g. Brussels sprouts, cabbages and

Humphries, D.J. (1997) The effect of replacement of grass

cauliflowers from vegetable processing plants, could

silage by increasing proportions of urea treated whole crop

have a similar feed value to kale. Potato waste, pressed

wheat on food intake and apparent digestibility of milk

sugar beet, peas and beans are occasionally available.

products by dairy lows. *Animal Science*, **65**, 343.

Good storage facilities and the avoidance of waste are

Thomas, C., Aston, K., Daley, S.R. & Hughes, P.M. (1982) A necessary for the above products. They will all need to

comparison of red clover with grass silage for milk produc-

fit in with the ration criteria for the appropriate class of

tion. *British Society of Animal Production Winter Meeting,* stock.

Harrogate.

Thomas, C., Aston, K. & Daley, S.R. (1985) Milk production from silage, 3. A comparison of red clover and grass silage.

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crude protein concentration of mixed swards of white

Gleadthorpe Experimental Husbandry Farm (1984) In

clover/perennial ryegrass grown without fertilizer N in an

Gleadthorpe Experimental Husbandry Farm Annual

organic farming system in the United Kingdom. *Grass and*

Review, pp. 15–17.

Forage Science, **56**, 92.

Gleadthorpe Experimental Husbandry Farm (1985) In

Wilkinson, J.M. & Stark, B.A. (1990) *Whole Crop Cereals –*

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pp. 1–86.

Part 2

DISEASE

Chapter 11

Diagnosis and Differential Diagnosis

in the Cow

R.G. Eddy and P.J.N. Pinsent

The clinical attitude

135

Thus normality is relative to environment. The vet-

The clinician's approach to the clinical case

136

erinarian, therefore, must consider the environment as

The clinical examination

136

critically as he does the patient. Is it suitable? Does it

The main presenting syndromes

138

predispose to, or even cause, the abnormality present

Drooling at the mouth (kiddling, slobbering)

138

in the patient? Does it cause stress? Remember that

Vomiting

139

the environment can only be appreciated if one con-

Acute abdominal pain (colic)

139

siders the animal’s viewpoint: for example, if it is

Acute abdominal distension

140

Anterior abdominal/posterior thoracic pain

142

thought that the ventilation in a calf house is suspect, it

Chronic bloat (chronic and subacute ruminal tympany)

146

may well be advisable to get your head down among

The liver

147

the calves!

Constipation

148

If it is accepted that disease is often related to envi-

Diarrhoea

149

ronment, nutrition or management, then it follows that

Tenesmus (straining)

150

in an adverse environment other animals in the group

The unthrifty or emaciated cow

150

may also be affected. In such circumstances, it is always

The ‘downer’ cow

151

well worthwhile looking carefully at the rest of the

The cow ill during or after calving

151

group, if necessary, animal by animal. It may well be

Pyrexia of unknown origin (PUO)

151

that others are showing the same signs albeit to a lesser

Sudden death

152

extent. Such an observation may be very helpful not

Jugular stasis (cording)

153

'Redwater' (blood or blood pigments in urine)

154

only in diagnosis, but also from the viewpoints of treat-

Cows breathing badly (hyperpnoea and dyspnoea)

155

ment and prevention.

Acute nervous and convulsive syndromes

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The veterinarians of today must concern themselves

with the health of the herd as well as the individual and

it is almost negligent to omit from the examination of

the individual cow, a look, however brief, at the other

The clinical attitude

stock in the group.

The other side of the coin is that, in unusual envi-

Veterinary clinicians must develop certain special

ronmental conditions, when you are not certain

attributes in relation to their environment. They must

whether the cow's response is normal or not, it is often
be inquisitive, questioning, curious and observant. They
very helpful to look at the rest of the group. If they are
must notice everything around them, and, if possible,
all showing the same response, then either they are all
explain it. They must always be critical in the true sense
abnormal, which is unlikely, or they represent normal-
of the word. They spend their lives diagnosing disease
ity, in which case, the patient is also normal.
and must understand quite clearly that, as health is nor-
It should be remembered that the owner and his staff
mality, then disease is simply deviation from normality.
are an important part of the patient's environment, and
From this, it follows that veterinary surgeons will never
can play a large part in the disease process and progress.
be able to detect and recognize disease, i.e. deviation
They, equally with, or perhaps even more than, other
from the normal, until they know the normal. They
environmental factors, merit critical assessment. Are
must learn the normal in all domestic species in many
they competent? Are they humane? Are they inter-

different circumstances. For normality is relative, not

ested? Are they truthful? Have they contributed to the

absolute. It is relative to breed, age, nutrition, the stage

disease process? They merit critical study, for the staff

of lactation or pregnancy, management and many other

are inextricably involved with their animals and the one

factors.

cannot be considered without the other.

The important diagnostic principles that should

(1)

The time of year. Many diseases are seasonal, e.g.

always be followed are shown below.

the coughing calf indoors in November probably

has a viral or bacterial based pneumonia, but the

(1)

Be systematic.

coughing calf at grass in August probably has

(2)

Adopt a routine that is found suitable and stick to husk.

it.

(2)

The part of the country. Each type of country has

(3)

Take nothing on trust.

its own disease problems, e.g. in the hills one meets

(4)

Apply continual critical assessment to oneself and

malignant catarrhal fever, bracken poisoning and

monitor one’s own attitudes and techniques.

piroplasmosis, while in intensive lowland dairying

(5)

Consider all the time:

areas one meets coliform mastitis, milk fever and

(a)

Is there a problem?

hypomagnesaemia.

(b)

If so, then define it.

(3)

The individual farm. The clinician will often know

(c)

Having defined it, what is best done about

that a specific farm has a particular disease

it?

problem, e.g. a parasitic problem among the

young stock, because they are overcrowded and

The clinician’s approach to

underfed.

(4)

The type of management. For example, heavily

the clinical case

stocked cubicle yards with straw bedding often

lead to environmental mastitis.

There is nothing magical about clinical work. It depends

upon care, patience, thoroughness, method and logical

Such patterns of disease become second nature to

routine; a routine of examination that covers all the

veterinary surgeons, and always hold good for the part

likely eventualities. Once having evolved such a proce-

of the country in which they work, although revision dure, there should be no short cuts without good

might be necessary in a practice 400 miles away.

reason, and, however cursory some sections of the

The clinician will, therefore, arrive at the farm with a

examination, for various reasons, sometimes have to be,

diagnosis already half formed. It will be adaptable, not

nothing should be omitted without due consideration.

dogmatic, a *working hypothesis,* to be confirmed or

refuted; however, it is quite remarkable how often this

hypothesis stands up to the test of full clinical exami-

The clinical examination

nation, and, more importantly, refutes the presence of

The owner's message

any other disease process.

Thus, if the clinician knows that the cow to be visited

The owner's message (usually termed the owner's com-

is showing convulsive signs at pasture, that it is early

plaint) should include name and full address, and may

May, that it is an intensive dairy area in Britain the

reach the clinician by direct word of mouth, by tele-

chances that the disease condition is anything other phone or by mobile or radio telephone direct to his car.

than hypomagnesaemia are too remote to be signifi-

The owner’s complaint will also include the type of

cant. Nevertheless, a clinical examination is always

animal and the main presenting syndrome, e.g. a scour-

necessary.

ing cow, a downer cow, a convulsing cow or a bloated

cow. It is important to distinguish between the owner’s

complaint and his diagnosis. The owner’s message will

History

often be in the form of a diagnosis and the clinician

must be aware that this will frequently be wrong. For

History is all important and the foundation of

example, a farmer may assume that a recumbent cow

diagnosis.

and recently calved will be suffering from milk fever.

(1)

Immediate history is the story of the present

However, a full clinical examination may reveal acute

illness.

mastitis or calving paralysis.

(2)

Past history is anything in the animal’s earlier life

There are a limited number of main presenting syn-

that may be relevant, e.g. calving and service dates,

dromes, and the clinician should learn differential lists

something similar at the same point in a previous

for each of them, to include only the major differential

lactation, and so on.

conditions, not the rarities. It should be remembered

(3)

Herd or group history is important when adverse

when considering the differential lists that the common

nutritional or management factors may be rel-

things occur commonly; that is why they are common!

evant to the present illness.

The clinician should know the main presenting syn-

drome and its differential list, and during the journey

History taking is an art – it does not come naturally,

to the farm should consider the following points.

but must be learnt and practised. After a few pleasant introductory words, questioning can begin while

(1)

One must know the normal.

walking to the animal, which may be approached, but

(2)

If the animal is frightened, pushed about or even

should not, if at all possible, be disturbed. First, look.

handled, abnormalities may appear due to annoy-

Check the owner's statements mentally by reference to

ance and fear. The minutiae that might have given

the animal and the surroundings. Do not hurry the

a diagnostic lead will be masked. Condition,

owner at first: let him or her talk, then ask your own

vigour, demeanour, respiratory pattern, appetite,

questions, checking each statement and following a

rumination, faecal passage and type, and response

routine that suits you. You are not wasting time for you

to environment should all be noted.

are, meanwhile, carrying out the next two parts of the

clinical routine.

Preliminary examination

Do not ask leading questions in the hope of
saving time, or in the hope of confirming one's half
The animal may now be touched but it is essential to
formed diagnosis, for they often produce inaccurate or
proceed quietly, with as little fuss as possible. This stage
misleading answers. Human nature being what it is,
of the examination includes the rate and character of
owners may either agree with you because they think
the pulse, the temperature and a check on skin, eye,
they ought to, or disagree because they are contra-
membranes, udder and ruminal movement. Although
suggestive.
pulse character and rate are very important, it is fre-
Study the owner or stockworkers. Are they reliable?
quently quite impossible to examine the pulse properly
Are they telling the truth? Are they covering up errors
in a modern dairy cow that has been separated from the
in management? Are they guessing? Every clinician
others, driven into a crush and clamped by the neck. It
must be interested in the human animal; after all, it is
is usually not possible to do more than check the heart

the owner whom you serve, advise, encourage or

and heart rate with a stethoscope.

console. In a way, the owner is as much your patient as

The clinician may well have arrived at a diagnosis at

the cow. Admittedly, owners seldom deliberately

this stage, but if not is probably aware of the system of

falsify their story, but it is wise to beware the guilty

the body involved. In this case, he may only need to

one, the bombastic one, the one who knows it all or the

confirm his views, by examination of that system and by

one involved in the sale or purchase of the affected

checking out the other systems quickly, even mentally.

animal.

Nevertheless, the position may still be far from clear,

and the clinician will then have to embark upon a sys-

tematic examination. The procedure so far described

Description

will have taken no more than a few minutes, but if a full

systematic examination becomes necessary, the case

A formal description is more relevant to the examina-

becomes much more time consuming.

tion of a horse, but it is often very useful for the clini-

cian to classify the animal under observation mentally

while the history is unfolding, e.g. a young Friesian cow,

Systematic examination

recently calved and heavily in milk. It is always dan-

This includes all the manual and instrumental tech-

gerous to be uncertain as to the exact type of animal

niques necessary as part of such an examination, even

under examination as it may lead to loss of face in dis-

including surgical intervention in some cases. The clini-

cussion of the case and, occasionally, even to serious

cian, according to training and inclination, may inter-

error.

pret the word systematic as meaning (i) thorough,

starting at the nose and finishing at the tail or (ii) system

by system, in which case a mental list of the systems or

Preliminary inspection/observation

sections that should be examined can be ticked off men-

Like the description, this inspection, *note* inspection not tally when satisfied.

examination, takes practically no time, and is carried

There is merit in adopting the second routine. It out during history taking. The clinician observes the

enables one to examine first the system or disease

behaviour of the animal or group of animals and

section that seems most likely to be affected from the

makes a mental note of the conditions in the animal's

preliminary evidence. Should the provisional diagnosis

environment.

be confirmed, then a great deal of time will be saved,

At this stage, do not touch, do not disturb. Stand well

for it will only be necessary to check the remaining

back and observe from a distance, looking over the pen

systems briefly, even, in some cases, mentally, to make

wall or gate. Put the picture in its frame. One is looking

sure that there is no other disease or lesion present. If

for the deviations from normality that constitute

there is no provisional diagnosis in mind, then it is rea-

disease, so:

sonable to begin the systematic examination with the

digestive system. In cows, this is the most likely cause

a logical course of treatment and, where relevant, pre-of illness in obscure cases. Subsequently, the less

vention. The clinician must be prepared to think, form

important systems and sections can be examined as

a working programme even on insufficient evidence,

necessary.

have enough confidence to convince the owner and

A logical list of systems and disease groups for exam-

enough adaptability to modify the programme tactfully

ination is as follows:

if, and when, new evidence appears.

Owners, of course, are only partly interested in diag-

• Digestive system

nosis. Prognosis is much more important to them. Will

• Respiratory system

the cow get better? Will she be fully productive again? Is

• Circulatory system

she worth treating? And today, unfortunately, another

• Urinary system

factor enters the equation. Will it be inconvenient to

• Genital system

treat the cow; will she need nursing or extra care? If so,

• Locomotory system

she is likely to be slaughtered, provided that she has

• Nervous system

antibiotic clearance and is likely to pass meat inspection.

• Skin

• Sense organs

• Lymphatic system

The main presenting syndromes

• Liver

• Udder

It is not intended to discuss here the detailed techniques

• Parasite problems

of the clinical examination of the various body systems.

• Metabolic disease

Every clinician has learnt these techniques as part

• Allergies.

of basic training, and there is excellent coverage in

The last five headings on this list are, of course, not

many textbooks, e.g. Boddie's *Diagnostic Methods in*

systems: nevertheless, they are very important disease

Veterinary Medicine (1970). Instead, this chapter sets sites (liver and udder) or disease groups that are logi-out to consider the differential diagnosis of some,

cally considered as entities on the clinician's list.

although by no means all, of the main presenting

A rectal examination is an important and useful aid

syndromes that occur from day to day in the dairy cow.

to diagnosis and must always be included if the pre-

senting signs are not conclusive. The bladder, uterus

Drooling at the mouth

and ovaries, kidney and rumen are easily palpable, as

(kiddling, slobbering)

are the caecum and small intestines if dilated.

This is due to factors causing excess salivation, or

factors preventing normal swallowing or combinations

Laboratory and special examinations

of both.

These are very important today, although increasing

costs and the decline of dairying have unfortunately

Bacterial or viral lesions in mouth

decreed that most laboratory work, apart from statu-

tory Ministry investigations, or that done in the prac-

In countries where foot-and-mouth disease (FMD) has

tice, is limited to the diagnosis of herd problems, rather
not occurred for a number of years, the possibility of
than individual cow disease.
infection must always be considered (see Chapter 43c).
It is important that the clinician should never become
Thus the UK outbreak of 2001 shows how important it
a slave to the laboratory. The laboratory investigation
is that the disease is always remembered in differential
is intended to confirm or refute the provisional diagno-
diagnosis. Its occurrence was 33 years after the last
sis (working hypothesis) already in your mind.
major outbreak. The consequences of failure to recog-
Clinical examination comes first. Laboratory results
nize this disease are quite terrifying. Any salivating
can be inaccurate, irrelevant and confusing as well as
bovine animal, whether lame or not, whether pyrexic or
expensive, but if used logically and critically they can be
not, must be treated as a possible case of foot-and-
of great help.
mouth disease until the clinician is satisfied that it is not.
Laboratory investigations include: haematology, bio-

Other pyrexic diseases with oral lesions may give cause
chemistry, bacteriology, virology, parasitology, serology,
for concern, particularly bovine virus diarrhoea
biopsy (histology) of tissues or fluids and, finally,
(BVD)/mucosal disease (see p. 853), infectious bovine
necropsy.
rhinotracheitis (IBR) (see p. 289) and occasional cases
Even after full examination, one may not have a com-
of malignant catarrhal fever (see p. 935), but, fortunately,
plete diagnosis. However, there should be sufficient evi-
the mouth lesions and signs caused by these three dis-
dence to make a provisional diagnosis, which will allow
eases are usually relatively superficial and mild.

Actinobacillosis causes mechanical difficulty in
Excess salivation of CNS origin
tongue movement. The lesion is obvious, but painless
This may be seen in lead poisoning, for the toxin affects
even when ulcerated (see p. 824).
the salivary nucleus. Blindness and aimless wandering
Calf diphtheria is limited to the young animal, causes in the cow, abdominal pain

and convulsions with bel-pain as well as difficulty in mastication or suckling and

lowing in the calf, should help the diagnosis.

produces inflammatory swelling with necrosis of the

In the ‘licking mania’ ketotic complication of milk

mucous membrane of the cheek (see pp. 250, 822, 825).

fever or in ‘nervous acetonaemia’ (see p. 794) excess

salivation is due to the compulsive chewing so charac-

Foreign bodies

teristic of the disease.

These are rare in the mouths of cattle, but the lids of

cans occasionally become wedged between the lower

Rhododendron poisoning

molars and the cheek. Rarely, a stick becomes impacted

between the rows of lower molars, or a molar itself

This may cause profuse salivation, and even vomiting,

loosens (see p. 825).

as well as diarrhoea (see p. 943).

Interference with swallowing

Organophosphorus compounds

This may be due to paralysis of the fifth or seventh

These may also cause salivation and diarrhoea (see cranial nerves which, in turn, may be due to listeriosis,

p. 940).

meningeal abscesses or, particularly in the case of the

seventh nerve, to trauma to the side of the head or face.

Acute photosensitization syndromes

Fifth nerve paralysis makes the cow unable to close her These may well cause profuse salivation, as well as

mouth completely. The lips are in apposition but the

lacrimation, jaundice and, later, the onset of necrosis of

teeth are not, a fact which is easily checked by flicking

the non-pigmented skin areas (see p. 884).

the lower jaw upwards, when the clicking together of

upper and lower molars may be heard. Fifth nerve

Acute dyspnoea

paralysis may often lead to accumulation of partly mas-

ticated food or cud in the pharynx, producing marked

This condition, as in very severe pneumonia, may cause

discomfort and gagging.

obvious salivation as a result of mouth breathing.

Seventh nerve paralysis causes unilateral or bilateral paralysis of the lips and cheek, and if of central origin,

Acute anaphylactic shock

as in listeriosis (see p. 904), also causes flaccidity of the

This often causes profuse drooling of saliva as well as

eyelids, with resultant keratitis and drooping of the ear

tachypnoea, subnormal temperature, cold extremities,

on the affected side. This condition also leads to drop-

oedema, and a very rapid heart (see p. 927).

ping of the cud bolus out of the mouth on the affected

side and thus, ultimately, to loss of condition.

Vomiting (see p. 825)

Oesophageal choke, particularly in the high oeso-

Vomiting is very rare in the cow and, to all intents and

phageal position, causes anxiety, even distress, with

purposes, only occurs in *laurel* and *rhododendron poi-arching of the neck and profuse salivation. Choke may*

soning (see p. 943). Very occasionally a peptic ulcer of also cause varying degrees of ruminal tympany (see

the abomasum will cause problems (see p. 844). Regur-

p. 826).

gitation of rumen fluid or content (false vomiting) may

Dilatation and diverticulum of the oesophagus, particu-occur in cases of acute bloat (see p. 852), acidosis (see

larly in the low cervical position, may produce similar, *p. 829) or where there are lesions in the oesophageal*

though milder, signs, as accumulation of food in the

groove (see p. 147), e.g. actinobacillosis or a foreign

diverticulum may eventually lead to blocking of the

body ('wire') (see p. 837).

oesophageal lumen, with resultant accumulation of

Occasionally, cases of oesophageal dilatation and

food and saliva above the lesion.

diverticulation may accumulate material above the

obstruction until it overflows into and out of the mouth.

Actinobacillosis of the oesophageal groove may lead not only to low-grade ruminal tympany but also to reflux of

Acute abdominal pain (colic)

ruminal and reticular fluid into the mouth, so that in

shippen-housed (i.e. tied) cows, a pool of such fluid may

It is interesting that acute colic pain of the type seen in

be found in the manager in the morning (see p. 823).

the horse is relatively rare in cattle, and several of the

syndromes that cause the most acute pain are not, in

Acute fermentative colic

fact, obstructive gut lesions, as one would expect, and

This condition, involving the caecum and colon and pro-

may not even involve the alimentary tract at all.

ducing right flank tympany, may occur on rich pasture,

particularly in wet weather, and may be difficult to dif-

Acute gut obstruction

ferentiate from acute obstructive conditions. Fortu-

This may be due to the following causes:

nately, these conditions generally respond to analgesics

and antispasmodics before serious diagnostic errors

• Abomasal torsion (see p. 842);

occur (p. 847).

• Torsion of caecum, colon, or ileum or common

mesentery (see p. 847);

• Strangulated mesenteric hernia (see p. 1113);

The passage of a calculus down the ureter

• Strangulated scrotal hernia (see p. 1113);

• Gut tie: the entrapment of gut in peritoneal tears at

This may produce the most spectacular colicky pain,

the edge of the internal inguinal ring due to castra-

which fortunately is usually relatively transient. Diag-

tion by traction in the slightly older animal (see p.

nosis is obviously extremely difficult (see p. 263).

1113);

• *Intussusception (see p. 847);*

Photosensitization involving teats

• *Obstruction of ileum by the stalk of a lipoma (see p. 849).*

Acute photosensitization (see p. 884) in cattle, e.g.

Ayrshires with sparingly pigmented teats and udders,

Abomasal or large gut torsion produces a degree,

can produce an inflammatory exudative lesion of teats

sometimes very considerable, of right-sided abdominal

and skin of the udder that is so painful that the cow

distension, not normally seen in small gut obstructions.

behaves exactly as if suffering from an acute abdomi-

In gut tie, there may be considerable distension in the

nal catastrophe. Diagnostic error will only be avoided

inguinal region, whilst scrotal hernia obviously pro-

if the clinician remembers the invariable rule that

duces distension of the scrotum on the affected side.

whatever may seem to be affecting a cow, the udder and

It is, however, very easy for the clinician to overlook

teats must always be examined.

scrotal or inguinal swelling unless aware of the pos-

sibility. These acute obstructive conditions cause the

most acute colicky abdominal pain in the very early

Acute abdominal distension

stages, but such pain is often very transient and by the

This is one of the important and relatively common pre-

time the case is presented to the veterinary surgeon,

senting syndromes in the cow. All causes of abdominal

temperature is falling, pulse rate is rising, body surfaces

distension in the cow are covered by the memory rhyme

are becoming cold and even clammy, and a dull tox-

(the seven Fs), which runs as follows: fat, fetus, fluid,

aemic and shocked appearance develops as circulatory

flatus, faeces, food or foreign body. Severe abdominal

obstruction, necrosis and gangrene of the obstructed

distension may originate at several sites.

gut supervenes. Intussusception is sometimes an excep-

tion in that many cases of bovine intussusception, par-

ticularly if large gut is involved, show little more than

Ruminal

depression and dullness even in the early stages. Rectal

Dietary ruminal impaction: This occurs in housed fat-

examination is a useful diagnostic procedure.

tening cattle on store diet, hay or straw, with limited

water (see p. 236). The massive ruminal impaction,

Acute enteritis (Chapters 14, 15, p. 850)

absence of ruminal movement, raised temperature and

Acute enteritis, particularly salmonellosis (see Chapter

pulse rate, painful frequent abdominal grunt, and hard

15), is similar to acute cereal overeating, e.g. barley

scanty faeces produce a syndrome requiring differenti-

poisoning, in that some cases show spectacularly acute

ation from acute traumatic reticuloperitonitis ('wire') abdominal pain, often with some degree of tympany,

(see p. 837) in its very early stages, although the

which remains noticeable for a considerable time, often

impactive mass in the 'wired' rumen is never so great.

several hours, before the characteristic profuse diar-

A similar condition, although much less severe, may

rhoea begins. Laparotomies have been performed on a *occur in dairy cows tied in shippens during the winter*

number of occasions at this stage of the disease in the

should the water bowl cease to function, a mishap that

belief that the condition was one of acute gut obstruc-

frequently escapes the attendant's notice, and is always

tion. Once diarrhoea appears, temperature falls often to

worth checking. Modern systems of building and man-

normal or below, while signs of dehydration, electrolyte

agement have markedly decreased the incidence of

imbalance and shock appear.

these two conditions.

Impaction of the rumen with grain (see p. 829) occurs

fails for various reasons, allowing a virulent diffuse

in cows that have broken into a food store and eaten

exudative process to spread across the peritoneal

greedily, but even when the attendant is unaware of this,

cavity. Usually, the condition stems from the break-

or will not admit it, the nature of the case generally

down of the defensive mechanisms isolating 'wire' in

becomes apparent in two to three days when profuse *reticular diaphragmatic adhesions, but the leakage or*

diarrhoea, staggering, recumbency, subnormal temper-

rupture of a superficial liver abscess may produce the

ature, rapid pulse rate and other evidence of toxic

same result.

effects occur in severe cases. In cases seen soon after

The peritoneal cavity fills with thin evil smelling pus

ingestion of large quantities of grain, palpation of the

of Arcanobacterium (Actinomyces; Corynebacterium)

left sublumbar fossa may produce the same sensation

pyogenes: there are widespread adhesions, temperature

as handling a sack of grain. If, as is generally the case

falls, pulse rate rises, scanty diarrhoea develops, body

in Britain, the grain is barley, the interim period of

condition falls away and the cow is toxic and in pain.

impaction, with arched back, grunt, depression and

The fluid wave is very obvious and confirmation by

moderate tympany is usually transient, and within a few

paracentesis is easy. The condition most likely to cause

hours the profuse diarrhoea so characteristic of barley

confusion is the massive milky ascites that may follow *poisoning appears.*

extensive liver damage and obstruction to the portal

circulation. Inspection and examination of peritoneal

Vagus indigestion (see p. 855): This condition is usually fluid provides straightforward differentiation.

a complication of ‘wire’ that has produced adhesions,

involving the medial wall of the reticulum and the

Peritoneal tympany: A gas-filled abdominal cavity may

cranial sac of the rumen, interfering with the function

occur following perforation of an abomasal ulcer at a

of the vagus nerve receptors in their walls. The atonic

point free of attached omentum, causing acute pain

rumen, gradually filling with water and saliva, eventu-

over much of the anterior abdomen, particularly on the

ally produces a massive left-sided fluid distension in a

right side. Grunting, tooth grinding, falling temperature

cow steadily losing body condition.

and rising pulse rate are followed by progressive peri-

toneal tympany due to leakage of gas from the abo-

masal lumen into the abdominal cavity.

Acute ruminal tympany (see p. 832): Acute ruminal *tympany presents relatively little diagnostic difficulty.*

The condition includes clover and kale bloat and

Abomasal

oesophageal obstruction (choke). The history, environ-

mental circumstances, season of the year and the

Dilatation and/or torsion of abomasum (see p. 842):

gagging, retching and salivating associated with most

Dilatation and/or torsion of the abomasum on the

cases of choke are generally reasonably conclusive,

right produces right-sided distension, very marked in

although in very acute cases, of course, it pays to relieve

cases of torsion, which also causes acute and even

the tympany via the left sublumbar fossa before worry-

colicky pain.

ing too much about the aetiology.

It is worth remembering that a thirsty cow, housed

Acute left abomasal displacement (see p. 839): This con-overnight in old-fashioned accommodation and

dition produces significant abdominal distension of the

released to drink its fill of very cold water, may easily

left flank, but such cases are exceptional. All abomasal *become, transiently, quite alarmingly tympanitic, due*

cases are amenable to diagnosis by normal auscultation

presumably to the chilling effect of the frosty water on

methods.

the rumen musculature.

The acute ruminal tympany of a cow that, for one

reason or another, e.g. milk fever, has collapsed into

Intestinal

lateral recumbency should not require mention. It is,

Acute tympanitic fermentative intestinal colic: This

however, surprising that it is still quite commonplace to

condition, which usually resolves without too much dif-

find that such a cow has not been supported in sternal

ficulty, can produce massive right-sided distension.

recumbency, as the condition demands.

Torsion of caecum and colon on the common mesentery

(see p. 847): This serious and usually fatal complication

Peritoneal

of fermentation and atony also produces massive

Acute diffuse peritonitis (see p. 849): This condition right-sided distension. Differentiation depends upon occurs when the special ability of the bovine peri-

demeanour, rectal examination, pulse rate and upon

toneum to withstand and localize peritoneal infection

progress of the case following initial medication.

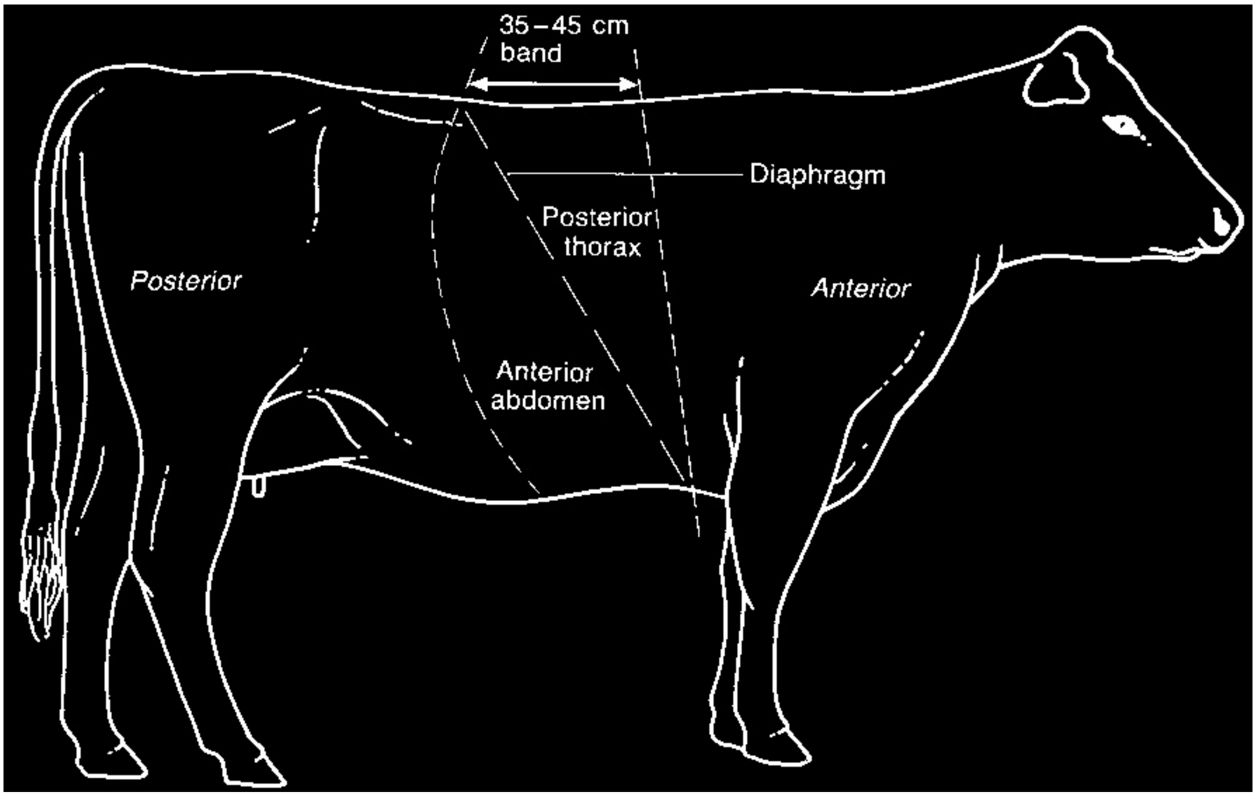

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Fig. 11.1

Lateral view of cow showing

anterior abdominal/posterior thoracic

area.

Uterine

Traumatic reticulo-peritonitis

Hydrops amnion and allantois (see p. 1119): These con-

The classical and traditional condition affecting this

ditions produce very marked abdominal distension.

area is traumatic reticulo-peritonitis (‘wire’) (see p.

Diagnosis is helped by rectal examination. Uterine

837) and it is very convenient to use this condition, less

rupture producing extra-uterine pregnancy in the last

common nowadays, but well known and recognized, as

third of pregnancy is marked by the formation of much

a yard-stick with which to compare the numerous other

fibrinous exudate in an abdomen filled with free uterine

conditions of the posterior thorax and anterior

fluid and containing fetus and membranes. Such an

abdomen.

abdomen is distended and shows a fluid wave which, on

The possibility of overlooking a penetrating foreign

rectal examination, appears to be unassociated with the

body, a serious mistake for both patient and clinician,

uterus. There is abdominal pain, rapid pulse and often

is always at the back of one’s mind when examining

severe illness. Diagnosis depends upon an accurate *a bovine abdomen. It is always a considerable relief if*

history and the ballottement of a fetus in the lower

one can eliminate the possibility of a foreign body and

abdomen, even though rectal examination reveals a

its complications, and such a process is, of course, very

partially involuted uterus.

important to the surgeon when considering the site

of a possible exploratory laparotomy. Nevertheless,

neither the confirmation nor the refutation of a provi-

Anterior abdominal/posterior thoracic pain

sional diagnosis of traumatic reticulitis is easy without

The organs and structures enclosed within a 35–45 cm

exploratory laparotomy. Thus, the clinical syndrome

band encircling the cow immediately behind the withers

presents such wide variations in both the extent and

provide a group of diseases of great importance to the

intensity of signs that it is probably true to say that the

bovine clinician. Viewed from a lateral position, the

only constant clinical sign is the presence of some

diaphragm divides this area into the posterior thorax

degree of pain in the anterior abdomen. The range of

anteriorly and dorsally, and the anterior abdomen ven-
differential diagnoses is therefore wide and includes
trally and posteriorly (Fig. 11.1).
several groups of clinical conditions, each capable of
The band described encircles lungs, mediastinum,
confusion by virtue of exhibiting one or more of the
heart, pleural cavity and great vessels in front of the
signs associated with reticulitis.
diaphragm, and rumen, reticulum, omasum, abomasum,
The acute clinical syndrome not infrequently encoun-
liver, gall-bladder, spleen and the anterior part of the
tered at the onset of the condition includes complete
peritoneal cavity posteriorly with much of the greater
inappetence, and ruminal and reticular atony, resulting
and lesser omental sheets. Differential diagnosis is
in ruminal impaction and slight tympany, with absence
often difficult and is not helped by the fact that both
of ruminal movement and cudding. Constipation may
thoracic and abdominal lesions occur within this imag-
also be a feature. Temperature may be 40–40.5°C
inary belt.

(104–105°F) with a pulse rate of 80–90/minute. There is

a marked drop in milk yield. The painful focus in the

traumatic reticulitis if seen in the early stages

anterior abdomen results in general rigidity with arched

before diffuse peritonitis, collapse and death

back and protruding neck, disinclination to lie down

occur. However, there is likely to be acute pain

and spontaneous grunting accentuated by movement,

over a much wider area of the anterior abdomen,

defaecation and micturition, and very marked on

particularly on the right side, than is the case in

pinching the withers or applying upward pressure to

reticulitis. Any temperature rise is likely to be

the xiphisternal region.

transient only, but the pulse rate will be consider-

This acute syndrome is by no means constant, even

ably in excess of that expected in reticulitis and

at the onset of reticulitis, and when present usually

may exceed 100/minute. There will be grinding of

abates in 24–36 hours as the intensity of pain lessens *the teeth and loud groaning as well as grunting of*

and varying degrees of ruminal and reticular motility

a similar type to that seen in acute reticulitis. The

return. Temperature tends to fall into the 39–39.5°C

cow will not eat, is greatly depressed and remains

(102–103°F) range, pulse rate may be in the normal

largely recumbent. In a proportion of cases,

range or slightly raised, appetite, although poor, is not

though by no means all, the abdomen becomes

completely absent, ruminal impaction and tympany

distended with gas, presumably by leakage

largely disappear and faeces regain normal consistency.

through the perforation, and a state of true peri-

The painful rigid stance relaxes and although the back

toneal tympany develops. This syndrome must

remains somewhat stiff and arched, pain may require

also be considered in the differential diagnosis of

elicitation by the clinician rather than being obviously

acute abdominal distension.

spontaneous. Rumination, however, nearly always

remains absent, or irregular and occasional.

(4)

A peritonitis syndrome varying from a very acute

In some cases the only clinical signs are slightly

picture associated with shock to a subacute picture

depressed appetite and rumination, subnormal milk

sometimes associated with straining is occasion-

yield and indications of pain so slight that they amount

ally met with as the result of penetration of the

to no more than unwillingness to depress the back, so

rectum by a foreign body, usually a broom or

that even mild and painless diseases such as aceton-

pitchfork handle, introduced through the anus by

aemia have to be considered in differential diagnosis.

a person with sadistic tendencies. Such a lesion is

always detectable by rectal examination.

Localized peritonitis

(5)

The more acute lesions of tubercular peritonitis

(see p. 863), as seen in the breakdown forms of

The acute and subacute syndromes described above

the disease, occasionally produce an abdominal *are, of course, essentially those of localized peritonitis,*

syndrome similar to that of traumatic reticulitis.

and pictures similar in broad outline will result from

Unless there are obvious coincidental signs of

other causes of localized peritonitis, although the vet-

tuberculosis, diagnosis is made only on opening

erinarian may be able to differentiate the focus of pain.

the abdomen with the intention of performing

(1)

Penetration of the involuted uterus or the vaginal

rumenotomy when the blood-streaked, caseating

fornix by a catheter or damage to the anterior

and even exudative lesions of the acute disease

vagina at service may produce a picture similar,

may be only too obvious. This syndrome is now

save for considerably less interference with ali-

rare in more developed countries but might occur

mentary motility and for pain response on

should the disease again break out.

pressure over the posterior abdomen or on

rectal examination. Such injuries frequently

Having considered the differentiation of traumatic

evoke straining, indicating the need for vaginal

reticulitis from other causes of peritonitis, one must

examination.

now be prepared to differentiate moderately severe

forms of the disease from conditions which, although

(2)

Postoperative peritonitis may well provide a syn-

not involving peritonitis, cause pain in the anterior

drome similar to that of moderately acute trau-

abdomen or posterior thorax. This question of pain in

matic reticulitis, but the fact of recent operation

the anterior abdomen or posterior thorax is, of course,

and the possibility of peritonitis resulting there-

very important in the diagnosis of reticulitis. One must

from will be obvious to the clinician, particularly

remember that the reticulum, diaphragm, liver, aboma-

after procedures such as trocharization for the

sum, omasum, heart, pleurae, oesophagus and the pos-

relief of bloat.

terior lung areas all lie approximately along the vertical

(3)

Perforation of an abomasal ulcer (see p. 844) may

line between the point at which one pinches the withers

present a picture broadly similar to that of acute

and the point at which one applies the bar.

Bacterial endocarditis (see p. 726)

sand or gravel, may occur very occasionally. There is a

slow diminution in appetite and milk yield and pro-

Classically described and reviewed by Rees Evans

gressive ruminal impaction comprising solid food mat-

(1957), bacterial endocarditis obviously requires differ-

erial with, occasionally, a little gas. Rumination ceases

entiation from other cardiac diseases, but it is not gen-

and constipation occurs. Temperature is never more

erally realized that, in its earlier stages, before signs of

than slightly raised, but pulse rate may eventually

venous congestion and circulatory stasis supervene,

exceed 100/minute. At first, there is slight anterior

endocarditis can easily be confused with traumatic reti-

abdominal pain only, but as the disease progresses, *culitis. Pain, often intermittent in nature, and causing pinching of the withers and pressure over the xiphis- rigidity of stance with abduction of the left, or both, ternum are resented markedly. Pain may, in contradis- elbows, and discomfort when pressure is applied to the tinction to the case in reticulitis, be evoked by pressure withers, xiphisternum and left ventral aspect of the over the anterior part of the right flank. The white cell chest, is probably due to infarction of the lungs or picture may be in the normal range or similar to that myocardium. This is not unlike that due to a foreign of 'wire'. Although the patient becomes much weaker body penetrating the reticulum. Once venous conges- and more depressed than is the case in reticulitis, it is tion is clinically obvious, the fact that the heart is doubtful whether differentiation will be made before diseased becomes apparent and from this point the cli- exploratory laparotomy reveals the distended doughy nician must eliminate other cardiac diseases, particu- abomasum.*

larly traumatic pericarditis.

The author believes that true abomasal impaction is

Previous to the development of venous congestion,

very rare, and that most of the cases described as abo-

accelerated respirations with dyspnoea and coughing

masal impaction in the past have shown distension of

on exercise, the peculiar 'shifting' lameness of endo-

the fundic portion of the abomasum with material like

carditis, the tendency towards a markedly high pulse

dry rumen contents and an accumulation of fluid within

rate even when temperature is responding to antibiotics

the rumen, which suggest very strongly that they are,

and the presence, in some cases, of recognizable abnor-

in fact, cases of 'vagus indigestion' (p. 855). Lym-

mality of heart sounds may all help in differentiating

phosarcoma can cause the problem (p. 693).

endocarditis from reticulitis. The author is cautious

on the subject of heart sounds, for although he has

frequently been assured by skilled cardiologists that a

Painful conditions of the liver (see p. 147)

murmur will always be audible in this disease, he has

These obviously present a problem in differentiation *frequently failed to detect one in cases with a right-*

within the group of diseases causing pain in the ante-

sided lesion. It is noticeable that endocarditis cases tend

rior abdomen or posterior thorax. The liver is a very

to retain a relatively bright demeanour and reasonable

difficult organ from the clinician's viewpoint. It is

appetite until the late stages of the disease. The white

anatomically inaccessible and, in spite of the consider-

cell picture is of limited value as many cases present

able volume of work carried out in recent years, there

total and differential counts similar to those produced

are still no entirely satisfactory tests of liver function in

by a penetrating foreign body, although there is a ten-

the bovine species.

dency for both total white cell count and neutrophil

The cow has large reserves of liver tissue, and very

percentage to be higher than in that disease.

considerable damage may occur without the production

of a clear-cut syndrome. Liver biopsy is of limited value

Certain cases of pneumonia and pleurisy

in that the portion of liver obtained may be quite unrep-

(see Chapter 49a,b)

resentative of the whole. The author prefers to make an

These conditions, particularly the latter, exhibit signs of

incision behind the last rib, in the right sublumbar fossa,

posterior thoracic pain that may simulate reticulitis and

sufficiently large to allow a manual examination of the

careful auscultation of the chest is necessary in an

liver and even, using a small torch, limited visual exam-

attempt to confirm the presence of abnormal thoracic

ination. A biopsy specimen can, if required, be obtained

sounds. Pleurisy is very painful in the early dry stages,

through such an incision with the minimum of risk.

but becomes painless as effusion develops. Respirations

are rapid and shallow, but as effusion builds up, they

Pyelonephritis (see p. 725)

become deep and swinging.

In its more severe forms pyelonephritis produces pain

that, although not sited in the anterior abdomen, can

Impaction of the abomasum (see p. 844)

easily lead to confusion with traumatic reticulitis, par-

Impaction of the abomasum, involving primarily the *ticularly as the white cell count is also usually raised. It*

pyloric outlet with large quantities of fibrous foodstuffs,

may be said that, in spite of the raised temperature and

pulse rate, the arched back and the grunt not infre-

Subacute and chronic ruminal tympany (see p. 832):

quently present, urine examination leaves the diagnosis

These do occur in traumatic reticulitis, particularly in

beyond doubt. Nevertheless, failure to observe the

the early stages, and often superimposed on a degree of

urine may easily lead to error. Rectal palpation will

ruminal impaction. A number of other conditions also

reveal an enlarged kidney or differentiate cystitis from

result in slight ruminal tympany, which forms a differ-

pyelonephritis (p. 725).

ential group in its own right (see chronic bloat, p. 832).

Impaction of the omasum

Cases of traumatic reticulitis (see p. 837) requiring Another confusing condition, which is practically

differentiation from other causes of anterior

impossible to diagnose in life, is impaction of the *abdominal pain and conditions causing stiffness*

omasum. The disease, which is fortunately very rare,

and rigidity of stance

produces slow weight loss, inappetence, low-grade

Tetanus (see p. 733): This is not infrequently misdiag-anterior abdominal pain and general dullness. Ulcer-

nosed as reticulitis in the first instance. Not only is there

ation and necrosis of the abomasal leaves are found at

subacute tympany, but the arched back, stiff unbending

post-mortem examination.

stance and marked constipation of tetanus can be quite

confusing.

Diaphragmatic hernia (see p. 848)

Bilateral solar ulcer (see p. 417), laminitis (see p. 420) In cattle diaphragmatic hernia produces signs much

and other hind foot lesions (see Chapter 31): Similarly, more suggestive of anterior abdominal pain, particularly

but with less justification, cases of bilateral solar ulcer,

reticulitis, than of any thoracic involvement. It is, in fact, laminitis (coriosis) and other painful bilateral hind foot

probable that many cases arise due to weakening of the

lesions may cause similar confusion.

diaphragmatic muscle by previous foreign body ('wire') *damage. The hernial ring is usually small, involving parts*

Injury to lower cervical vertebrae: Occasionally, cows of the reticulum and sometimes the omasum. The result-suffer injury to the lower cervical vertebrae, resulting in

ing low-grade pain may actually be due to areas of peri-

pain, stiffness and reluctance to bend the lower neck or

tonitis caused by the original ‘wire’. The interference

back, and such cases have sometimes been diagnosed as

with reticulum and omasum, due to the constriction of

traumatic reticulitis.

the hernial ring and the development of adhesions,

sometimes leads to ‘vagus indigestion’ (p. 855).

Complications of, and sequelae to, traumatic

reticulitis (see p. 837) causing confusion in diagnosis Uterine torsion (see p. 1118)

of anterior abdominal/posterior thoracic pain

It is worth remembering that the occasional cow which

(1)

Cases are encountered where a piece of wire loose

develops uterine torsion very early in parturition may

in the reticulum, by reason of its shape, repeatedly

show subacute or chronic abdominal pain with pro-

pricks the reticular wall and is then dislodged, pro-

gressive inappetence and constipation. Such a case may

ducing minor episodes of pain and localized peri-

show little or no further signs of developing labour.

tonitis that rapidly resolve. By the time operation

has been decided upon, the animal is substantially

Cases of acute traumatic reticulitis (see p. 837) with normal and surgery is withheld, only for the syn-ruminal impaction requiring differentiation from

drome to be repeated after varying intervals of

other conditions presenting this feature

time. It is possible that such ‘pricks’ should

be included with transient phases of abomasal

These conditions are discussed in the section on

displacement as the reason for many of the ‘non-

ruminal impaction and include dietary ruminal

specific inappetence’ cases so well known to every

impaction in yarded cows on fibrous feeds, e.g. hay or

bovine clinician.

straw, with limited access to water. A less spectacular

ruminal impaction may occur in dairy cows tied in ship-

(2)

A difficult problem is the case where traumatic reti-

pens during the winter should the water bowl cease to

culitis is strongly suspected and rumenotomy

function or in groups when the water supply is reduced

carried out, only to find that in spite of the presence

or ceases, e.g. freezing, bursts in piping, etc.

of definite reticular adhesions, no foreign body can

Impaction of the rumen with grain shows varying

be found. There are three possibilities. Firstly, the

degrees of ruminal distension and discomfort for

adhesions may be longstanding and bear no

varying periods before diarrhoea supervenes (p. 829).

relation to the present illness, i.e. the diagnosis is

incorrect. This possibility can be checked by apply-

syndrome previously mentioned, but with reticulorumi-

ing digital pressure to the adhesions – if pain is pro-

nal interference as well. Extensive liver lesions of this

voked, they are probably pertinent to the present

type occasionally interfere sufficiently with the bile

ill health. Secondly, the foreign body may have ducts to cause jaundice.

become dislodged and passed down the gut, or

(5)

Occasionally, traumatic reticulitis leads to acute

even regurgitated, in which case prognosis is good.

diffuse peritonitis, the abdomen filling with pus

Thirdly, the foreign body may have passed com-

and producing abdominal distension, toxaemia,

pletely through the reticular wall and be buried in

depression, weakness and diarrhoea, leading to

adhesions and reactionary tissue beyond. Here the

death (see abdominal distension, p. 140).

prognosis is obviously grave.

(6)

Vagus indigestion is also a complication of trau-

One can only advise a wait-and-see policy, but such

matic reticulitis (see abdominal distension, p. 855).

cases do present difficulties in the management of

clients who expect the production of a foreign body

and, in its absence, are frequently inclined to doubt the

Chronic bloat (chronic and subacute

diagnosis and regard the operation as an error on the

ruminal tympany) (see p. 852)

part of the clinician.

All conditions producing low-grade ruminal tympany

(3)

An occasional, but nevertheless difficult, case is

must fall into one or other of two main groups: (i) those

the cow from whose reticulum a foreign body has

affecting normal rumino-reticular tone and motility

previously been removed and which now, weeks

and (ii) those causing partial obstruction to the escape

or months later, is showing a clinical syndrome

of gas from the rumen, motility and tone remaining

suggestive of ‘wire’. Has there, in fact, been a pen-

normal.

etration by a further foreign body or are the signs

due to further infection or abscess formation in

Conditions affecting normal rumino-reticular

the old adhesions? In cases that do not respond

tone and motility

promptly to antibiotic therapy it is always wise to re-operate, for even if no further foreign body is

Chronic inflammatory lesions of the mucous membrane

involved, an abscess may be found that can be

and wall of the reticulum and the oesophageal groove:

drained into the reticulum.

Actinobacillosis of these sites is the most important

condition of this group (see p. 823). The smooth pain-

(4)

A further group of conditions occurs where a

less fibrous plaque of this disease interferes with both

foreign body penetrating the reticulum has since

eructation and rumination, producing a mild tympany

penetrated another organ. Signs, in these cases, are

most obvious after feeding. If the oesophageal groove

usually related largely to this secondary occur-

is badly affected there is often a prolonged retching gur-

rence and the signs, all-important prognostically,

gling noise as the cow makes laboured attempts to bring

of the primary foreign body aetiology tend to be

up the first bolus of a new period of rumination. There

masked. The classical example of this type of may be drooling from the mouth.

condition is traumatic pericarditis, producing a

Therapeutic response is normally rapid enough to be

syndrome very well recognized, but presenting

considered diagnostic.

considerable difficulty at times in differentiation

Occasionally,inflammatory thickening and *A. pyogenes*

from endocarditis.

abscessation of the area resulting from foreign body lac-

Penetration of the thoracic cavity to produce suppu-

erations and partial penetrations may occur,also affecting

rative pneumonia or pleurisy also occurs, tending to

eructation and rumination. Chronic ruminal atony can

produce a subacute thoracic syndrome with progressive

occur in calves with oesophageal groove problems.

loss of condition. It is of considerable importance prog-

nostically to know whether such a condition is due to

Inflammatory changes (peritonitis):

Inflammatory

a penetrating foreign body or not and it is often

changes involving the serous lining of rumen, reticulum extremely difficult, in the presence of pain in the pos-

or even abomasum are more important, leading to poor

terior thorax, to decide whether pain exists in the

motility and even atony of the rumen-reticulum. The

anterior abdomen as well. The white cell picture will

classic syndrome in this group, as already mentioned, is

not help, and exploratory laparotomy may be necessary

traumatic reticulo-peritonitis (‘wire’, p. 837). Even in as a diagnostic aid.

longstanding cases, where some degree of rumen

Similarly, foreign body penetration of the liver may

movement has returned, there may well be chronic

occur causing a large area of suppuration, which may

ruminal tympany often superimposed on low-grade

produce a clinical picture similar to the acute liver fluke

ruminal impaction.

A *peptic abomasal ulcer* (see p. 844) sufficiently

cattle (p. 698) and enlarged posterior mediastinal lymph

advanced to involve the peritoneal lining may well form

nodes in the adult. Such enlargement is an important

omental adhesions, and may even perforate among cause of chronic tympany and is usually due to one of

these adhesions, so that there is no leakage into the

three infective organisms: *A. pyogenes*, *Actinobacillus* peritoneal cavity itself. Such a cow, instead of dying

ligneresi and, occasionally, *Mycobacterium bovis*.

within 24–36 hours of acute diffuse peritonitis, toxaemia

and shock with massive peritoneal tympany, as

Diaphragmatic hernia (see p. 848): This condition also described under abdominal distension, will pass into a

not infrequently leads to chronic tympany.

state of intermittent low-grade pain, abnormal or neg-

ligible rumino-reticular movement with slight and inter-

Diagnosis of chronic and subacute ruminal tympany

mittent ruminal tympany. There will be lethargy, weight

loss and intermittent diarrhoea.

Diagnosis depends firstly upon a careful clinical exam-

ination to decide whether the tympany is related to a

Acidosis (see p. 829): This shows its classical features specific alimentary condition or whether it is due to loss

in barley poisoning, but many recently calved high-

of gastric tone as a result of a more general disease. If

yielding cows on a high-energy diet develop mild the condition is primarily alimentary, and one believes

acidosis after each feed. The slight ruminal tympany

there is no oesophageal obstruction, then auscultation

plus near-diarrhoeic faeces in a lethargic cow with sub-

should be carried out to check that the left flank

optimal appetite and milk yield is familiar in intensive

tympany is ruminal and not abomasal (i.e. left dis-

dairy herds.

placement). Auscultation should leave one in no doubt,

although it is not always easy to distinguish between a

Vagus indigestion (see p. 835): Occasional cases of

gas-filled abomasum, early vagus indigestion (p. 855)

vagus indigestion (see complications of traumatic reti-

and reticular actinobacillosis (p. 823).

culitis, p. 837, and abdominal distension, p. 140) show

an accumulation of ruminal gas forming a marked, but

chronic, tympany that may even mask the fluid present.

The liver

The liver is practically impossible to examine clinically

Tetanus (see p. 733): Tetanus frequently produces a

by normal methods. It is unfortunately true that unless moderate tympany (see rigidity of stance and gait,

one adheres to a strict routine, it is only too easy to

p. 145).

examine a cow without even thinking about the liver.

The liver has many functions and failure, therefore, may

Cold water: Under ruminal distension, the effect of

produce a variety of signs.

cold water on the ruminal musculature is mentioned.

Signs include lethargy, slow weight loss, anaemia, low-

In some herds, in which all the cows drink water from

grade or acute abdominal pain, massive abdominal

troughs in the yard, the whole herd may show a degree

haemorrhage, ascites, abdominal distension, chronic

of post-drinking tympany.

venous congestion, ataxia, ventral oedema, photosensi-

Botulism (see p. 721): With its generalized muscle

tization, endocarditis, encephalopathy, dyspnoea with

weakness, botulism shows subacute tympany as a minor

pulmonary thrombosis, massive nasal haemorrhage

part of a fatal progressive disease.

and, occasionally, jaundice. All these conditions may originate in hepatic disease. Also, one must consider the

diverse problems of the high-yielding cow calving down

Conditions causing partial obstruction to the

with a very fat liver predisposing to metritis, coliform

escape of gas from the reticulo-rumen

mastitis, ketosis, low solids, milk fever and even

Motility and tone being normal, these conditions will

infertility.

cause low-grade tympany.

The liver, it seems, not only is the site of specific

disease conditions in its own right, but also may be a

Oesophageal wall lesions (see p. 825): Usually trau-

background factor predisposing to disease in other

matic in origin, these include oesophageal stricture,

organs and systems. In the face of this diversity of signs,

oesophageal wall abscesses, oesophageal dilatation and

all one can suggest is that the clinician should always

oesophageal papillomata, which are usually sited at the

consider the possibility of liver disease when examining

cardia.

a cow. He/she is then unlikely to miss liver pathology when it occurs.

Lesions causing external pressure on the oesophagus (see Laboratory tests, e.g. haematology, serum proteins,

p. 832): These lesions will also produce chronic

serum enzymes (aspartate aminotransferase (AST),

tympany. They include thymic lymphosarcoma in young

serum alkaline phosphatase (SAP) and particularly

gamma-glutamyl transferase (gGT)), may be helpful,

fluke infestation (p. 276). This condition must never be

though by no means conclusive. Paracentesis may occa-

forgotten. It occurs in adults as well as young stock, in

sionally help in the presence of ascites, while liver

herds as well as individuals, and although wasting, sub-

biopsy is at least theoretically useful. Unfortunately,

maxillary oedema and anaemia may well be present, the

these techniques are expensive and the farmer of today

disease may merely cause chronic unthriftiness and sub-

is very unwilling to authorize them in any but the most

optimal yield during the winter months, thus needing

valuable of individual cows.

differentiation from a nutritional energy deficit. In fact,

So consideration of the liver must be as rigid a rule

both problems may occur in the same herd, particularly

as checking the udder, and a mental list of the syn-

between parturition and peak yield.

dromes involved in hepatic disease can be a great help.

It is worth remembering that in severe fluke infesta-

tion, constipation is more likely than diarrhoea, and

Abscessation (see p. 830)

that during the migratory stage of the young flukes, a

low-grade abdominal pain syndrome may occur that

This is usually due to *A. pyogenes* or *Fusobacterium* requires differentiation from ‘wire’.

necrophorum en route from the rumen, and is probably

Liver fluke infestation (see p. 276) has far-reaching

only clinically significant when extensive. Obviously,

effects. It may lead to infertility, presumably due to

cereal overeating and other conditions likely to damage

weight loss, to low milk solids and to salmonellosis, or

the rumen wall will predispose to liver abscesses. Bac-

to endocarditis due to bacteria passing to the liver and teraemias also come from navel infections and pyaemias.

then into the circulation.

Complications of hepatic abscessation may be very

Cirrhosis also results from ragwort poisoning (p. 945),

serious:

causing weight loss, ataxia, encephalopathy, occasional

• Rupture into the abdominal cavity leading to an

jaundice and terminal tenesmus in the affected animal.

acute diffuse peritonitis.

The encephalopathy produces blindness, head pressing

• Rupture into a major vessel, leading to major haem-

and dragging of the hind fetlocks reminiscent of lead poi-

orrhage, shock and sudden death.

soning in the adult cow. Ragwort poisoning during the

• Vena cava thrombosis, usually where the vena cava

grazing period may well trigger photosensitization.

passes through the diaphragm. This produce

hepatic portal obstruction leading to abdominal dis-

tension and ascites; however, it may produce pul-

Other syndromes involved in liver disease

monary thromboembolism leading to pulmonary

Tuberculosis (see p. 862) and *neoplasia* of the liver are abscessation. There will be a painful cough, and dys-relatively rare. Neoplasia includes lymphosarcoma

pnoea, with rupture of abscesses into blood vessels

and adenocarcinoma and is, to all intents and purposes,

producing severe and often recurrent haemorrhage

impossible to diagnose in life, while fatty livers

via the nose and mouth (see p. 867).

may follow bacterial or chemical toxicity, but are much

more common as the result of overfeeding or inappro-

Hepatic necrosis

priate feeding.

Hepatic necrosis due to *Fusobacterium* invasion causes The fatty liver syndrome (see p. 801), resulting from

pyrexia, inappetence, lethargy, rapid pulse, weight loss,

excessive weight gain pre partum, has gained promi-

ataxia and occasionally signs of anterior abdominal

nence in recent years, but is probably less common

pain. The presence of jaundice is variable, but is diag-

today. The syndrome may be involved in many diseases

nostically helpful when it occurs.

in early lactation.

Cholecystitis

Constipation

This condition is rare and difficult to diagnose. Such

Quite apart from the acute gut obstruction syndromes,

cases show ataxia, anterior abdominal discomfort and

constipation may occur in diverse circumstances in

jaundice, with lowered appetite and milk yield. Tem-

cattle.

perature may be raised.

It is interesting that jaundice is much more likely

(1)

Unsuitable fibrous diet, e.g. straw, may produce

to occur in obstructive hepatic conditions than in

ruminal impaction.

parenchymatous change.

(2)

Insufficient water intake may produce ruminal

impaction.

Cirrhosis

(3)

External pressure on the gut, e.g. fat necrosis (see

Cirrhosis in cattle, for all practical purposes, means liver

p. 849), lymphosarcoma (see p. 693), adhesions.

(4)

Pain:

Chronic diarrhoea

(a)

Postoperative pain.

(1)

Johne's disease (see p. 857): the classical form of

(b)

Injured back – faeces dry out in rectum.

chronic diarrhoea with loss of weight, particularly

(c)

Injured anus and rectum – painful bladder.

from the hindquarters, ventral and submaxillary

(5)

Weakness or paresis: milk fever, broken back.

oedema and anaemia.

Constipation is, of course, a very useful differen-

(2)

Tuberculosis of the intestine (see p. 862), very rare tial sign of milk fever (p. 781).

today, is always secondary to pulmonary lesions,

(6)

Some poisons, e.g. lead (see p. 944) and ragwort

and is similar, clinically, to Johne's disease.

(p. 945).

(3)

Ulceration of the abomasum (see p. 844) produces

(7)

Pyrexia.

scanty and intermittent diarrhoea in a cow losing

(8)

Anaemia. e.g. fluke (see p. 276), piroplasmosis

weight, becoming anaemic and showing signs of low-

(see p. 748). In both these diseases, constipation

grade anterior abdominal pain. Erosion of such an

becomes very marked in long-standing cases.

ulcer into a blood vessel in the abomasal wall pro-

(9)

Ketosis: mild constipation is a frequent clinical

duces more profuse,tarry faeces and may cause death.

sign (see p. 793).

(4)

Amyloidosis is very rare indeed (see p. 928).

(10)

Hypocalcaemia (see p. 781).

(5)

Lymphosarcoma of the large gut is also very rare

(11)

Peritonitis (see p. 849).

in cattle (see p. 693).

Constipation is, of course, rare in dairy cattle and if

faeces are completely absent, acute gut obstruction (p.

Herd diarrhoea

1113) caused by intussusception (p. 847), caecal or intes-

tinal torsion (pp. 846, 847) will be the most likely reason.

(1)

Winter scours, or winter dysentery, has long been

recognized as an acute, pyrexic and occasionally

Diarrhoea

slightly dysenteric condition, which races through

a housed dairy herd in winter conditions and then

Varying degrees of diarrhoea are normal today in inten-

dies out with minimal long-term damage. There

sive dairy herds feeding concentrates and silage.

has been discussion as to the aetiological organ-

Not all conditions causing diarrhoea originate pri-

ism, various viruses and *Campylobacter* spp.

marily in the digestive tract, but from the viewpoint of

having been incriminated (see p. 852).

differential diagnosis, it is best to consider all conditions

(2)

Various nutritional diarrhoeas:

causing diarrhoea together.

(a)

Spring grass.

(b)

Frosted roots or kale.

Acute diarrhoea

(c)

Fodder beet poisoning, the leaves of which

causes a hypocalcaemia-like syndrome and

(1)

Most toxaemic conditions produce diarrhoea, e.g.

diarrhoea.

diffuse peritonitis (p. 849), acute mastitis (staphy-

(d)

Acidosis (see p. 829), whether due to exces-

lococcal, coliform or *A. pyogenes* (Chapters 23,

sive root feeding or more commonly due to

24)), acute septic metritis (p. 519), traumatic peri-

excessive cereal overload. The classical aci-

carditis. These conditions all involve damage by

dosis syndrome is that of barley poisoning

bacterial toxins, and the diarrhoeic faeces tend to

with its acute abdominal pain and low-grade

be relatively scanty, but dark and sticky with a

tympany, followed by profuse diarrhoea (see

fetid odour.

p. 830).

(2)

Several acute septicaemic diseases are associated

(3)

Mineral deficiencies, e.g. copper (see pp. 254, 298) with acute enteritis and diarrhoea, e.g. anthrax

and cobalt (see p. 295) deficiency, producing

(see p. 717), transit fever (see p. 286) and other

chronic diarrhoea with weight loss and anaemia.

forms of acute pasteurellosis (see p. 728), and, of

(4)

Parasitic diarrhoea, e.g. parasitic gastroenteritis

course, salmonellosis (see Chapter 15).

(see p. 267) and coccidiosis (see p. 282), largely

(3)

Some virus diseases, e.g. malignant catarrhal fever

affecting young stock.

(see p. 935) or the BVD/mucosal disease complex

(5)

Toxicity, e.g. antibiotic contamination of the feed.

(see p. 853).

(4)

Several plant poisons, e.g. solanin from green

There is no easy way to diagnose the diarrhoeic

potatoes (see p. 943), water dropwort (see p. 943),

animal. It is necessary to consider all environmental and rhododendron (see p. 943).

factors, including nutrition, stage of lactation, season of

(5)

Several chemical poisons, e.g. arsenic (see p. 941)

year, housing or pasture; whether the condition is an

and certain organophosphorus compounds (see p.

individual animal or herd problem and whether it is

940).

acute or chronic in nature.

Other signs besides diarrhoea may indicate whether

months when autumn-calved cows are at peak yield and

the faecal changes are due to a primary gut problem or

possibly in energy deficit, accentuates the whole picture

are secondary to a systemic disease.

of energy deficit and ketosis.

Finally, one must utilize whatever laboratory tests

for bacteria, parasites, viruses or minerals are available

Chronic hypomagnesaemia (see p. 787)

under the circumstances. Even so, there will be one-off

In cold windy weather in late winter, heavily pregnant conditions, rarely met with in one's practice area, which

cattle develop a state of chronic hypomagnesaemia as

will, from time to time, elude the diagnostic net!

a result of low food intake and cold, becoming thinner

and poorer until some additional stress triggers off the

Tenesmus (straining) (see p. 838)

acute convulsive phase.

This condition occasionally occurs in cattle. *Coccidiosis*

(see p. 282) in calves is an excellent example due to

These four conditions, interconnected to varying

painful inflammatory changes in the hindgut. The

degrees, account for much of the unthriftiness found

BVD/mucosal disease (see p. 853) complex in young

in dairy herds. A further condition, which may also be

stock may have the same effect. Straining is also seen

involved, is copper deficiency (p. 298).

in the late stages of *ragwort poisoning* (see p. 945), in occasional cases of
terminal intussusception (see p. 847) *Copper deficiency* (see p. 298)

and sometimes in *urolithiasis in the male* (see p. 263).

Copper deficiency may be either in its own right or

It may also follow *sadistic human behaviour*, when resulting from molybdenum excess. In the latter case,

sticks or broom handles have been forced into the

there will be diarrhoea, but many herds exist in a low-

rectum, frequently penetrating the wall of the hind gut

grade copper deficiency, particularly at the beginning of

some 30–45 cm (12–18 inches) proximal to the anus.

the grazing season when the rapid grass growth dilutes

Occasionally, there will be sufficient straining to pass

the copper uptake, with weight loss and infertility the

hard dry faeces in the cow with milk fever of some

only signs.

hours duration, to produce transient doubt in the atten-

dant's mind as to the possibility of there being a further

Other conditions leading to weight loss

calf *in utero*. Obviously, the most frequent causes of

straining in the cow are obstetrical, e.g. parturition, dys-

On an individual animal basis, Johne's disease (p. 857),

tokia (p. 1115) or vaginal injury (p. 519).

which does not always cause diarrhoea in the early

Rectal examination may make things much worse if

stages, and, historically, tubercular emaciation (p. 862) tenesmus is marked, but a look at the mucous mem-

are important causes of weight loss, as are abomasal

brane just within the anus with a pencil torch may be

disorders such as left displacement (p. 839) and ulcera-

very helpful. In coccidiosis, cryptosporidosis and the

tion (p. 844). Chronic liver disorders, e.g. ragwort toxi-

BVD complex, particularly, the acutely inflamed nature

city (p. 943) or multiple abscessation (p. 829), may also

of the hindgut often spreads right to the anus itself.

result in poor thriving to the point of emaciation before

clear-cut aetiological pointers appear.

The unthrifty or emaciated cow

A number of other conditions lead to weight loss

and suboptimal yield, but reasonable and sensible

Starvation

clinical examination should produce a definitive diag-

Even in developed countries today, starvation can still

nosis without real problems. These conditions include

be seen in poorer areas as a primary condition, but

the following.

much more frequently appears as a relative energy

• Lameness (laminitis, solar ulcer and white line

deficit in high-yielding cows near peak yield. In the

lesions) (Chapter 31), often ignored by farmers who

period from parturition to peak yield, it is frequently

completely fail to realize the serious nature of the

associated with ketosis.

long-term effects.

• Chronic pyelonephritis (see p. 725), which should

Ketosis (see p. 793)

be obvious provided the clinician remembers to

Ketosis is nothing more nor less than energy deficit and

examine the urine.

may if untreated produce very severe weight loss.

• Actinobacillosis of the tongue or oesophageal

groove area, already discussed on pp. 823–6.

Liver fluke infestation

• Paralysis of the fifth or seventh cranial nerve.

(see p. 276)

• The long-term toxic and depressing effects of

Liver fluke infestation, reaching its most dangerous in

mastitis, metritis, or postoperative peritonitis with terms of liver damage in the late autumn and winter

adhesions and peritoneal abscessation.

The 'downer' cow (see pp. 439, 797)

• Acute staphylococcal (see p. 332) or coliform (see

p. 334) mastitis.

A 'downer' cow used to be defined as a cow that

• Acute septic metritis (see p. 519).

remained recumbent after treatment for milk fever due

• Hypomagnesaemia (see p. 787).

to a continuing hypophosphataemia (p. 791). But, by

• Cereal over-eating: acidosis (see p. 829).

general usage, the term has come to mean any cow

• Fodder beet poisoning (see p. 149).

recumbent at, or near, parturition, and thus there is a

• Botulism: a condition increasing in frequency and

large differential list.

associated with the feeding of big bale silage. Diag-

nosis is aided by a normal temperature, slow pulse

Preparturient

rate and slowly progressive generalized muscular weakness affecting both voluntary and involuntary

• Liver fluke (see p. 276) and/or starvation (see p.

muscle (see p. 721).

796). These cows may have cirrhotic livers. They are

• Internal haemorrhage, with fast pounding heart,

thin, weak and lethargic, but not ketotic.

white membranes, rapid respirations and often a

• The fat cow syndrome (see p. 796). Occasionally,

subnormal temperature.

grossly fat preparturient cows with pathologically

fatty livers may become recumbent.

Diagnosis of the ‘downer’ cow is never easy, unless

there is an obvious major fracture.

It is important that every ‘downer’ cow should be

Parturient

given full doses of calcium and phosphorus, and possibly

(1)

Prolonged dystokia may lead to exhaustion.

also magnesium. It may be very logical to argue that a

(2)

Rupture of cervix or uterus leads to recumbency particular cow cannot possibly be a case of hypocal-

through shock and is quickly fatal.

caemia, but it is easy to be wrong. It is much safer to treat, (3)

Traction injuries.

just in case. With reasonable care no harm can be done.

(a)

Sacroiliac disarticulation (see p. 448).

Once satisfied that metabolic possibilities have been

(b)

Sciatic nerve paralysis (see p. 439).

covered, a careful examination of the available parts of

(c)

Torn adductor muscles (see pp. 439, 459).

the skeleton should be carried out, but may not be very

(d)

Fractured pelvis (see p. 446).

fruitful. It is not easy to assess injuries to the legs of a

(e)

Fractured femur (see pp. 441, 444).

‘downer’ cow deep in sludge or slurry!

(f)

Peroneal paralysis, which is much more

It is vital that the udder and the uterus should be prop-

likely to occur after milk fever than after

erly checked and, as far as the udder is concerned, every parturition, because it is secondary to muscle

quarter must be examined however difficult access may

atony in recumbency (see p. 438).

be.

Parturient and postparturient

The cow ill during or after calving

• Complications of milk fever (see p. 781)

There is no excuse in cases of periparturient illness for

• Fractures, dislocation and muscle injuries (see

the taking of any form of short cut. The clinician must

Chapter 32).

be satisfied that the cow has not developed any form of

• Ruptured gastrocnemius (see p. 451).

milk fever, and even when satisfied, it may be wise to

• Peroneal paralysis (see p. 438).

give calcium/magnesium mixture subcutaneously as a

• Sciatic nerve paralysis (sensory and motor) (see precautionary measure.

p. 439).

The uterus must be examined to make sure that it is

• Pressure ischaemia of hindleg or legs, which may

not infected and not damaged and, above all else, that

lead to ischaemic muscle degeneration, particularly

there are no more calves within. Even after removing the

the semimembranosus and semitendinosis muscles.

third calf, the uterus should be checked for the fourth!

Serum AST and creatine phosphokinase levels rise

It is essential that the udder is properly examined. A

markedly (see p. 439).

parturient dairy cow may be very ill and dangerously

• Ketosis and licking mania (see p. 793).

toxaemic before the udder shows more than a small

• The cows seems bright and well, but stays down.

crepitating area just above the teat, and that may be all

Never attempt to make a cow with milk fever get

that is noticeable in some cases.

up before it is entirely ready to do so (see p. 797).

Pyrexia of unknown origin (PUO)

Notice that the following conditions are all important

in the differential diagnosis of the ‘downer’ cow (see pp.

Obviously, many conditions may cause a marked rise

439, 797).

of temperature in a cow, but a lethargic cow with a

temperature of 40.5–41°C (105–106°F) is more likely to

chauvoei and bruising of muscle groups predisposes

be a case of incipient mastitis (Chapter 23) than any-

to the problem (see p. 723).

thing else, and should always be treated as such in the

• Wound gas gangrene infections: other clostridial

absence of other signs.

organisms involved in wound infections, usually

The next possibility is an active pulmonary hyper-

obvious at post mortem (see p. 724).

aemia as an early stage of pneumonia, while an acute

Occasional cases of acute coliform (see p. 334) infec-

septicaemic condition, such as salmonellosis (Chapter

tions, salmonellosis (see Chapter 15), pasteurellosis (see

15), may show pyrexia and little else for some 8–12 pp. 281, 728) and RSV pneumonia may produce a very

hours before diarrhoea supervenes. A rectal examina-

rapid, sudden and unexpected death.

tion may discover diarrhoea in the early stages that will

not have been seen by the stockman. During this

period, the total white cell count may be as low as

Acute pasture conditions

1500–2000 per mm3, with a neutrophil percentage of

• Bloat: classical signs and environment, with a

less than 10 per cent.

reasonably clear post-mortem picture, provided

One should remember that *anthrax* (see p. 717) is

that the carcass is examined within an hour or so of

also an acute septicaemic condition, and there have

death (see p. 832).

been many cases of early anthrax where lethargy and a

• Hypomagnesaemia: classical convulsive syndrome

temperature of 41–42°C (106–108°F) are the only signs

on spring grass. The carcass is often covered with

present. In young stock, severe diarrhoea, often

debris, sweat and mud, with signs of convulsive bloodstained, with injected membranes, may supervene

movement in the grass for a considerable distance

within a few hours to be followed by ataxia, collapse

around (see p. 787).

and death. In the adult cow, it is not infrequent for the

• Fog fever: occurs in late summer or early autumn.

hyperpyrexic early anthrax picture to be followed by

As it is a herd problem there are usually other

collapse, subnormal temperature, clammy skin, cyanotic

animals with signs. The lungs show a fairly charac-

mucous membranes, restlessness and anxiety, followed

teristic post-mortem picture (see p. 866).

quickly by coma and death. The clinician must beware

of a stage in this process when the cold recumbent cow

is easily mistaken for a severe milk fever case. Realiza-

Electrocution and lightning strike (see p. 930)

tion will come when it is seen that injection sites are

There may be no signs whatsoever on the carcass, partic-

trickling dark blood, while spreading haematomata

ularly in electrocution cases. The behaviour of neigh-

appear where a vaginal examination has been perbouring cows, if there is any witness, may help in

formed, the teats have been handled or the stockworker

electrocution, while it goes without saying that if a cow is

has gripped the cow’s nose.

to be struck by lightning, there must be a thunderstorm.

Sudden death

Accident or catastrophe

This is a dangerously misleading heading. Very many

Road traffic accidents do occur but strangulation and

cows that the owner regards as cases of sudden

asphyxiation as a result of faulty yokes and feed trough

death are in fact cows found dead, which is quite a

fittings are probably more common.

different matter. A cow found dead may well have

Catastrophes also include such events as a wire in the

taken 12 hours or more to die, depending on the dili-

reticular wall being forced in one movement into the

gence of the stockworker and when the cow was last

heart. The perforated abomasal ulcer leading to shock,

seen.

peritoneal tympany and toxaemia is also included in

If one can assume that sudden death means that a

this grouping.

cow has collapsed and died, if not immediately then

within the hour, then the differential diagnosis is fairly

clear-cut.

Acute haemorrhage

This may result from the following:

Acute infections

• Wire penetration into a great vessel.

• Anthrax: every case of sudden death is anthrax until

• Mammary vein rupture following injury.

proved otherwise (see p. 717).

• Teat vessel haemorrhage following injury.

• Blackleg (see p. 723): usually young stock but may

• The rupture of a coronary vessel.

occur in young adults. The lesion is usually obvious

• The erosion of an abomasal ulcer into an artery in

at post mortem. The causal organism is *Clostridium*

the abomasal wall.

• Damage to uterine or vaginal vessels after forced

Nevertheless, the more common causes of jugular

traction in dystokia cases.

stasis (distension) stem from the heart itself.

• The erosion of a hepatic abscess into a major vessel.

• A thromboembolic pulmonary lesion originating

Traumatic pericarditis (see p. 731)

from liver (see p. 867).

• A superficial haemangioma, often sited dorsally in

Previously the most common form of cardiac disease in

the lumbar sacral area.

the cow, this condition has now become relatively rare

• Occasional acute cases of the pyrexia, pruritis and

in Great Britain.

haemorrhage syndrome (see p. 884) bleed from the

gut, and all other tissues. They also show raised

Chronic vegetative endocarditis (see p. 726)

temperature, severe general pruritis and aggressive

behaviour before collapse and death.

This condition has become much more frequent. It is

probable that, 30 years ago, many cases of endocarditis

It should be noted that all these haemorrhagic

were missed completely for the clinician was so used to
syndromes, with the exception of rupture of a coronary
'wire' and pericarditis that all cases of congestive heart
vessel, may not necessarily produce immediate death,
failure were diagnosed as pericarditis and sent to the
but may instead produce a cold, staggering and severely
knacker's yard after the most superficial examination.
anaemic animal with rapid pulse rate, rapid respirations,
There are a number of important clinical differences.
loudly beating heart and subnormal temperature. Early
The pericarditis case is much more toxaemic and there-
anthrax, peracute salmonellosis, acute babesiosis and
fore more depressed. Transition from relative health to
acute bracken poisoning may produce the same col-
acute illness is much more sudden, although there may,
lapsed and anaemic syndrome.
of course, have been low-grade reticulitis signs at some
previous stage. Pain is more marked and very readily
Acute anaphylactic reactions (see p. 927)
elicited by wither pinching. Cardiac sounds start with
slight friction sounds synchronous with the heart beat,

There may be much saliva around the mouth with

which is usually more than 100/minute. Within a day or

oedema of the larynx, pharynx, eyelids, skin of face and

so, the tinkling splashing sounds indicative of gas/fluid

head, etc. On the other hand, the only lesions may be

production within the pericardium can be heard, and in

pulmonary.

a further day or so the sac is grossly distended with pus,

and splashing and tinkling have ceased. The heart

Poisons (see Chapter 54)

sounds are now muffled and may, in fact, be louder on

Theoretically, a number of poisons may cause sudden

the right side because the pressure of the distended

death in the cow but, practically, sudden death by

pericardium against the left thoracic wall tends to

poisoning will be due to one of the following:

extend the whole structure across to the right.

Gross jugular and mammary engorgement and

• Yew (see p. 947);

dependent oedema will now be present at jaw, neck,

• Water dropwort (see p. 943);

brisket and lower abdomen. Pulse rate may well reach

• Bracken: acutely haemorrhagic (see p. 946);

140/minute.

• Strychnine: rarely found today in Britain;

Endocarditis, on the other hand, runs a more gradual

• Arsenic: rarely found today (see p. 941);

course. For some time, the picture may be one of low-

• Lead: may cause sudden death in calves, but not

grade anterior abdominal pain, plus a temperature rise

usually in cows (see pp. 906, 944);

to 40–41°C (104–106°F). Pain is felt over a much wider

• Copper (see p. 948).

area of the chest. The pulse rate is not generally very

greatly raised at first. The cow is often relatively bright

Jugular stasis (cording)

and may even eat a little, but exercise tolerance is very

Care must be taken in the interpretation of jugular

poor. Heart sounds, at first, are often no more than

stasis. There is often confusion between jugular stasis

loud, and even later in the disease it is not always pos-

and jugular pulsation, and it must be emphasized that

sible for ordinary mortals to hear the cardiac murmur
jugular pulsation may occur in perfectly normal cows,
that is stated to be invariably present in this disease. The
especially if the head is held low as while grazing.
reason for this seems to be that, in most cases, the lesion
Jugular stasis may occur in conditions involving
is right-sided.
space-occupying lesions in the anterior mediastinum,
At first, therefore, and for several days at least,
e.g. thymic lymphosarcomata in young stock, mediasti-
vegetative endocarditis falls within the anterior
nal lymphosarcomata in the adult (p. 693) or large
abdominal/posterior thoracic pain grouping and is
mediastinal abscesses.
easily mistaken for 'wire'. There may even be a wire, for

although most cases derive the valvular infection from
Haematuria
the rumen via the liver, from the udder, uterus, pharynx
or feet, occasional cases are met in which the primary
• Chronic cystic haematuria (enzootic haematuria

(see p. 947) or chronic bracken poisoning (see p.

pyogenic focus is a penetrating reticular foreign body.

946));

It is interesting that, in most cases of vegetative

endocarditis, the white cell count and the temperature

• Pyelonephritis (see p. 725);

fall during antibiotic treatment, but the pulse rate is

• Calculi (see p. 263);

unaffected.

• Neoplasia other than is involved in the first list point.

Eventually, jugular congestion, shifting lameness,

These four conditions show primary lesions within

dependent oedema, pulmonary signs, and even haema-

the urinary tract.

turia may all appear.

Enzootic haematuria (see p. 946) has a regional inci-

In right-sided cases, pulmonary thromboembolism

dence dependent upon the prevalence of bracken. It

may cause marked thoracic pain, whilst ascites and

tends to occur in older home reared cows and the blood

engorged mammary and jugular veins are very notice-in the urine, slight at first and slowly increasing, contains

able. In left-sided cases, pulmonary congestion causes

very little pus or exudative material.

dyspnoea and coughing with less pain, but haematuria

due to renal infarction is more likely.

Pyelonephritis (see p. 725) is much more likely to be

encountered in dairy herds, but is, for some reason, a

rare disease today in Britain compared with its inci-

Myocardial abscesses

dence in the 1950s and 1960s.

Myocardial abscesses of considerable size may some-

There are systemic signs varying from very acute to

times occur, producing a clinical picture similar to that

very mild, but diagnosis is greatly assisted by the pres-

of endocarditis, but with lower temperature rises and a

ence of pus, debris and renal casts, as well as blood, in

slower course.

the urine. Rectal examination may help and the pres-

ence of pain is another differential point, for enzootic

haematuria is painless and afebrile. Bacteriology on the

Other causes of jugular stasis

urine of pyelonephritis may, in fairly early cases,

Fatty degeneration of the heart, and tubercular peri-

produce a culture of *Corynebacterium renale*, which is

carditis, are usually masked by more obvious systemic

the primary causal organism. Remember that the pain,

signs of the respective diseases.

the temperature and the arched back invite confusion

with 'wire' unless the clinician keeps pyelonephritis in

mind in such cases, particularly in the first third of

'Redwater' (blood or blood pigments

lactation, and insists on inspecting a urine sample.

in urine)

Urolithiasis (see p. 263) occurs largely in the young male, With very few exceptions, disease of the urinary tract in

and other signs such as straining, the absence of sig-

cattle produces significant urinary haemorrhage, and

nificant amounts of urine and, eventually, 'water belly'

the differential diagnosis obviously includes the numer-

overshadow the presence of blood spots in the urine.

ous haemolytic conditions producing urinary haemo-

globin.

Neoplasia of the urinary tract, other than that due to Obviously, therefore, when presented with a ‘redwa-chronic bracken poisoning, is very rare.

ter’ case, the first stage in diagnosis is to decide whether

the case is one of haematuria or haemoglobinuria.

A number of conditions occur in which haematuria is

Microscopical examination or centrifuging the urine

but one of a number of fairly obvious systemic signs, so

will supply the answer, but usually the simple expedi-

that the urinary blood, when present, is not important

ent of standing some urine in a container for a few

in diagnosis:

minutes, while clinical examination is proceeding, will

give a satisfactory answer. The clinician must remem-

• Vegetative endocarditis (see p. 726).

ber that many cows with redwater are not presented as

• Septicaemic conditions, e.g. anthrax (see p. 717) and

acute pasteurellosis (see pp. 286, 728).

such, for stockworkers rarely notice or even see a cow

urinate, except by chance. If asked whether the urine is

• Acute bracken poisoning: a disease with markedly

raised temperatures and generalized haemorrhages, normal, the invariable answer is that it must be or it

which behaves like an acute septicaemia and prob-

would have been noticed. This is wishful thinking, upon

ably is one (p. 946).

which no reliance can be placed.

Once differentiation between blood and blood

It is worth remembering that very high doses of sul-

pigment has been made, diagnosis becomes much easier.

phonamides may theoretically produce crystalluria and

haematuria, but sulphapyridine, the sulphonamide that

comment on a cow's respiratory pattern, it is always

most frequently produced these signs, is no longer used.

worth comparing it with that of neighbouring cows.

Haemoglobinuria

Pathological

Piroplasmosis is an acute, pyrexic, and acutely

Respiratory rates:

haemolytic tick-borne disease of certain areas of Britain

and other countries caused by *Babesia divergens*. The

(1)

Increase markedly in many diseases due to

clinical signs include profuse diarrhoea, followed by

pyrexia.

stubborn constipation in a non-premune cow, progres-

(2)

Increase and become jerky in acutely painful con-

sive anaemia, with very rapid pulse rate, loudly pound-

ditions, e.g. septic feet, acute laminitis (see p. 417).

ing heart, and deep port wine coloured urine (see p. 748).

(3)

Increase in acute toxaemic conditions, e.g. summer

mastitis (Chapter 24), coliform mastitis (see p.

Bacillary haemoglobinuria is a peracute and rapidly

334) and acute septic metritis (see p. 519).

fatal pyrexic disease due to *Clostridium haemolyticum*

(4)

Increase in metabolic disease, e.g. hypomagne-

(now renamed *Cl. oedematiens* type II). It affects young saemia (see p. 787) or acidosis (see p. 829).

stock in certain rough hill areas, but is of relatively little (5)

Increase markedly with a much shallower thoracic importance overall (see p. 719).

excursion in conditions that prevent full pul-

Postparturient haemoglobinuria is seen during the

monary expansion, e.g. ruminal tympany, ruminal

weeks following parturition in cows in certain parts of

impaction and pleural effusion.

eastern Scotland and occasionally in England. It is non-

(6)

Increase in conditions in which the upper respira-

febrile, but progressive and frequently fatal due to very

tory tract is blocked at least in part, e.g. malignant

severe anaemia, and is possibly associated with root and

catarrhal fever, IBR (see p. 289) and pharyngitis.

straw feeding and abnormalities in phosphorus metab-

(7)

Increase and become shallow in conditions that

olism. It is too rare today to be of real significance (see

interfere with the function of the respiratory

p. 792).

muscles, e.g. tetanus (see p. 733).

(8)

Increase very markedly in severe anaemic

Kale and rape poisoning are too well known to merit

conditions, e.g. piroplasmosis (see p. 748) and

detailed consideration. Large quantities are required

haemorrhage.

and wilted kale is much less likely to cause problems. It

(9)

Increase and become laboured in conditions that,

is worth remembering that rape in excess may also

for various reasons, decrease the amount of active

produce abdominal pain, nervous signs and/or dysp-

lung tissue, for example:

noea (see p. 941).

(a)

active pulmonary congestion prior to pneu-

Leptospira icterohaemorrhagiae produces haemoglo-

monia (see p. 860);

binuria in the calf, but this is most unlikely to occur in

(b)

chronic venous congestion, e.g. vegetative

the adult (see p. 735).

endocarditis (see p. 726);

(c)

acute anaphylactic conditions (see p. 927);

Very cold water, thirstily drunk, may cause haemoglo-

(d)

'fog fever' (acute pulmonary oedema and

binuria in the calf, but not in the adult.

emphysema) (see p. 866); and

Copper toxicity, increasing in the UK, may apparently

(e)

pneumonia (see p. 864).

produce haemoglobinuria (see p. 948).

Acute nervous and convulsive syndromes

Cows breathing badly (hyperpnoea and

Nervous signs occur relatively frequently in cattle of all

dyspnoea)

ages, and vary from mild signs of ataxia and head press-

The clinician must not assume that rapid respirations in

ing on the one hand to hyperaesthesia, circling, muscu-

cattle necessarily indicate the presence of pneumonia.

lar tremors, aggression, collapse and convulsions, on the

Cattle ‘blow’ for many reasons.

other.

Physiological

Acute hypomagnesaemia (see p. 787)

Cattle breathe more rapidly when full after feeding,

This condition occurs in dairy cattle on heavily fertil-

after exercise, in hot and humid weather and when they

ized high-protein pasture at turn-out in spring, and

are nervous or frightened. A herd coming in for milking

again in the autumn. It also occurs in winter and early

on a hot summer afternoon after a mile walk from lush

spring in beef cattle on exposed pasture. Hyperaesthe-

grazing may all appear dyspnoeic! When asked to

sia, with muscular tremors of face, eyelids, ears and

muscles of the head and neck, is followed by strabismus,

may be complicated by dyspnoea, haemoglobinuria and

generalized muscular tremors and collapse in general-

constipation.

ized clonic convulsions.

Listeriosis (listerellosis) (see pp. 251, 904)

Transit tetany

Listeriosis occasionally occurs in silage-fed cattle, pro-

This occurs during transport, largely in preparturient

ducing an initial pyrexia followed by hyperaesthesia, a

cattle under stressful conditions. Signs are similar to

tendency to aggression, circling, head pressing, facial

those of hypomagnesaemia, but blood may be low both

paralysis with drooping of one or both upper eyelids

in magnesium and calcium.

and a dry keratitis. One or both ears may also be

involved, and occasionally the fifth cranial nerve as well

as the seventh is affected so that chewing and swallow-

Bovine spongiform encephalopathy (BSE)

ing are impaired and food becomes impacted in the

(see p. 909)

pharynx and mouth.

This shows more slowly developing hyperaesthesia with

ataxia and behavioural changes prior to collapse. These

Ketosis (acetonaemia) (see p. 795)

changes include apprehension occasionally amounting

to panic, obsessive licking of nose and lips, semaphor-

Ketosis is normally a sign of energy deficit in high-
ing of ears, refusal to pass through doorways, kicking
yielding dairy cattle between two and six weeks after
off the milking clusters in the parlour, reflex kicking
calving. The condition may well be subclinical, doing no
at other times and muscular tremors of neck and
more than reducing yield. At its worst, it produces inap-
shoulders.
petence for concentrates, lethargy and constipation,
with a normal or subnormal temperature and pulse
rate.

Hepatic encephalopathy

Occasionally, a nervous form occurs producing ataxia
Hepatic encephalopathy, occurring as a complication of
and excitement, with marked head signs, the patient
certain forms of liver disease, e.g. ragwort (see p. 945) or
licking itself and anything within reach in an obsessive
other forms of plant poisoning, is due to the effect upon
fashion, holding the bars of the shippen or parlour in its
the brain of ammonia released from the damaged liver.
teeth and chewing to such an extent that tongue and

Signs are ataxia, dullness, slow circling, head pressing

lips may bleed forming a bloodstained froth. Ketone

and collapse. Occasional periods of excitement are seen.

bodies are present at high levels in blood, milk and

urine.

Occasionally, this licking frenzy may occur as a com-

Tubercular meningitis (see pp. 251, 862)

plication of milk fever. It is known as ‘licking mania’

Not to be forgotten in these days when bovine tuber-

and is believed to be ketotic in origin.

culosis is on the increase, tubercular meningitis may be

seen in half-grown cattle as a sequel to congenital

Acute inflammatory, exudative and/or haemorrhagic

tuberculosis or the consumption of milk from cows with

lesions in the brain

mammary tuberculosis. Ataxia, stumbling, bellowing

and an inco-ordinate aggression with head pressing fol-

Acute inflammatory, exudative, and/or haemorrhagic

lowed by collapse were frequently seen in this condi-

lesions within the brain may cause marked excitement

tion. In the days of horned cattle, fracture of one or bordering on mania before collapse occurs. This picture

both horns often occurred as a result of head pressing.

may occur in anthrax (see p. 717), in which case diag-

Blindness in one or both eyes might also occur.

nosis will be helped by generalized haemorrhage and

oedema, and is also sometimes seen in malignant

catarrhal fever accompanied by marked nasal and

Lead poisoning (see p. 944)

ocular discharge, with heat and pain over the sinuses of

In the adult lead poisoning produces blindness and

the head. Horns, if present, feel hot and in cattle with

aimless wandering, often complicated by trauma due to

white horns they become very reddened and may, in

collisions with walls, trees, etc. Bellowing frequently

fact, become loose. There is usually profuse diarrhoea.

occurs.

Convulsive syndromes that are relatively frequent

Rape poisoning (see p. 941)

among calves

Rape poisoning may produce excitement, aggression,

Lead poisoning (see pp. 906, 944): This is still common, blindness and bellowing, a nervous syndrome, which

causing abdominal pain, blindness, salivation and con-

vulsions, with marked bellowing and leading rapidly to

Muscular dystrophy (see pp. 258, 302): Calves dying of death.

heart failure due to the cardiac form of muscular dys-

trophy will normally be housed calves fed only on dam's

milk. Vitamin E intake may therefore be low, and at two

Magnesium tetany (see p. 255): In beef calves fed dam's to three months of age any sudden excitement, such as

milk alone without supplement magnesium tetany

the arrival of the dam at feeding time, may trigger off a

appears at 12–16 weeks of age, producing star gazing,

cardiac failure episode with cyanosis and anoxia which,

stilted gait, muscular tremors and hyperaesthesia

nevertheless, may superficially resemble a convulsive

leading to convulsions and death. Abdominal pain,

syndrome.

blindness and bellowing are not features of magnesium

tetany.

Cerebrocortical necrosis (see p. 261): Cerebrocortical necrosis (CCN) occurring in housed or yarded calves

Gammexane (gamma BHC) poisoning (see p. 942):

may produce star gazing, hyperaesthesia and ataxia but,

This condition is due to feeding milk in buckets con-

occasionally, leads to a severe convulsive picture.

taminated with gammexane, after mixing insecticides,

and causes very severe clonic convulsions and death.

References

Linseed poisoning (see p. 941): The acute dyspnoeic

picture with gasping and muscular spasm that follows

Boddie, G.F. (1970) *Diagnostic Methods in Veterinary Medithe feeding of warm wet linseed to calves may look*

cine, 6th edn. Oliver and Boyd, Edinburgh.

much like a convulsive picture unless one is aware of

Rees Evans, E.T. (1957) Bacterial endocarditis of cattle. Vet-the signs of prussic acid poisoning.

erinary Record, ***69****, 1190–202.*

The Calf

Chapter 12

Outline of Clinical Genetics

G.B. Young

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Introduction

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Genetics in hereditary diseases corresponds to the

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microbiology of infections. Before Pasteur's contribu-

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tion to bacteriology, infections were crudely controlled

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by isolation, but his work greatly improved preventive

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measures. Similarly, genetics greatly improves the

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Many genetic problems are complex and exhibit a

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spectrum from being entirely genetic to entirely envi-

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ronmental. The genetic component may be divided into

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major gene and polygenic effects. Polygenes each have

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a small effect and produce continuous variation. Most

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disease due to major genes is, however, also influenced

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by minor genes and many diseases currently considered

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polygenic may in reality be affected by relatively few

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major genes.

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Observations and experimentation indicate that, like

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the well-studied Drosophila, cattle carry a genetic load Pedigree analysis

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of deleterious major genes producing gross abnormality

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and of deleterious polygenes producing subfertility,

Differentiating genetic and infectious diseases

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increased disease susceptibility and poor physique. With

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current knowledge many polygenic constitutional

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defects can only be studied biometrically, but the final

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aim is to recognize individually every gene and its

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location on specific chromosomes. Recombinant DNA

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technology now makes this theoretically feasible.

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Deleterious major genes

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Every body system is subject to abnormal inheritance.

Balanced selection

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Indeed, if, as the embryo unfolds, a defect occurs early,

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several subsequent systems may be involved, produc-

Selection and longevity in dairy cows

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ing a syndrome. Environmental disturbances, or other

Bull mothers

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genes sometimes inherited differently but affecting

Crossbreeding

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the same developmental pathway, can produce identi-

Health recording schemes

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cal diseases or syndromes.

Recent advance

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Genetic diseases affect all ages from conception

Cloning

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to senility. Congenital malformations, observed at birth,

The genomics revolution

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Conclusions

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may be genetic or due to maternal effects such as

infections, nutritional deficiencies or drugs. Genes

control the synthesis of proteins and, when defective, *generally result in an enzyme reduction or deficiency.*

Molecular genetics has developed the concept of

Few breeders escape genetic disease at some time.

control genes, influencing structural genes, but most

Economic data are not available on either the direct

genetic diseases are still thought of in terms of struc-

loss due to major deleterious genes or the greater indi-

tural or chromosomal mutations.

rect loss from counterselection. Genes capable of pro-

ducing defects are, however, abundant and most cattle

Genes and disease in different species

probably carry several. Only fear of inbreeding and

continual selection against defects prevents more

The basic genetic physical structure of all species from

frequent outbreaks.

worms and fruit flies to humans is similar. For example,

the control homeobox genes, the molecular architects

organizing other genes and switching them on and

Modes of inheritance

off at the correct time, are universally responsible for the division into head, thorax and abdomen. The gene Inheritance is duplicate: each individual has two genes that controls eye development in humans, when (units of inheritance) for a particular character or func- inserted into a fly, produces normal fly development. tion at each locus on the chromosomes. A parent passes This common, genetic, evolutionary heritage implies one on a random basis to an offspring, the other coming that genetic malformations present in one species will from the second parent. Chemically, genes are deoxyri- often also be present in others. The luxate gene in mice, bose nucleic acid (DNA) and the fine structure of the humans and Galloway cattle is an example. Further gene has been elucidated, but for most clinical purposes genes can be transferred from one species to another. the gene may still be regarded as the unit of inheritance. Using transgenics, most known human genetic diseases have been transferred to mice.

Dominant genes

Mammalian species probably have around thirty

In regular dominance every carrier is affected. The

thousand genes and yet only three hundred are thought

disease is generally inherited from one parent and

to separate mice from men. Different species are

half its offspring are affected. A new dominant gene

therefore likely to suffer from similar infections and

producing a severe effect tends to be lethal and produces

infestations. Tuberculosis and the influenzas illustrate

single isolated effects. Surviving dominants produce

the point. Studying genetic disease similarities and dis-

relatively minor defects, e.g. notched ears in Ayrshires.

similarities between species constitutes comparative

Irregular rather than regular dominants are more

genomics.

common in cattle. An individual may carry the gene but

not manifest it due to intangible environmental effects

Genetic epidemiology

or modifying genes (incomplete penetrance). Half of its

offspring also carry the abnormal gene but a proportion

All cattle breeds possess several genetic diseases, some

similarly do not manifest it, producing irregular segre-

common to many breeds, others specific to individual

gation ratios.

breeds. Several hundred have been described and many

Hereditary ataxia (p. 178) in Aberdeen Angus illus-

more are known.

trates this inheritance. Transmitting bulls mated to non-

Most persist at a low frequency. Some appear almost

carrier cows leave around 25–40 per cent of calves

sporadically in many different herds over the years.

affected instead of the expected 50 per cent, so pene-

Others are concentrated in a few herds in sudden out-

trance is from 50 to 80 per cent.

breaks. Occasionally, a defect increases until individual

Some late-developing defects, such as arthritic con-

or collective action reduces its frequency. If breeders

ditions in bulls (p. 176), could, in theory, be due to dom-

relax, its frequency increases again, producing a cyclical

inants. The bull would not exhibit the disease until old,

pattern.

and bred from, and because of culling, the relationship

and ratios between bull and offspring might not be

Economic loss

easily noticeable.

Calf loss may reach 20 per cent within a herd for several

Semidominant genes

years, as in Galloway tibial hemimelia (p. 176). Maternal

mortality may be high as in prolonged gestations in

These are quite common in cattle. A single gene pro-

many breeds (p. 183). Difficult parturitions reduce yield

duces a defect but a double dose increases its severity.

and late abortions result in long dry periods. In later

In the single dose, the abnormal gene converts a Kerry

developing defects, e.g. hip dysplasia (p. 453), only cull

into the small, more desirable, Dexter, but a double

value is obtained. The bull has to be replaced, the breeding

dose produces monsters. Matings of Dexters produce

programme is disrupted and pedigree sales drop. Coun-

on average 25 per cent Kerry types, 50 per cent Dexter

terselection substantially reduces economic selection.

types and 25 per cent bulldog monsters (see p. 175).

Many dwarves exhibit this inheritance. Often, as in

Multiple alleles

snorter dwarves in Herefords, the carrier conformation

Each locus on the chromosome may have not just two

is only slightly different from normal and slightly better

but several genes present. Various combinations of these

(heterozygote advantage). Selection for carriers then

genes may produce a gradation of severity of a con-

spreads the disease. At the limits, one-quarter of the

dition. For example, a series of multiple alleles reducing

calves are defective.

melanism successively dilutes coat colour from normal

agouti to albinism. Multiple alleles may contribute to the

variation in clinical expression of many diseases.

Recessive genes

They are also a common form of inheritance in many

disease-related biochemical variants.

A single gene does not show in a carrier because of the

normal dominant gene. The defect only appears with

a double dose. Neither parent is affected yet the defect

Irregular inheritance

has come from both parents.

In carrier matings one in four of the offspring are

Many, indeed most, genetic diseases of cattle are

normal (RR), two are carriers (Rr), and one will be

inherited irregularly. They do not provide simple

affected (rr). This is true on average but not for

genetic ratios and are characterized by sporadic

individual or small groups of matings. Moreover, pure

incidence and occasional concentration within families.

recessives giving exact ratios are rare, even with the

Arthrogryposis in Charolais characterized by calves

traditional genetic model of Drosophila.

with twisted limbs (see p. 177), cleft palates and a

The abnormal gene is usually considered neutral in

twisted spine, illustrates the problem. More than half of

carriers but in some cases, probably more than is

all artificial insemination (AI) bulls produce a few

currently understood, it may be detected biochemically.

defective calves but a few (about 5 per cent) leave

Carrier recognition is a major field of genetics and

around five per cent of affected calves.

should always be sought in major recessive outbreaks

Cryptorchids provide another example of non-

in cattle.

Mendelian inheritance. Cryptorchidism is frequently

Recessive defects may also have reduced penetrance.

sporadic (p. 182). Most extensively used sires leave

Since the frequency of recessive homozygotes is gener-

some cryptorchids. Many cryptorchids leave mainly

ally low, if further reduced by incomplete penetrance,

normal offspring and most cryptorchids have normal

inheritance is best described simply as irregular, and

parents. Occasionally, however, affected or normal bulls

calculating the penetrance of a recessive is generally

sire a higher proportion of affected offspring than

unprofitable.

average. Their incidence also increases markedly on

Recessive defects often appear following line breed-

inbreeding. Cryptorchidism thus has a genetic compo-

ing. A breeder obtaining good daughters from one

nent and probably both male and female contribute to

bull is often tempted to use related bulls on these.

its occurrence.

These related males may carry the same recessive gene

Such defects result from unknown environmental

derived from a common ancestor. Some second matings

factors and genetic susceptibility, either recessives or

are thus between carriers, and defects appear. The

dominants, exhibiting a very sensitive threshold of man-

pedigrees of affected animals often reveal common

ifestation.

ancestors within a few generations.

Genetic polymorphism

Sex-limited and sex-linked genes

This is a discontinuous variation which persists in a

population apparently more or less at random. Cattle

Many cattle diseases are limited to one sex, for ex-

blood groups are an obvious example. Their relative

ample, testicular hypoplasia (p. 182). The other sex,

proportions are not maintained by a balance between

however, plays an equal role in inheritance and the

mutation increasing the defect and selection removing

defective genes are in the non-sex autosomes. This

genes in affected animals. Most, however, will probably *inheritance must be distinguished from sex-linked*

be ultimately shown to affect fitness. Many may be

recessive inheritance where the abnormal gene is

relics of resistance mechanisms to much earlier plagues.

carried on the X chromosome and a carrier cow trans-

mits the disease to half her bull calves, and leaves half

her heifer calves as carriers; a cow with a double dose

Chromosomal abnormalities

of the harmful gene would show the disease. Since sex-

linked recessives are not transmitted by unaffected

Structural chromosomal mutations, such as duplications,

bulls, they are rare in cattle.

deficiencies, inversions, translocations (p. 184) and alter-

ations in chromosomal number, are not uncommon in

the proportion of genes of a particular type in the pop-

cattle. Large chromosomal breakages produce complete

ulation. Since each animal has two of these genes, the

sterility and small breakages subfertility. Both are

proportion of carriers is approximately twice the gene

inherited like irregular dominants. Bulls with low con-

frequency, and the incidence of affected individuals is

ception rates due to minor chromosomal abnormalities

the square of the gene frequency. Thus, if the incidence

pass the defect directly to their sons.

of a recessive defect is 1 per cent, the gene frequency is

Many chromosomal defects, often difficult to detect,

10 per cent and the proportion of carriers about 20 per

are probably present in early embryos, and account

cent. Even a low incidence of defects thus implies large

for a considerable proportion of early embryonic morta-

numbers of carriers.

lity and some reduction in conception rate. The uterus,

Moreover, this gene frequency will be the average for

however, acts as a clearing house for such defects and

the whole breed and much higher frequencies will occur

few progress to birth.

in farms that have used carrier males recently. Thus

the outbreaks and frequencies will be patchy with

some farms heavily affected and others with few or no

Epidemiology and control

defects. This often renders measurement of the *incidence of a defect in a breed difficult. A useful guide*

Breeds are generally organized hierarchically. A few

is that a defect attracts notice when around 1 per cent

top herds supply bulls to less influential breeders who

of calves are affected in the breed so that about 18–20

in turn supply commercial producers. If a harmful

per cent of animals are carriers.

gene spreads in the top strata these bulls spread carriers

Reduction in frequency can be rapid if the initial

through the breed. Similarly, if the defect is eliminated

frequency is high but is slower as the frequency de-

from the top herds then sires free from the defective

creases or if the initial frequency is low. Thus breed-

gene slowly reduce the defect in the other herds. The

ers can rapidly reduce a recessive defect at high levels

origin and increase of a harmful mutant in the top herds

but eliminating it completely is very difficult.

is probably due to mutation and genetic drift.

The main difficulty in selecting against a recessive is

Control is the sum of the control efforts of individual

the large number of carriers that cannot be recognized *breeders. Affected herds select against the gene, and*

on visual inspection. However, if all bulls and cows

breeders soon learn from which herds to reduce their

producing defects are culled, experience shows the

purchases. The distribution of non-carrier bulls reduces

incidence of the defect soon drops to acceptable levels.

the incidence.

The desirability of control will vary with the severity

and frequency of the defect. A defect causing dysto-

kia justifies considerable counterselection, but a minor

Controlling an irregularly inherited defect

defect such as colobomata very little. Strong selection

In a disease such as arthrogryposis (p. 177) all bulls

against a defect may also relax selection for important

leaving defects cannot be culled but only bulls trans-

economic characters.

mitting most frequently. Similarly, in defects such as

cryptorchidism, control is based on not using affected

Controlling dominants

animals or close relatives and this is effective in main-

A regular dominant spreads directly down through *taining a low frequency.*

a breed but such direct transmission is rare in cattle

Irregular defects such as cryptorchidism (p. 182)

except for minor defects such as some forms of

would only increase if affected animals were continu-

polydactyly. If required, culling all affected animals

ously used. Why they persist at a low level despite gen-

eliminates the defective gene.

erations of natural and artificial selection is unknown

Dominants exhibiting incomplete penetrance, how-

although carrier advantage may be suspected.

ever, commonly spread directly. The lower the pene-

trance, the greater the likelihood of this occurring. If

penetrance is high a few offspring will pinpoint a carrier

Genes exhibiting good and bad effects

parent and transmitters can be culled. If penetrance is

low, control is more difficult, since many offspring are

Some pleiotropic genes or closely linked gene

required to detect carriers.

complexes produce both desirable and undesirable

effects and selection for the good effects may spread the *gene. For example, some genes producing desirable*

Controlling recessives

coat colours also cause infertility. Selection for the coat

At breed level, epidemiology and control of recessive

colour may thus spread infertility or maintain it at a low

genes will depend on the gene frequency. This is simply

level, as in white heifer disease (p. 183).

A gene may be beneficial when single but harmful

Pedigree analysis

in a double dose as in selection for the desirable

A few generations intensively studied are better than

conformation in American beef breeds resulting in

long pedigrees. A list of normal and affected animals

unconscious selection for carriers.

born during and immediately prior to the outbreak,

Inheritance involving advantageous and disadvanta-

their sex, sire, dam and maternal grandsire is generally

geous effects may be much more common in cattle than

adequate. This list will indicate if simple genetic ratios

suspected.

exist.

With recessives one out of four offspring of carriers

Assessing controls

are affected, but in practice the common ratio obtained

is one in eight. This occurs when two carrier males are

Excessive controls, such as compulsory recording of

used successively. The first carrier leaves on average

all abnormalities, are sometimes advocated. Controls

half of his daughters carriers (as well as half his sons).

are essential, particularly where a defect has become a

In mating the second carrier bull to the carrier daugh-

problem, but they should be kept in proportion. They

ters, one out of the four offspring are defective. About

should be kept to the minimum level necessary, so that

one in two ¥ one in four, i.e. one in eight of the second

selection for efficient production can proceed as rapidly

bull's offspring are defective.

as possible.

Care has to be taken with pedigrees since as many as

10 per cent may be inaccurate. Few pedigree investiga-

tions fail to produce anomalous cases.

Investigating genetic diseases

DNA analysis

Inheritance may be suspected when other factors

are excluded, the defect runs in families and previous

Almost weekly a new gene for a human disease, located

reports implicate genetics. Since environmental defects

by deciphering the genome, is recorded and some

may simulate genetic conditions and similar clinical

breast cancers are already subject to routine screening,

defects have different genetic causes inheritance in the

particularly in patients with a family history. Although

affected herd should be investigated.

mapping the genome in cattle is being pursued in some

Inheritance exists when one bull has sired all the

laboratories,

financial restraints limit progress.

defects and another contemporary bull has left none

Moreover, reliable results require great technical skill

when mated to similar females in a similar environ-

to narrow down the suspected DNA sequences, which

ment. However, such controls are often not available *may involve several hundred genes, to the required*

and a properly designed experiment may be necessary.

gene and to assure the specific gene is involved. Until

If line breeding is being practised a new defect is

more progress is made reliance for diagnosis and

probably genetic. If recessive, both sexes are affected

control in livestock has to be placed on the more

equally and the incidence within a herd seldom rises

standard but still relevant procedures such as pedigree

above 15–20 per cent. The disease may disappear as

analysis outlined previously.

unaffected males are brought in. Since environmental

Predicting future diseases seems to cause substantial

changes are often made simultaneously confusion may

ethical and insurance problems in humans, but in

arise.

livestock, while similar problems will arise, they are

Simple recessive defects resemble each other

relatively trivial. In contrast, predicting future diseases

fairly closely – one dropsical calf tends to be similar

in livestock is one major way ahead in reducing disease *to another. Where considerable variation in clinical*

incidence.

appearance or age of onset is present a simple recessive

is unlikely.

Differentiating genetic and

In cattle, and especially in a small herd, establishing

infectious diseases

the exact inheritance may be difficult. Often all that can

be said is that the disease runs in families and comes

Genetic and infectious diseases may, on occasion,

from either one parent only or, alternatively, the genetic

be confused. Their epidemiology can be similar, with

factors are present in both parents.

deleterious genes or infectious agents radiating out

Breed differences are also suggestive of genetic

from heavily diseased foci. Moreover, many infectious

disease but not conclusive because of possible con-

diseases through close contact are familial and genetic

founding between breed and environment. This is par-

resistance may be present, enhancing the familial

ticularly true where infections or mineral deficiencies *aspects. Pathology may even be similar, since an*

are involved.

invading organism can affect the same developmental

pathway as a deleterious gene. The crucial distinctions

Automatically eliminating bulls leaving three or so

are the isolation of an infectious agent and experimen-

affected offspring is rather rigid. Selection against bulls

tal transmission of the disease or the establishment of

leaving calves causing maternal mortality, late develop-

fairly clearcut genetic ratios, perferably the former.

ing defects, or leaving three affected calves in their first

100 offspring should be more intense than against bulls

producing unimportant defects, or producing a few

Genetic counselling

abnormalities among several thousand normal calves.

Again, a few defects among several thousand normal

calves is tolerable from a bull transmitting efficient

In the event of a genetic disease a breeder should be

production.

advised to change the bull immediately, thus eliminat-

When an undesirable gene is increasing, an AI centre ing the appearance of the defect and reducing the should buy bulls from sources thought to be incidence carrier incidence in offspring. Continuous use of non-free. Even with limited numbers of offspring and a low carrier bulls gradually reduces the number of carriers. gene frequency, carrier bulls should soon be detected. If a carrier male has had only restricted use all his For a serious condition, bulls might be progeny tested daughters should be culled. However, where the herd on known carrier females.

has many carrier females, culling should be gradual Testing all bulls on their daughters would test for to avoid decimating the herd. Known carriers and any deleterious gene. Since most bulls probably carry low-producing females should be culled first. Where several such genes, the bulls available would be limited. the abnormal gene occurs in a particularly good strain Where older bulls are being used, the test might be its frequency should be reduced rather slowly so as to of some value, although low production in the inbred *preserve the strain intact, i.e. some defects should be*

daughters would be a disadvantage.

suffered to maintain production qualities.

Generally, AI, because of its scientific basis and mon-

In a serious outbreak a breeder might test a male on

itoring procedures, is an agent for reducing rather than

about 20 of its daughters or half sisters, or on 10 known

increasing defects.

carrier females. Generally, however, test mating is

expensive and best avoided.

Control of defects inherited as irregular dominants

Genetic defects and egg transplanting

or in a non-Mendelian fashion, follows the same

Routine egg transfer permits intense selection among

principles. The bull should be changed and transmitting

females and potentially concentrates even further the

females culled.

genetic base. It thus enhances the risk of spreading

When a defect rises in frequency, the breed society

genetic defects. Provided proper surveillance is insti-

should seek veterinary advice. After ensuring that the *tuted and donors transmitting defects rapidly with-*

disease is recognizable, both clinically and pathologi-

drawn, like AI, it should however decrease rather than

cally, its mode of inheritance and methods of control are

increase genetic disease.

then explained to breeders so they can counterselect

most effectively. Prenatal diagnosis and selective

abortion, although feasible, should only have limited

Polygenic deleterious genes

application in valuable animals in cattle practice.

There is very marked individual variation in fertility, in

susceptibility to infections and metabolic diseases and

Genetic defects and

in conformation and physique. The genetic part of con-

***artificial insemination** (see Chapter 39)*

tinuous variation is considered to be due to many addi-

tive genes, each with a small effect. They produce a

Artificial insemination centres seldom suffer outbreaks

bell-shaped distribution whose mean can be shifted by

of genetic disease because they avoid inbreeding, par-

selection.

ticularly in the larger units, and rapidly withdraw bulls
Multifactorial inheritance, particularly from field
transmitting defects. Although most bulls carry several
data, is measured by a heritability estimate – the ratio
defective genes, few leave many defects in their progeny
of genetic influences to all influences (genetic and
since their cow population is unlikely to have a high
environmental). Heritability estimates tend to vary
gene frequency for the same defect. While a carrier
widely according to the method of calculation and the
bull leaves half his daughters carriers, each time a non-
particular field data chosen and are commonly aver-
carrier is used on the succeeding daughter's genera-
aged to obtain a generalized more reliable estimate.
tions, the carrier incidence is halved.
Individual estimates have to be treated with great

caution, especially when used to predict rates of
calving problems. Friesians, for example, have more dif-
progress under selection. Strictly speaking they apply
ficulties than Jerseys or Ayrshires. At the extreme limit

only to the population from which they are obtained

in pure, large, continental breeds cows can only produce

and their predictive value is limited to a few generations

a few calves before becoming sterile. Counterselection

at most.

is impossible as long as growth rate is given priority and

the only remedy is Caesarean section.

Sterility and infertility genes

Susceptibility and resistance genes

Infertility genetics is little understood. Although there

is substantial automatic natural selection present for

Susceptibility and resistance genes are widespread and

fertility, the marked decline in fertility with inbreeding

genetic variation in disease resistance has always been

and its restoration on crossbreeding demonstrates the

demonstrated when adequately sought. Animals rela-

existence of many infertility and subfertility genes.

tively resistant to one disease are often susceptible

Difficulties and inaccuracies in statistically measuring

to another. Resistance is sometimes polygenic but,

fertility, and the different indices used, have produced *with increasing research, it has often been found to be*

very different estimates of its heritability. Most studies

dependent on relatively few genes.

suggest the heritability of pregnancy rate in cattle is

In natural epidemics an invading organism frequently

low, almost zero. Some based on sire/son comparisons,

spreads rapidly causing heavy mortality. Some geneti-

however, suggest figures as high as 40 per cent.

cally resistant animals almost invariably survive and

Intense selection for yield is thought by some workers

subsequently multiply. After initial oscillations, host

to lower fertility. It can be argued that a few per cent

and parasite settle down to coexist. Initially acute dis-

decrease in pregnancy rate might be overestimated in

eases tend to become chronic as genetic immunity

comparison with high yield. Lengthening calving inter-

develops.

vals, however, markedly reduce profitability and selec-

Before control, selection for resistance genes must

tion for fertility should remain a high priority with some

have been intense. This effect is still obvious in tropical *culling of sons of bulls with low pregnancy rate.*

countries, for example, where Zebus are markedly more

Semen volumes and sperm numbers, concentration,

resistant to local disease than exotic breeds. In grading

motility and morphology show marked age, breed,

up by crossbreeding, a proportion of Zebu genes has to

weight and individual variation (see p. 604). Semen

be retained and indeed in high-disease areas improve-

characteristics are considered to be moderately herita-

ment of indigenous cattle may be preferable. For many

ble (15–20 per cent) and should respond to selection to

large countries resistance genes dictate a stratified

improve semen quality but progress would be slow. The

breeding programme from pure exotics to pure indige-

correlation between sperm characteristics and fertility

nous cattle. In tropical countries genotype–environment

is, however, not entirely clear and some semen stand-

interactions are of prime significance.

ards may be unnecessarily high, leading to reduced

In European cattle the most obvious example of

selection for other characters. Specific sperm defects *genetic resistance is in mastitis. There are marked breed*

which are common, e.g. knobbed sperm, are often due

differences. Heritability estimates vary enormously

to single genes and should be strongly selected against.

but are probably around 10–15 per cent. Daughters of

Testicular size and conformation are also influenced

infected dams are more susceptible and some bulls

considerably by genes. The difference in libido between

transmit substantially more mastitis than others. In one

beef and dairy bulls is sufficient to indicate the strong

extensive survey most mastitis cases were daughters of

genetic influence in libido.

relatively few AI sires.

At the herd level most infertility problems are tran-

Selection to raise the frequency of mastitis-resistance

sient and non-genetic. Similarly, repeat breeding in

genes, even with AI, although feasible, would be diffi-

individual cows is usually of environmental or manage-

cult. Many daughters, perhaps 250, would be required

ment origins. Oestrous expression, however, plus time

to classify the bull. Currently sires' daughters are clas-

of onset of post partum cyclicity, probably has a con-

sified mainly on first lactation yield when mastitis is less

siderable genetic component associated with hormonal

frequent and the effect of AI on mastitis incidence is

differences.

probably neutral. It is dangerous to assume that selec-

tion for high heifer yield automatically implies selection

Calving difficulties

for health, as many diseases occur in later lactations.

Genetic selection for yield and growth rate increases

Calf scours and pneumonia also have a genetic com-

body size and larger cows inevitably have increased

ponent, associated with colostral antibody. This varies

genetically, as does the vitality of the calf, influencing its ceptible cows can be. There are also breed variations,

suckling ability.

Channel Island breeds being particularly liable. Breed

BSE is another infectious disease where mouse

variation in hypomagnesaemia and acetonaemia also

research published and some unpublished research *exists.*

on scrapie and BSE's epidemiology suggest there are

The anaemia common in high-yielding cows provides

strong genetic and familial factors operating. Research

one of the best experimental examples of the strength

has been hindered by the need to prevent its spread to

of biochemical individuality. In one unpublished twin

humans. Since safety in humans can only be guaranteed

study, despite marked prolonged nutritional and weight

by its elimination in cattle, the genetic factors involved

differences, haemoglobin, red blood cells, packed cell

justify much further research.

volumes and mean haemoglobin concentrations were

There are marked species and individual differences

all so highly determined by individuality that pair

in the severity of foot-and-mouth disease and selection

members closely resembled each other in blood

could probably enforce this resistance, but vaccination

pattern, despite the nutritional differences within and

would seem the best approach in such an infectious,

between pairs. Individual differences overshadowed *rapidly spreading disease involving many viral strains.*

the nutritional effect.

Isolating the experimental animals could also prove a

Such individual differences indicate the need for

major, although not insuperable, problem.

caution in interpreting disease status from blood analy-

Parasitic infections, however, are emerging as a very

sis in individuals. Because of individual variation nor-

possible candidate for scientific counterselection. They

mality is difficult to define. A single animal with a low

tend to be chronic, natural selection resistance already

haemoglobin may not be anaemic but merely exhibit-

exists and regular treatment is expensive. This field is

ing a normally determined low value. Blood tests are

likely to develop, perhaps particularly in tropical live-

generally most valuable at the herd level in preventive

stock development centres (LDCs).

medicine.

The greatest progress in artificially selecting for

Selection for increasing yields is putting dairy cows

disease resistance depends on detecting biochemically *under increasing stress and metabolic diseases are*

resistant and susceptible animals.

Considerable

steadily increasing in developed countries. Both milk

progress is being made on this front, centring around

fever and acetonaemia are basically diseases of high

immune response genes. These control the ability of

yielders and almost unknown in less-developed

the animal to produce antibody against certain specific

countries.

antigens. The Ir genes are on the part of the chromosome that contains the genes controlling the acceptance

of tissue grafts, the histocompatibility genes. These

Disease genetics and cattle

latter can be detected serologically and both Ir genes ***improvement schemes***

and histocompatability genes form a multiple allelic

series.

These are essentially interwoven.

Improvement

As knowledge of this gene complex increases and

schemes carry risks as well as rewards. Those based on *the genetic basis of immunity is understood in finer*

AI and egg transplants steadily to improve rates of

detail, positive selection for resistance to disease may

progress involve the risk of inbreeding depression.

become more feasible. Artificial insemination, egg trans-

planting and, ultimately, gene transfer are the obvious

instruments.

Inbreeding depression

Selection for disease resistance is likely to be

profitable, however, only where vaccines are not

Since relatively few males are required to avoid

available, although in some cases genetically more

inbreeding, in theory it presents little problem in

resistant animals respond more effectively to vaccines.

improvement schemes.

Both approaches may in some circumstances be

As technology reduces bull numbers and AI sires are

complementary.

followed by their sons more care will be necessary.

Using a few score bulls for several million cows should

not cause serious inbreeding provided sons are not

Metabolic disease genetics

chosen repeatedly from only the very best sires, causing an undue concentration on very few sires. However, Individual variation in susceptibility to metabolic after many decades, such a system could cause a serious disease is well demonstrated by milk fever. It has a accumulation of inbreeding effects. Remedies would heritability estimate of around 20–25 per cent and a include importations, using stored semen or splitting repeatability of about 20 per cent, indicating how sus- the breed into small units and exchanging bulls. Simi-

larly, with egg transplanting overconcentration on a few selection for longevity at the end of the first lactation mothers has to be avoided.

is possible but would require too many daughters

In practice, however, more inbreeding may be occur- and measurements to be economically feasible. As bio- ring than is generally suspected and with inadequate chemical individuality is explored in greater depth it recording the risks may be being underestimated.

may become possible.

Intense single-character selection

Bull mothers

Single-character intense selection in all species

A simple approach to improving health, and longevity

reduces fertility and frequently produces other unde-

is to place a much greater emphasis on older bull

sirable correlated responses. The balanced homeostasis

mothers, cows that have successfully over five or six lac-

of the animal is upset. At the extreme it often uncovers

tations resisted mastitis, metabolic disease and infertil-

major defects, e.g. pygmies in downward selection for

ity. This approach is now being implemented.

weight.

Intense selection for yield in dairy cattle increases

mastitis, udder oedema and metabolic diseases. The

Crossbreeding

genetic, early, high-peak yields in dairy cows, much

higher than in any other species, induces stress.

Crossbreeding schemes, even those where the primary

High yielders also suffer increased digestive dis-

objective is blending different maternal and paternal

orders, foot problems and calving difficulties. High

characters, greatly improve health and vigour.

yielders, although more profitable, thus require expen-

The simplest explanation of hybrid vigour is that

sive health care, particularly to maintain mammary

the load of recessive deleterious genes, which can

function.

be exposed on inbreeding, are covered up by normal

The genetic reduction in fertility associated with high

alleles on crossbreeding. Crossbreeding is extensively

yield is probably sufficiently serious to reassess current

used in beef production, particularly where hardiness

selection programmes in dairy cattle. Increased effi-

is vital, as in exposed hill areas.

ciency of production, rather than yield alone, should be

Systematic crossbreeding schemes are being used

the objective.

in some Scandinavian, eastern European and tropical

countries but generally have been little developed in

western Europe.

Balanced selection

The best schemes of cattle improvement, maximizing

In future, greater emphasis is likely to be placed on bal-

both health and efficiency, are probably based on com-

anced selection. Factors such as growth rate and mature

bining crossbreeding and selection and using selection

size, body conformation and composition, food intake

indices. Dairy cattle improvement is only in its infancy

and efficiency and perinatal mortality and disease

and with increasing research and development such

resistance are likely to be built into selection indices.

schemes are likely to develop in the West.

Selection will probably also occur under controlled

conditions as well as using field data. The aim will be

Health recording schemes

better balanced and healthier animals and hence more

profitable dairy cattle.

Another approach to genetically improving health is

a greater emphasis on health recording schemes.

Currently, the most effective of these are devoted to

Positive selection for health

improving fertility control, particularly regular calving
and improved heat detection and, to a lesser extent,

Selection and longevity in dairy cows

early detection of metabolic breakdown. With im-
proved design, however, they are likely to detect bulls
The very short lifespan of dairy cows (and bulls) is
transmitting undesirable qualities such as mastitis sus-
probably due to poor management and particularly
ceptibility and poor heat expression.
inadequate fertility control. Genetic selection for
health and longevity could, however, contribute
substantially to better health. In livestock, positive
eugenics is possible.

Recent advances

Longevity has a considerable genetic component
independent of yield. The heritability of survival to the
The full significance and utility of the two fundamental
sixth lactation may be around 20 per cent. Theoretically,
genetic achievements of the last decade, the human

genome project and cloning, are only now being *is, therefore, untenable and each gene must encode for*

explored, but the genetic revolution will have a major

several proteins – estimates vary from the tens to

impact.

several hundreds.

This conclusion leads to a switch in emphasis from

genomics to proteomics as the fundamental key to

understanding the body and attempts are now being

Cloning

made to produce a comprehensive catalogue and map

Livestock cloning, when a relatively reliable success

of all the proteins. This will be very difficult since

rate is achieved, should greatly advance medical

proteins are complex, may interact with other

science, enabling the rapid build-up of flocks and herds

proteins, once created may be modified and can be

containing specific genes for generating pharmaceuti-

transient.

cal products, as in various Roslin Institute research

This changing emphasis is having a major effect on

projects. Investigation of the current reproductive *drug development and therapy. Although in a fluid*

and malformation difficulties should also enhance our

state, the new concepts are already tending to empha-

understanding of cell differentiation, and cell multipli-

size the importance of individual drug treatment, and

cation and division, with implications for genetic dis-

helping to explain why different drugs act differently

eases and even ageing and cancer.

in different patients and the occasional side-effects

Commercial cloning to achieve rapid once and

in block busters and vaccines. The key seems to lie in

for all improvement may require greater caution.

genetic individuality producing genetic variation in

Widespread use of identical animals could leave

individual proteins and hence different responses to dif-

them exposed to new, rapidly spreading, emerging

ferent drugs. Medicine, at present, could be regarded as

diseases and without biological diversity, whole

a diverse collection of symptoms and empirical treat-

populations could be affected. The Irish potato famine

ments, but is slowly being converted into a science. The *was basically caused by cloned potatoes. Moreover,*

day when each valuable animal has its own genetic

the aim is to improve animals every generation

profile and can be treated accordingly, however,

rather than stabilize current populations with prize-

is a very long way off, but that is the direction in

winning livestock. In certain circumstances, however,

which genomics and proteomics seem to be leading

where scientifically improved animals have been

pharmacogenetics.

developed, limited commercial cloning could prove

Not only some mammals but many infectious agents,

worthwhile. Cloning valuable animals before they

such as the cholera bacterium, have been successfully

succumb to infertility or disease could be regarded as

sequenced, work which should lead to more effective

dysgenic.

vaccines. Likewise sequencing biting insects such as the

One underestimated benefit would lie in exploring

mosquito should ultimately lead to better insecticides.

nature and nurture. Currently, field heritability studies

With infectious agents and parasites evolving rapidly to tend to produce lower values than twin studies, and the overcome current therapies, sequencing should provide problems of nature and nurture are far from being a better understanding of the resistance mechanisms satisfactorily resolved. In twin research the existence they are developing (they are fairly well understood in of only two identical twins reduces replication and bacteria already) and this in turn should help provide requires very complex experimental designs. Clones better control systems.

would greatly simplify this. In field studies the intro-

In evolutionary terms the reduction in gene numbers duction of clones into different herds and environments seems to imply that the vast variation in life forms, would also greatly improve the measure of genetic vari-including the domestic species and their parasites, may ation. Apart from specific genetic studies, readily avail-be due more to control genes, switching genes on and able clones would improve nutritional and disease off, rather than a large number of genes producing dif-

research, raising the whole standard of cattle research,

ferent proteins.

as pure lines have done in mice.

In animal breeding terms it is difficult to over-

estimate the significance of genomics and proteomics.

Currently improvement is largely based on biometrics,

particularly heritabilities. In the future this is likely

The genomics revolution

to be supplemented and possibly finally replaced by

The most significant result from the human genome

screening the DNA and looking for genes, particularly

project is a reduction in the gene count from an esti-

major genes, which influence production and disease.

mated hundred thousand or so to nearer thirty to forty

In the even longer term such genes are likely to be

thousand. Since there are probably hundreds of thou-

inserted into the genotype – after all, all genes in dif-

sands of proteins, the one gene, one enzyme hypothesis

ferent species can be regarded as part of one vast

network – and the future of livestock improvement lies

Further reading

in genetic engineering.

Perhaps after a long latent period, during which the

Brock, D.J.H. & Mayo, O. (eds) (1972) The Biochemical

immense successes of microbiology has dominated med-

Genetics of Man. Academic Press, London and New York,

icine, the old-fashioned subject of medical diathesis or

pp. 1–725.

constitutional medicine, rejuvenated by Mendelism, is

Emery, A.E.H. (1983) Elements of Medical Genetics.

now reasserting itself.

Churchill Livingstone, Edinburgh, London, Melbourne,

New York. pp. 1–283.

Hamori, D. (1983) Constitutional Disorders and Heredi-

Conclusions

tary Diseases in Domestic Animals. Elsevier Scientific Publishing Company, Amsterdam, Oxford, New York. pp.

1–728.

Thus in cattle improvement, the future is likely to see

Lerner, I.M. (1954) Genetic Homeostasis. Wiley, New York, a greater emphasis on selection for survival and effi-pp. 1–134.

ciency as well as production, and genetics will become

Nicholas, F.W. (1987) Veterinary Genetics. Oxford University a core subject in cattle preventive medicine. With gene

Press, Oxford, UK, pp. 1–580.

transfer enabling resistance genes to be built in to

Pirchner, F. (1983) Population Genetics in Animal Breeding.

cattle, a new Pasteurian age is developing and the

2nd edn.

Plenum Press, New York and London, pp.

prospects seem limitless.

1–414.

Chapter 13

Congenital Conditions

A.H. Andrews

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syndrome)

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chondrodystrophia fetalis)

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Complex vertebral malformation (CVM)

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decarboxylase deficiency, BCKAD)

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Ovarian aplasia

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with large herds and limited labour, abortions or

Ovarian hypoplasia

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deformities are often missed. When the condition is

Müllerian duct aplasia

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present in the offspring of bulls used in artificial insem-

Duplication of the reproductive tracts

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ination the frequency may again be hard to determine

White heifer disease

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because of the disinclination of farmers to report the

Prolonged gestation

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problem. An indication as to whether or not a problem

Hermaphroditism

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is of genetic origin may be obtained from the type of

Freemartinism

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Urinary system defects

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defect apparent and the knowledge already available

Pervious urachus

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about the condition. Other evidence may be a sudden

Other defects

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outbreak of a defect following the use of a new sire and

Congenital porphyria

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which only affects calves of his parentage. In some cases

Familial polycythaemia

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there is evidence of a gradually increasing number of

Congenital goitre

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similar abnormalities that occur over a number of years.

Anomalous twins

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Following an investigation, it may be shown that a

Chromosomal translocations

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defect is confined to a particular family within a herd

or to the progeny of certain dams.

Introduction

In most cases the history will show a much lower inci-

dence of any inherited defect in crossbred animals than

Most farmers will, at times, have calves that show
in pedigree ones. Some genetic problems are noted as
defects of a varying degree at birth. Such defects,
being very common in certain breeds or families within
although congenital, may be due to genetic or environ-
the breed and this aids a tentative diagnosis of the con-
mental factors or their interaction. The overall level of
dition, e.g. hip dysplasia in Herefords (see p. 453). The
incidence of congenital defects ranges considerably in
history should be indicative of a relationship between
surveys from 0.2 to 3.0 per cent. It should be remem-
the condition and mating systems rather than the time
bered that genetic defects are not always apparent at
of year, disease incidents, etc. The reuse of the same
birth. The incidence of all specific defects is very small,
bull in repeat sire–dam matings may also indicate the
but detailed investigation of any anatomical system will
inherited nature of the condition and its mode of inher-
often show slight deviations from the norm. Genetic
itance, as also can sire–daughter or sire–half-sister
causes can be inherited on a dominant, recessive or

matings, but these involve a considerable period of time

additive basis and often they are influenced by the envi-

before any mode of inheritance can be suggested or

ronment. In many cases all that can be said about a par-

confirmed.

ticular condition is that it is familial. Factors connected

Some of the more common conditions are described

with the environment are many-fold. Other problems

under generalized headings of the systems involved.

are the result of bacterial or viral infections, nutritional

deficiencies, chemical poisoning and physical insults. If

the condition occurs in the early stages following fertil-

Cardiovascular system

ization (i.e. up to day 14 after fertilization), death of the

embryo occurs and it is resorbed. During the embryo

Ectopia cordis

and organogenesis stage (15–44 days after fertilization)

This is an uncommon congenital abnormality where the

the effect is variable. In many cases there is death of the

heart is present outside the thoracic cavity. The cause is

embryo with resorption or abortion, whereas in others *unknown. The heart is usually positioned in the region*

the embryo remains viable and there is congenital

of the lower neck and can be seen pulsating when some

absence, deficiency or disturbance in function. Once the

distance from the calf. Some cases are displaced into the

fetus stage is reached (day 45 to birth) then again death

abdominal cavity.

can occur resulting, if early, in resorption, otherwise

mummification or abortion and, if later, in stillbirth. In

Ventricular septal defects

other cases the fetus survives and may be normal or

suffer growth retardation, reduction in size or organic

These are the most common form of congenital heart

function, or the animal may become weak.

lesion in calves. They vary in their size, which determines

It is often difficult to diagnose the problem and to

the severity of the signs and their location, but they are

decide whether a congenital condition is inherited or

often high on the septum. In some cases the animal sur-

not, and if it is, whether control of the condition is nec-

vives for many years with nothing untoward being sus-

essary. Often it is hard to ascertain the frequency of a

pected. The defects can be single or combined with

problem, as farmers are reluctant to admit its presence

abnormalities of the blood vessels. The defect allows

and also how frequently it is occurring. In many cases

blood to pass from the left to the right ventricle.

The signs mainly depend on the size of the defect. If

five days old. The condition is relatively common and

it is small the animal may grow normally, have a normal

the cause is unknown. Blood passes from the aorta to

exercise tolerance and a normal life expectancy. Such

the pulmonary artery. Signs are often limited other than

cases are usually only detected when the animal is

poor exercise tolerance and lassitude. There is no

examined for some other reason. Occasionally, calves

cyanosis, but there is a continuous murmur often known

will suddenly drop dead with no premonitory signs at a

as a machinery murmur as it increases and decreases

few weeks to several months of age. In severe cases

with each cardiac cycle. The condition can be corrected *there will be some stunting in growth, decreased exer-*

surgically.

cise tolerance and a varying degree of listlessness.

Other calves will remain recumbent at birth and die

soon afterwards. In the uncomplicated case there is no

Aortic stenosis

cyanosis, but on auscultation all animals have a systolic

This is very uncommon and is just below or at the aortic

murmur that is very obvious and can be heard on both

semilunar valves' attachments. Some animals show

sides over a wide area of the chest. At necropsy there

few signs, others show dyspnoea. There is a systolic

is an interventricular defect and this is often just ventral

murmur. Death can occur suddenly with respiratory

to the aorta. In some cases there may be an enlarged

distress.

liver.

Multiple cardiac lesions

Persistence of the right-sided aortic arch

There are many of these but all tend to be uncommon.

This is rare, but when it occurs the oesophagus is

In most cases the animal is born dead, weak or stunted.

encircled by blood vessels, causing constriction. There

Often other congenital defects are also exhibited.

is usually regurgitation of milk after feeding and this

Tetralogy of Fallot is probably the most common and

normally starts at birth or soon afterwards.

involves a ventricular septal defect with pulmonary

stenosis, a dextroposed aorta and a secondary ventric-

Persistent truncus arteriosus

ular hypertrophy. Eisenmenger's syndrome is relatively

similar to tetralogy of Fallot with a ventricular septal

This condition occurs very rarely.

defect, a dextroposed aorta but there is no pulmonary

stenosis. Other multiple cardiac lesions include a

double aortic arch and a double outlet to the right

Abnormal origin of the carotid arteries

ventricle.

This may affect one or both arteries, which may derive

The affected animals usually die. Those that survive

from the pulmonary artery instead of the aorta. This

show a very poor growth rate, severe dyspnoea when *results in weakness of the myocardium in the ven-*

exercised, and lassitude. Cyanosis is present in many

tricle of the affected side due to anoxia, and leads to

cases, particularly after exercise, although in Eisen-

congestive heart failure.

menger's syndrome, cyanosis may not develop until

late. Auscultation of the heart will reveal a murmur.

Aortic coarctation

Patent foramen ovale

This is a constriction at the site of entry of the ductus

This normally takes about seven to ten days to close

arteriosus and results in a systolic murmur and poor

completely in the normal calf. Patency is relatively

pulse.

common. In many cases there is little blood transport,

but if it does occur it is usually from left to right and so

Cardiomyopathy

there is normally no cyanosis. Hypertrophy of the right

ventricle may sometimes arise. There are usually no

A condition often with polydipsia, hyperpnoea and

signs unless other defects are present. Cyanosis is *dyspnoea for one to seven days before death has*

absent unless there is subsequent right ventricular

been described in Australian Poll Hereford calves

hypertrophy.

with a tight curly hair coat. At post-mortem examina-

tion there is vascular congestion of the liver, spleen

and lung with diffuse streaking of the entire

Patent ductus arteriosus

myocardium. It appears to be a genetic condition,

Although patent during intra-uterine life, the ductus

possibly associated with a simple autosomal recessive

arteriosus closes within a day of birth and at least by

mode of inheritance.

Blood disorders

then it should not be repeated and bulls should be used

which do not carry the BLAD gene.

Factor XI deficiency

Simmental hereditary thrombopathy

The main congenital coagulation deficiency reported in

cattle involves factor XI (plasma thromboplastin

A bleeding disorder resulting from impaired aggrega-
antecedent). It has been reported in North America and
tion of platelets has been diagnosed in Simmental-sired
recently in Britain. It has been shown to be present in
cattle. The signs may not be manifested early in life,
some Holstein–Friesian breed lines and is transmitted
although later it causes a prolonged bleeding time after
as an autosomal recessive trait. Factor XI protein is con-
even minor trauma. These animals become severely
cerned at an early stage of the contact or intrinsic acti-
debilitated or die. The problem has mainly been
vation pathway of blood coagulation. This pathway
recorded in Canada, where it is recorded sporadically
converges with the extrinsic one due to tissue damage,
in the cattle population. The data available suggest that
resulting in the activation of factor X. Following acti-
the inheritance is the result of the inheritance of at least
vation the factor converts prothrombin to thrombin,
two genes rather than a simple Medelian recessive.
which in turn changes soluble fibrinogen to an insolu-
ble fibrin clot. Bleeding problems can vary from minor

Skeletal defects

to profuse with haematuria and post-injection

haemorrhage.

Achondroplastic calves (bulldog calves,

chondrodystrophia fetalis)

Although it has been associated with the Dexter breed,

Bovine leucocyte adhesion deficiency

it can also occur in the Friesian, Hereford, Jersey and

(BLAD)

Guernsey. It is basically a defect of interstitial growth.

This is a genetic problem caused by an autosomal reces-

The condition is mainly a recessive gene except that it

sive gene type of inheritance in Holstein cattle which

is dominant in the Jersey. When Dexters are mated

came into prominence in the 1990s. It is characterized

together 25 per cent of the offspring are bulldogs, 50 per

by a deficiency in the Mac-1 (CD11b/CD1S) cell surface

cent are Dexters and 25 per cent are Kerry-type

receptor of the integrin family. The lack of adhesion

Dexters with long legs. Most calves are aborted at about

results in an inability to combat disease effectively.

seven months' gestation. The calves usually have very

The problem is seem in certain genetic lines of

short limbs, flattened skulls with a foreshortened face

Holstein bulls, some of which have been very widely

and short nose. There are often abdominal hernias and

used by AI for their increased milk production

anasarca. In many animals there is hydrocephalus due

characteristics.

to the deformed cranium.

Animals involved are not easy to detect initially as

they are more susceptible to infections and so suffer

Complex vertebral malformation (CVM)

more enteric and respiratory problems and growth

A problem recently discovered by Danish scientists. It

rates are poor. There is usually oral ulceration, which is

involves the Holstein breed and appears to have a

recurrent, and on post-mortem examination some have

genetic basis, possibly with a recessive-type inheritance

peritonitis. Most animals die between two and about

pattern. It appears to have been carried by some bulls

seven months old, although some have survived longer.

widely used for AI across the world. The problem is

Many of the signs are similar to BVD infection, BIV,

of malformed calves which appear visually to have a

mineral deficiencies and parasitic problems including

foreshortened neck and thorax; the spinal cord may be

coccidiosis, cryptosporidiosis and parasitic gastroenteri-

twisted, with deformed carpal and metacarpal joints. It

tis. Diagnosis is often difficult, but if BVD is eliminated

appears that there can also be an increase in abortions,

and the animal has a marked leucocytosis it is likely to

heart and lung abnormalities and low birthweight.

be the cause. This can be confirmed by laboratory exam-

Control is obtained by ensuring dams are not mated to

ination of blood to show the presence of the genetic

known carrier bulls or other bulls descended from the

defect and looking at the pedigree to determine the

same bloodlines.

presence of certain affected bulls. Many reputable

cattle semen companies will indicate the presence of

Congenital joint laxity and dwarfism

the BLAD factor within their bulls. Treatment has been

syndrome (CJLD)

successfully undertaken by bone marrow transplant but

is not recommended as it is helping to perpetuate a

The condition is also known as long bone

genetic defect. If a mating does produce an affected calf

deformity/chondrodystrophy syndrome and in Canada

'acorn calf syndrome', as it occurs at a time when

Mandible and face abnormalities

acorns are around. The condition is seen mainly in the

The terms 'overshot' and 'undershot' are often used for

calves of suckler cows and very occasionally dairy

these conditions, but they have variable definitions.

heifers. The calves are mainly born in the spring from

Abnormal length of the upper and lower jaws is better

dams which have usually been fed only pit or clamp

termed superior or inferior prognathia and shortening

silage or rarely big bale silage with no other feeds.

of the upper or lower jaw is superior or inferior

Various causes have been suggested but it appears to

brachygnathia respectively. Most newborn calves show *be nutritional in origin, directly or indirectly, as the*

a degree of inferior prognathia, but this condition

addition of another feed such as straw, hay, cereals,

resolves. However, persistent inferior prognathia is

etc. to the diet usually prevents or greatly reduces its

more common than inferior brachygnathia (parrot

occurrence.

mouth). The conditions are thought to be inherited.

There are various forms of the condition which have

Problems can arise from impaction or non-apposition

been grouped together and may be variations on the

of the molar teeth. Extreme hypoplasia or agnathia

same problem or different problems. In the dwarfism

are rare. Lateral deviation of the face with normal

syndrome animals are born at full gestation but

development of the mandible (campylognathia) is

have long bone shortening. Other signs can include

occasionally seen.

increased (laxity) or decreased joint movement (chon-

drodystrophy) and some of these can improve. The fet-

locks are often involved. The head may be domed or

Vertebral column defects

the face dished, there may be superior brachygnathia.

The fore limbs may show lateral bowing or the hind can

Various abnormalities have been reported including

be sickle hocked. Severely affected calves are unable

spirabifida, lordosis (ventral deviation), kyphosis (dorsal

to rise and my have kyphosis. Post-mortem reveals

deviation) and scoliosis (lateral deviation). Occasion-

the skeletal abnormalities; there may also be hepatic

ally, there is partial or total agenesis of the posterior part fibrosis.

of the spinal column; screwtails are reported in Red Polls

The cause is unknown although silage feeding is crit-

and wrytails in Jerseys and Holsteins. Ankylosis of the

ical. There appears to be an interference in normal bone

intervertebral joints has been recorded.

metabolism: it may be a calcium/phosphorus imbalance,

or vitamin D, A or copper deficiency. Manganese

Defects of the limbs and claws

problems have been suggested but supplementation

does not improve the problem. There appears to be no

Occasionally, duplication of all or part of the limb *genetic link.*

occurs and in other animals the whole or various bones

of the limb are absent. One problem recently described

is tibial hemimelia in Galloway cattle. Polydactyly or

Osteopetrosis (metaphyseal dysplasia)

extra digits have occasionally been seen. A quite

frequent abnormality is the partial or complete fusion

This has been recorded in black and red Aberdeen

of the digits (syndactyly or mule foot). The condition is

Angus and Hereford calves. It is thought to be due to

reported in the Holstein, Aberdeen Angus, Hereford

an autosomal recessive gene. The calf may be born

and Chianina. It occurs more commonly in the front

prematurely. At birth it is small and of low weight,

than the hind legs and the right limbs are more often

with brachygnathia inferior (shortened mandible),

affected. It can be inherited as a simple autosomal

protrusion of the tongue, impaction of the molar teeth,

recessive trait. Duplication of the whole limb (poly-

misshapen coronoid and condyloid processes, open

melia) is very rare. It can be attached to the thigh of the *fontanelle, thickened cranial bones, shortening of the*

normal limb by soft tissue and a pseudoarthrosis may

long bones and a lack of bone marrow. Radiographs

develop between the femoral head and the pelvis.

show the homogeneous bone shaft.

Osteoarthritis

Atlanto-occipital fusion

Although it can be nutritional in origin, it can also

This is rare and is due to a failure of the first cervical

be inherited in Jersey and Holstein Friesian cattle.

vertebra to separate from the occipit and thereby form

There are two main conditions, namely degenerative

a joint. It need not necessarily be apparent at birth. The

arthropathy, which mainly involves the hips, and degen-

main signs are ataxia with inability to coordinate limb

erative osteoarthritis, which primarily affects the stifle

movements. There are then abnormal flexures of the

joints. The latter condition develops in older cattle

cervical region and recumbency.

over a period of one or two years. The stifle shows *crepitation and the limb is not raised much off the*

tend to be in poor condition with a poor coat and

ground when walking. The articular cartilages show

increased salivation.

degeneration.

Atresia ilei

Arachnomelia

This condition has occasionally been reported and there

This condition involves the limbs having very long, thin

is disruption of patency. The signs are of a distended

distal extremities like a spider and the bones are brittle.

abdomen and this may lead to dystokia. Some cases are

It has been recorded in the Simmental breed. Often

due to a recessive gene.

there is spinal curvature and inferior brachygnathia,

which often affects other body systems.

Atresia coli

Displaced cheek teeth

This has been recorded in Aberdeen Angus and other

breeds. The calves survive only a few days.

The lower mandible tends to be shorter and narrower *than normal with abnormal eruption or impaction of*

the cheek teeth.

Atresia ani

This may be inherited and is seen in several breeds

including the Friesian. The animal is usually born

Lymphatic system

bright, but will usually die within a week unless surgi-

cal relief is provided.

Inherited lymphatic obstruction

This has been reported in Ayrshire calves and is caused

by the autosomal recessive condition. The lymph nodes

Muscular system defects

tend to be small and the lymphatic vessels are large and

tortuous. The condition results in oedema, which varies

Congenital flexure of the pastern joints

from slight to severe. The calves may be born dead. The

oedema may be so gross as to cause dystokia. Oedema

This is common and present in most breeds. In the

can be of the head, neck, ears, tail and legs. In slight

Jersey it is considered to be caused by an autosomal

cases there is oedema of the legs and these animals may *recessive gene. The calves show knuckling over on one*

survive. Accessory lobes may be present at the base of

or both front fetlocks, and occasionally the hind limbs

the ears.

are also affected. The condition is usually reversible and

most calves recover within about six weeks. In some

cases it may be necessary to splint the limbs. Manganese

Alimentary tract defects

deficiency in the dam can also lead to the condition

as can locoweed or poison vetch (Astragalus and

Oxytronis spp).

Cleft palate (palatoschiasis)

This can occur as an individual condition but is

normally associated with other conditions, particularly

Arthrogryposis ('curled calf disease')

arthrogryposis.

(see pp. 451, 925)

By definition this is a permanent joint contraction. The

Harelip

condition is normally bilaterally symmetrical and

the forelimbs are affected more than the hind limbs.

This has been recorded in cattle but its mode of inher-

The muscles show marked atrophy, they are pale

itance is not known. Occasionally, ingestion of lupin

in colour and there is replacement of many muscle

(Lupinus sericeus) can result in the condition.

fibres with fat. Cleft palate is often also present.

The condition is common in the Charolais breed where

it is a recessive gene. The gene is probably more

Smooth tongue (epitheliogenesis

prevalent than it should be because carrier dams

imperfecta linguae bovis)

appear to have advantages in improved longevity and

This is seen in the Holstein–Friesian and Brown Swiss.

fertility. Infection of the fetal calf by akabane virus can

It is the result of an autosomal recessive gene and leads

result in the condition, as can lupin (Lupinus sericeus) to the filiform lingual papillae being small. The animals

ingestion.

Muscular hypertrophy (double muscling,

the Holstein and Hereford and is in-herited. Infection

muscular hyperplasia, culard)

of the fetus with akabane virus can produce the

problem and it is thought vitamin A deficiency can con-

This is a characteristic with some production potential

tribute to the condition. It can result from obstruction

in that some muscles have increased numbers of muscle

to the drainage of cerebrospinal fluid from the ventri-

fibres. The condition is seen in the South Devon,

cles or cranial malformation. In both conditions the

Limousin, Charolais and Belgian Blue and the degree

animals are born dead or die in a few days. There are

of skeletal muscle involvement varies. It occurs most

usually ocular defects.

commonly in the hind limbs with a rounding of the

hindquarters. The muscles affected have deep grooves

along the intermuscular septa and this may be seen in

Cerebellar hypoplasia

the muscles of the shoulder, back, rump and hindquar-

This is also known as Hereford disease, but is seen in

ters. Many of the animals tend to stand in a stretched

the Holstein and Shorthorn and appears to be genetic.

position. The calves tend to be less viable at birth and

During pregnancy, infection with BVD or Neospora can

because of the increased muscle size dystokia is

produce the condition (see p. 900). The cerebellum

common. In the Belgian Blue dystokia results partly

tends to be small, tough and leathery or even absent.

from a narrowing of the dam's pelvis.

Most calves are obviously affected at birth; there is

swaying of the neck, with inability to stand and blind-

Multiple tendon contracture

ness occurring in severely affected animals. Less badly

affected calves have exaggerated and incoordinated

This has been recorded in Shorthorn cattle and results

limb movements. The animals are conscious and able to

in dystokia due to the calf's limbs being fixed in

drink. Some will survive for several months.

extension or flexion. There is a lack of mobility of the

limbs and often positioning is abnormal. The problem

involves the tendons and there is limb muscle atrophy.

Inherited cerebellar ataxia *(see p. 893)*

The calves are born dead or are destroyed because they

This condition is described as being due to a single auto-

are unable to stand. The condition is thought to be

somal recessive gene. It is seen in the Holstein, Jersey

inherited by a single recessive gene.

and Shorthorn and the signs are similar to cerebellar

hypoplasia, although they are not apparent at birth. The

Joint hypermobility

gross lesions are minimal and consist of a wet glisten-

ing appearance to the cerebellar white matter, which

The cause of the condition is unknown but in Jersey

appears on histology to be reticulate.

calves it is a single autosomal recessive gene. The joints

are very mobile and can be bent into very abnormal

positions with overextension and flexion of all or most

Cerebellar abiotrophy (premature ageing)

of the upper fore and hind limb joints.

This condition is seen in Hereford and Simmental

calves and appears when four to eight months old.

Achondroplastic deviation

There is the sudden onset of ataxia, which then pro-

gresses slowly. The animals are not blind. Calves remain

Most cases appear to be inherited as a single recessive

strong but become recumbent or decline slowly into

characteristic and involve the Aberdeen Angus and

a spastic ataxia. Histologically, there is ageing or

Hereford breeds but cases have been reported in the

degeneration of the cerebellar neurones (see p. 893).

Holstein and Shorthorn. The calves have short legs, a

wide, short head and the mandible protrudes far in

front of the dental pad. The eyes bulge and the tongue

Congenital spasms

protrudes. Breathing is stertorous with the forehead

The condition has only been reported in the Jersey and

protruding and the maxilla distorted.

there is a continual tremor of the head, neck and limbs.

The animal cannot walk and it may die in a few weeks.

***Nervous system defects** (see Chapter 51)*

***Familial ataxia and convulsions** (see p. 893)*

Hydrocephalus

These have been reported in Aberdeen Angus calves

This is uncommon in calves and can be inherited or

and appear to be an incomplete dominance. The signs *congenital. It is often associated with other deformities.*

are seen within a few hours of birth but can occur when

e.g. congenital achondroplasia. The condition is seen in

two or three months old with the sudden onset of

tetanic spasms, which last for three to twelve hours. In

an inability to bellow. Histological examination reveals

mild cases there is a stiff, exaggerated movement but in

accumulations of neurofilaments within the neurones of

the severe form there may be convulsions with recum-

the central, peripheral and autonomic nervous systems.

bency, opisthotonus and paddling of the forelimbs. Fol-

A similar clinical syndrome has been recorded in

lowing the initial signs there is a residual ataxia with a

Holstein male calvers and is probably caused by a

goose-stepping action, which lasts weeks or months.

sex-linked recessive mutation. On histology, there

Necropsy shows lesions of degeneration of the cerebel-

are spinal cord changes with spongiform lesions with

lar cortex Purkinje cells. Diagnosis depends on age,

cavitation.

signs and their remission.

Idiopathic epilepsy

Progressive ataxia *(see p. 894)*

This condition occurs when the calves are a few months

This has been recorded in the Charolais in Britain and

old and mainly involves the Brown Swiss. It is inherited

subsequently in France. The signs do not develop until

as a dominant characteristic. The convulsions are

the animal is about a year old and they are seen as a

epileptiform and are seen when the calf is stimulated.

progressive ataxia. The animal has increasing difficulty

They disappear once the animal is one to two years old.

in rising until it may become permanently recumbent.

Histologically, there is a myelin degeneration of the

Lysosomal storage diseases *(see p. 892)*

white matter of the cerebellum and internal capsule.

There is a generalized glycogen storage problem in beef

Shorthorns with muscle weakness, incoordination of

Bovine progressive degenerative

gait and eventual recumbency. In the Friesian there is

myeloencephalopathy

a GM1 gangliosidosis where there is an accumulation of

(Weaver syndrome)

ganglioside (GM1) in the nervous tissue due to reduced

activity of the enzyme b-galactosidase. At about three

The condition is inherited, appears to be linked with

months old the animal begins to grow more slowly, is

high milk production and occurs in the Brown Swiss

blind and has a staring coat.

breed, although a similar condition has been described

in the Murray Grey. Signs usually develop between five

months and two years, with the occasional one starting

Mannosidosis

after that time. The problem is one of a progressive

The condition has been recorded in Aberdeen Angus

(it often stretches over one to one and a half years)

and Murray Grey cattle in New Zealand, Australia and

bilateral hind limb weakness with the animal showing

recently in Britain (see p. 892). It is inherited as an auto-

an increasingly broad-based stance when standing,

somal recessive trait and is a deficiency of a specific

ataxia and dysmetria. Thus the animal gradually has *lysosomal hydrolase enzyme, a-mannosidase, and this*

increasing difficulty in rising, a weaving action and often

causes the accumulation of mannose and glucosamine

goose stepping of the fore limbs while starting to drag

in secondary lysosomes. The signs develop from one to

its hind legs. Although there are proprioceptive deficits,

fifteen months old and most animals die by one year.

limb reflexes are normal. The animal is bright and alert

There is, at first, slight hind leg ataxia, then a fine lateral throughout the condition. At post-mortem examination

head tremor, slow vertical head nodding, aggression and

there are lesions in the white matter of the cerebellum

loss of condition. Diagnosis is based on reduced tissue

and at all levels within the spinal cord. The lesions

and plasma levels of a-mannosidase. Histologically,

include axonal degeneration and vacuolation of the

accumulations of mannose and glucosamine are seen

white matter due to large intercellular spaces and

in the nerve cells, fixed macrophages and epithelial

axonal spheroidal degeneration.

There may be

cells of the viscera. Tissue and plasma levels of a-

muscular wasting but without muscular dystrophy.

mannosidase are about half the normal level in het-

Chromosomal examination confirms the defect.

erozygous animals and can thus be detected.

Inherited neurodegenerative disease

Spastic paresis *(see p. 458)*

(shaker calf syndrome)

There is an extension of the stifle and tarsal joints of

This syndrome, which has been described in Canadian

one or both hind limbs. The condition is seen in the

horned Hereford cattle, is evidenced by a severe mus-

Friesian, but other breeds can be affected. Signs are not

cular tremor and shaking of the head, body and tail. The

usually present until the animal is several weeks or

animal has difficulty in rising, a wobbly spastic gait and

months old, when they start to progress. Contraction

of the Achilles tendon, gastrocnemius and superficial

recumbent, often in lateral recumbency and some are

flexor tendons overstraighten the hock joint, so that the *unable to move their head. There is extension and os calcis is moved cranially towards the tibia. Usually, crossing of the hind limbs with hypersensitivity to noise one leg is more affected than the other and this limb and touch. Often when animals are encouraged to stand may appear shorter. In the later stages of the severe there are myoclonic spasms with the body becoming cases, the leg may swing backwards and forwards like a rigid. At necropsy there is usually damage to the hip pendulum. The condition is considered to be inherited. joints, probably secondary to myoclonic contractions. However, the genetic influence is considered to be There is no oedema of the central nervous system. The small, and it is thought that the phenotypic expression main differential diagnosis is maple syrup urine disease. as a probably multifactorial recessive genotype depends No treatment is possible and the same mating pattern on mostly unknown environmental factors. Where only should not be used again.*

small numbers of an AI bull's offspring are affected and the animal is of high genetic merit, it has been sug-

Maple syrup urine disease

gested that it should still be used as a sire (see p. 166).

(branched-chain ketoacid

Surgery can relieve the condition but the animals

decarboxylase deficiency, BCKAD)

should not be used for breeding. Recently, analysis of

cerebrospinal fluid concentrations of homovanillic acid,

This condition is possibly inherited as an autosomal

the main metabolite of dopamine, has shown levels to

recessive gene. It is very uncommon but may be seen in

be lower in spastic paresis calves than normal contem-

polled Hereford calves (see p. 893). There are higher

poraries. The possibility of a disorder in dopamine

than normal concentrations of branched-chain amino

metabolism has therefore been suggested as a possible

acids in plasma and/or serum, urine, cerebrospinal fluid

cause of the condition.

and formalin-fixed cerebral tissue. It has been sug-

gested that the condition is analogous to branched-

chain ketoacid decarboxylase deficiency or maple syrup

Neonatal spasticity

urine disease. There is dullness, opisthotonus and

This condition involves a single recessive characteristic

recumbency and a poor response to touch or auditory

in the Jersey and Hereford. The animal is born normal

stimuli. At post mortem there is severe stratus spon-

but within the first week it develops convulsions of the

giosus. The main differential diagnosis is inherited con-

head, neck and limbs, preceded by neck deviation and

genital myoclonus.

bulging eyes.

Congenital pastern paralysis

Periodic spasticity

The defect is lethal due to prolonged recumbency and

in Red Danish cattle at birth can take the form of

This has been recorded in the Guernsey and Holstein

opisthotonus–muscle tremor with spastic extension of

breeds. It appears to be a single recessive character with

the limbs and exaggerated tendon reflexes. There is

incomplete penetrance and is often not noticed until

neuronal degeneration in many parts of the brain and

the animals are adult. Early signs involve the hind end, *spinal cord. In the Norwegian Red Poll a similar*

with difficulty in rising; the hind limbs are stretched

condition is seen but only involving opisthotonus and

backwards and the back depressed. The back muscle

muscle tremors.

may fasciculate and the condition progresses from a few

seconds duration to last up to 30 minutes. The animal

cannot walk during the attack.

Perosomus elumbis

This occurs very occasionally in ruminants. There is

aplasia or hypoplasia of the spinal cord caudal to the

Inherited congenital myoclonus

thoracic area. This results in rigidity of the hind limbs,

The condition does not involve oedema of the central

there is muscle atrophy and no joint movement. Most

nervous system and is therefore described as inherited

cases are born dead.

congenital myoclonus (see p. 893). It is inherited as an

autosomal recessive gene and is seen in America, New

Zealand and Australia to affect Hereford and polled

***Ocular defects** (see p. 914 onwards)*

Hereford-cross calves. It has also been reported in

Britain in the Hereford, Jersey and South Devon.

Reports of ocular defects in cattle are few. Anoph-

Animals are usually produced after a shorter than

thalmia and microphthalmia occur infrequently.

normal gestation period. They are bright and alert but

Entropion is also very rare. Dermoids can occur on the

eyelids, conjunctiva and cornea, but they are common-

Persistent hyaloid vessels

est on the third eyelid.

These are quite common and are the vestige of the

earlier development of the eye. They have no practical

significance.

Exophthalmus with strabismus *(see p. 918)*

This has been recorded in the Hereford and Holstein is

combined with strabismus in Shorthorns and their

Skin defects

crosses in Britain and Jerseys in America. The signs,

particularly in the Shorthorn, are usually delayed until

Symmetrical alopecia

a year old, although occasionally young calves are
This is apparently inherited as a single autosomal reces-
affected. The condition is progressive and defective
sive characteristic in Holstein cattle. It involves animals
vision is observed first, followed by protrusion and devi-
born with a normal hair coat but which is then lost in a
ation of both eyeballs medially with difficulty in focus-
symmetrical pattern over the body. It occurs between
ing. The condition is considered to be inherited as a
six weeks and six months of age and affects both
recessive gene, but some occur in cases of cerebellar
pigmented and non-pigmented areas.
hypoplasia or mucosal disease.

Congenital hypotrichosis

Colobomata *(see pp. 923, 924)*

Several forms are recorded that vary both in inherit-
These problems appear to have a high prevalence in the
ance and degree. There may be partial or complete loss
Charolais. There is an absence of part of one or more
of hair and the condition is present at birth. In some
of the structures of the eye. The condition occurs during

instances the animals will grow satisfactorily provided

early gestation, when the eye is developing. Although

there is sufficient shelter.

always bilateral, it may not be symmetrical and it is

usually found associated with the optic disc and the

Epitheliogenesis imperfecta

tapetum nigrum below the disc. The retina is involved

and in some animals the choroid and sclera are also

This condition can occur in either sex and reports

affected. The condition is present at birth and does not

include Holstein, Ayrshire and Jersey calves. Most

progress. The mode of inheritance has been debated,

animals die within a few days of birth. It is considered

but a dominant gene with incomplete penetrance, auto-

to be caused by an autosomal recessive gene. There are

somal recessive or polygenic inheritance have all been

normally areas of varying size devoid of skin or mucous

suggested. Signs are not usually apparent although an

membrane. The defects are often distal to the tarsal and

ophthalmoscopic examination will reveal the lesion.

carpal joints. Lesions may also occur on the muzzle, *The very severely affected animal can be blind, and a*

tongue, hard palate, cheeks and nostrils.

few others are considered to be hyperexcitable due to

the defective vision.

Keratogenesis imperfecta (baldy calves)

The condition appears a few months after birth and is

Congenital cataract

lethal. It has been observed in the Friesian and is due

(see p. 923)

to an autosomal recessive gene. The skin tends to

Lens opacity is present from birth. The condition has

develop alopecia, there is a loss of body condition and

been recorded in the Friesian, Hereford, Jersey and

the horns do not grow. The skin then becomes scaly,

Shorthorn. Some cases in the Holstein and Jersey are

thickened and folded, particularly on the neck and

considered to be due to an autosomal recessive gene or

shoulders. There is alopecia and raw areas may develop,

infections. A form of nuclear cataract in Friesian and

particularly on the knees, hocks, elbows, axillae and

Friesian-cross calves appears to be more common in flanks. The joints tend to be stiff and there is

calves born in the summer months and is considered to

overgrowth of the hooves.

be of environmental origin. The condition is bilateral

and not progressive. In most animals the degree of

Inherited parakeratosis (lethal trait A46)

involvement of each eye is similar. In severe cases

blindness is apparent. It is not always possible to

This is possibly an autosomal recessive condition. It is

examine the fundus of the eye, but in most affected

seen in Friesian cattle and is thought to be due to an

calves there is no abnormality of the retina or optic disc

increased zinc requirement. The signs are usually seen

(see p. 923).

about four to eight months after birth with alopecia and

parakeratosis of the limbs, muzzle and under the jaw.

umbilical herniae are missed unless a conscious effort

The animal becomes stunted and, if untreated, it dies in

is made to look for the defect. This is due to the hernia

about four months. At necropsy there is thickened skin *occurring just anterior to the prepucial orifice. If the*

with thick crusts over the skin lesions. The spleen shows

hernia is small it may not need to be treated. Larger

hypoplasia. Diagnosis depends on low serum zinc levels

hernias may need surgical repair (see p. 1122) by sutur-

(normal 12–27 mmol/l; 80–120 mg/100 ml) and history of

ing across the hole or surgical webbing may need to be

parakeratosis. Therapy must continue for the rest of the

introduced. Many cases are inherited and the animal

animal's life and as a calf about 0.5 g zinc oxide or 1 g

should be recorded as often the hernia is hard to detect

zinc sulphate daily is required. The dose should be

in the adult. Do not breed from affected cattle.

increased as the animal grows older (see p. 260).

Inguinal herniae

Interdigital hyperplasia *(see p. 429)*

These occur far less commonly than umbilical herniae.

This condition is particularly seen in the Hereford and

Little is known about aetiology.

it is considered to have a genetic predisposition. The

condition tends to be present in the older animal and

Scrotal herniae

can be surgically removed, but has a tendency to recur.

Like inguinal herniae, these are rarely seen but can

occur in the Sussex and Friesian breeds. Little is known

Albinism

about the aetiology, but there is a familial trait.

Varying types occur. In partial albinism the coat colour

is normal for the breed or a dilute colour, but the iris is

Schistosoma reflexus

blue and white centrally, with a brown border. In-

complete albinism is characterized by a white or mainly

This is a group of conditions in which there is longitu-

white coat and the iris may be blue, grey or white. The

dinal fissure in the body wall. The cause is unknown, but

condition is inherited by an autosomal dominant gene.

it may be due to the failure of the somatopleure of the

In complete albinism the coat is pure white and the iris

blastodermic vesicle to close. At birth the vertebral

white or pink. The condition is inherited as a simple

column is angulated with the head and tail showing

autosomal recessive trait.

approximation dorsally. The abdominal and thoracic

organs lie free in the dam's uterine cavity.

Familial acantholysis

Diaphragm defects

This has been recorded in Aberdeen Angus calves.

There is a loss of skin at the carpal and metacarpal

These occur occasionally and, depending on size and

joints and coronet, where there is horn separation. The

position, they may or may not involve abdominal organ

defect is one of defective collagen in the basal and

herniation.

prickle layers.

Reproductive system defects

Congenital ichthyosis

This is also known as fish scale disease in that there is

Testicular hypoplasia *(see p. 618)*

alopecia and the presence of a horny epidermis.

This occurs sporadically in all breeds of bull. The

problem can be bilateral or unilateral as well as being

partial or complete. The left side is more commonly

Body cavity defects

affected. Work on gonadal hypoplasia in Swedish

Highland cattle showed an inherited origin and this is

Umbilical herniae (navel ruptures)

probably also the case in British breeds.

These are found with a low frequency in several breeds,

but especially the Friesian and Holstein. It would

Cryptorchidism (see p. 482)

appear in some cases to be due to the environment, fol-

lowing infection, to a dominant gene with incomplete

There is incomplete descent of the testicles into the

penetrance, or autosomal recessive genes. In one study

scrotum and this may be unilateral or bilateral,

of the progeny of Holstein bulls, more cases occurred

although the former is more common. Bilateral cryp-

in the female than the male offspring. In the male many

torchidism usually produces a sterile animal. The

condition occurs in most breeds including the Friesian

usually first stage labour is minimal, necessitating a

and Hereford. Although studies of aetiology are few, it

Caesarean section. The calves tend to be heavy, have *is considered to have an inherited basis.*

well-erupted teeth and a good coat growth. The adren-

als of the calves are hypoplastic and following delivery

most are weak and die in hypoglycaemic crisis. The

Wolffian duct aplasia

condition is the result of an autosomal recessive gene.

This is normally seen in the area of the epididymal

(2)

Prolonged gestation with adrenohypophyseal

head.

hypoplasia. This is due to a recessive gene and it is

mainly recorded in the Channel Island breeds. The ges-

tation length is increased by weeks or months and par-

Ovarian aplasia

turition occurs about seven to fourteen days after the

This occurs occasionally with or without other

calf's death. There is again no udder development and

reproductive abnormalities.

few signs of parturition. The calf in this case is small and

ceases to grow after the seventh month of gestation, so

it can often be delivered by manual traction. It may

Ovarian hypoplasia

show disproportionate dwarfism, craniofacial defects

As with testicular hypoplasia, this has mainly been

that may cause hydrocephalus, alopecia and abdominal

recorded in the Swedish Highland breed where it is

distension. There is no or only partial development of

inherited.

the adenohypophysis.

It should be remembered that the gestation period of

some of the larger beef breeds such as the Charolais,

Müllerian duct aplasia

Simmental and Limousin is longer than for the Friesian

Various forms can occur and all are uncommon, but the

or most British beef breeds.

main form is uterus unicorni.

Hermaphroditism

Duplication of the reproductive tracts

Both true and pseudohermaphrodites occur. In the true

This can occur as a deficient union or exaggerated

form there are gonads of both sexes, although they may

union of the Müllerian ducts. They can result in a partial *be combined into an ovo-testis. In the pseudoher-*

or complete duplication of the cervix or uterine body

maphrodite, cattle are genetically female with female

or vaginal septa.

gonads but they have partial masculinization of the

external genitalia. The animals usually exhibit normal

oestrous behaviour and on investigation have normal

White heifer disease

ovaries. However, the vulvar orifice is usually small and

The condition used to be common in the white Short-

displaced ventrally.

horn with up to 10 per cent of them being affected. It

is now rare, but can be found in other breeds. There are

Freemartinism

varying degrees of involvement. In all cases there is

partial or complete persistence of the hymen. This may

This is seen in twins where a female is developing with

be the only abnormality, but in other animals there are

a male and this affects about 11 out of 12 such twins.

abnormalities cranial to the hymen. These defects may

The calf contains both normal 60 XX chromosomes and *include the absence of the cranial vaginal cervix, uterine*

a few 60 XY (male) chromosomes. Occasionally, a

body or horns. The ovaries are functional and in most

female calf will be born singly with this abnormality and

cases there is a distension of the normal organs due to

this is due to the death of the other twin. Freemartins

the accumulation of the products of secretion.

are usually sterile.

The external genitalia resemble a female, but the

vulva is smaller than normal. Later a tuft of hair devel-

Prolonged gestation

ops at the vulva and in many cases an over-sized

This has been recorded in most dairy breeds and in

clitoris is found. Internally, there is a varying amount

some cases it has an inherited origin. There are two

of agenesis or hypoplasia of the Müllerian system and

main forms of the condition.

stimulation of the Wolffian system. The ovaries tend to

(1)

Prolonged gestation with fetal giantism. In these

be hypoplastic and the vagina is usually non-patent, *animals the fetus continues to grow in utero before par-which allows diagnosis of the condition in the calf by*

turition 21 to 100 days late. The cow usually calves with

the passage of a probe. However, occasionally the

no udder development or ligament relaxation and

vagina is tubular and terminates at the normal position

of the cervix, which is absent. The uterus tends to be

Congenital goitre

two thick cords and there are two thin ducts that extend

This is an inherited condition but animals can be kept

from the gonads to the intrapelvic urethra. There are

alive although mortality is high. Goitre also occurs

often seminal vesicles present and sometimes testicles.

when iodine deficiency affects the gestating dam (see

pp. 257, 301)

Urinary system defects

Anomalous twins

Pervious urachus

There is faulty division in monozygotic twinning and

The defect occurs occasionally in calves. However, it *this results in various abnormalities. There are varying may go undetected for weeks or even months, particu- degrees of conjunction, but double-headed monsters larly in the male. Urine is discharged in a dribble from are most often seen. Others have a single head and the the urachus. All urine may be passed via the urachus posterior part of the body is divided. In some cases although in some cases passage is also via the urethra. the separation of the vertebral column may be almost The condition may lead to cystitis and, as the umbilicus complete, resulting in Siamese twins. Occasionally, does not heal, there is often omphalophlebitis, septi- small amorphous monsters called amorphous globosus caemia and polyarthritis. Surgical correction of the or acardiac twins occur. They are related to double condition is possible and can be successful. monsters and identical twins. They are found attached to the fetal membranes of the other calves and comprise an outer skin enclosing adipose tissue.*

Other defects

Congenital porphyria

Chromosomal translocations

There are always 60 chromosomes present in the

This is very rare. It is mainly seen in the Friesian and

normal bovine. Translocation is the fusion of two mor-

Holstein. It is caused by a simple recessive gene and

phologically distinct chromosomes. The most common

occurs more frequently in the female than the male.

is 1/29 translocation where there is fusion between

There is increased porphyria in the blood and urine

number 1 and 29 pairs; it is also referred to as the

leading to the accumulation of the product in the

Robertsonian translocation. It has been recorded in the

tissues. The teeth tend to be pink or brown in colour

Swedish Red and White breed, Charolais, Red Poll,

and this can be seen in the newborn. The urine is red

British White and other breeds. The condition appears

or purple and animals will develop cutaneous photo-

to be of importance in that there is reduced fertility in

sensitization and anaemia. There are high levels of

such animals due to early embryonic death.

uroporphyrins and coproporphyrins in the blood.

Familial polycythaemia

Further reading

The condition is seen in the Jersey and is inherited as a

Blowey, R.W. & Weaver, A.D. (2003) Congenital disorders. In simple autosomal recessive trait. There are early deaths.

Colour Atlas of Diseases and Disorders in Cattle, 2nd edn.

Those alive have poor growth, congestion of the

Mosby, Edinburgh, pp. 1–9.

mucosae and dyspnoea. There is a reduced ery-

throcyte count, packed cell volume and haemoglobin

concentration.

Chapter 14

Calf Diarrhoea

P.R. Scott, G.A. Hall, P.W. Jones and J.H. Morgan

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permits a logical approach to disease control. Appro-

Causative mechanisms in diarrhoea

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priate advice on nutrition, colostrum feeding, vaccina-

Altered ion transport

185

tion, hygiene and the use of antibiotics can only be

Passive malabsorption

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given if it is clear which infectious agents are present

Intestinal motility

187

and what their contribution to the disease process

Osmotic effects

187

might be.

Tissue hydrostatic pressure and increased permeability

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Types of diarrhoea

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Role of the large intestine

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Effects of diarrhoea and their clinical signs

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Causative mechanisms in diarrhoea

Metabolic and hormonal changes

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Infectious agents

191

The digestive tract may be regarded as a high fluid flow

Bovine rotavirus

191

system in which 80 per cent of the fluid contained within

Bovine coronavirus

199

it is secreted into it and 20 per cent is ingested. Secreted

Calici-like virus (Newbury agent)

200

fluid originates from salivary glands, gastric mucosa,

Astrovirus

200

pancreas, liver and small and large intestinal mucosa.

Breda virus

201

Of the water that enters the digestive tract, 95 per cent

Escherichia coli

201

is absorbed. Diarrhoea may be defined as an increase

Campylobacter spp .

204

in faecal water loss due to increased faecal water

Cryptosporidium parvum

204

Investigating an outbreak of calf diarrhoea

206

content or to increased volume of faeces excreted or to

Epidemiology

206

a combination of both. The occurrence of diarrhoea

Mixed infections

207

indicates an imbalance between absorption and secre-

Management of diarrhoea

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tion of water and electrolytes. Only a slight imbalance

Rehydration

209

in the equilibrium between secretion and absorption,

Nutrition

210

in favour of secretion, may lead to severe diarrhoea

Drugs

210

because very large volumes of fluid are fluxing in

Environment

210

both directions. There are several possible causes of

Microbial environment

210

imbalance.

Immunological environment

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Nutritional environment

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Physical environment

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Altered ion transport

Necrotic enteritis

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Diarrhoea due to altered ion transport is caused by

reduced absorption of sodium ions by villous entero-

Introduction

cytes (Fig. 14.2), by increased secretion of chloride ions

by crypt cells (Fig. 14.3) or by both mechanisms acting

Diarrhoea in the neonatal calf is a serious welfare

together. These changes are stimulated in calf diarrhoea

problem and a cause of economic loss due to mortality,

by bacterial enterotoxins produced by enterotoxigenic

treatment costs and poor growth. Calf diarrhoea is an

Escherichia coli (Fig. 14.4). These bacteria, held on the example of a complex or multifactorial disease, result-gut surface by fimbrial adhesins, release enterotoxins.

ing as it does from an interaction between the calf, its

The subunit A of the heat-labile toxin activates adeny-

environment and nutrition and infectious agents (Fig.

late cyclase located on the basolateral membrane

14.1). Successful control of an outbreak will depend on

which, in turn, raises the production of intracellular

recognition of the important factors in that outbreak

cyclic adenosine monophosphate (cyclic-AMP).

and correction of the problems. Identification of the

Increased production of cyclic-AMP reduces sodium

infectious agents involved is important because it

ion absorption by villous cells (Fig. 14.5) and

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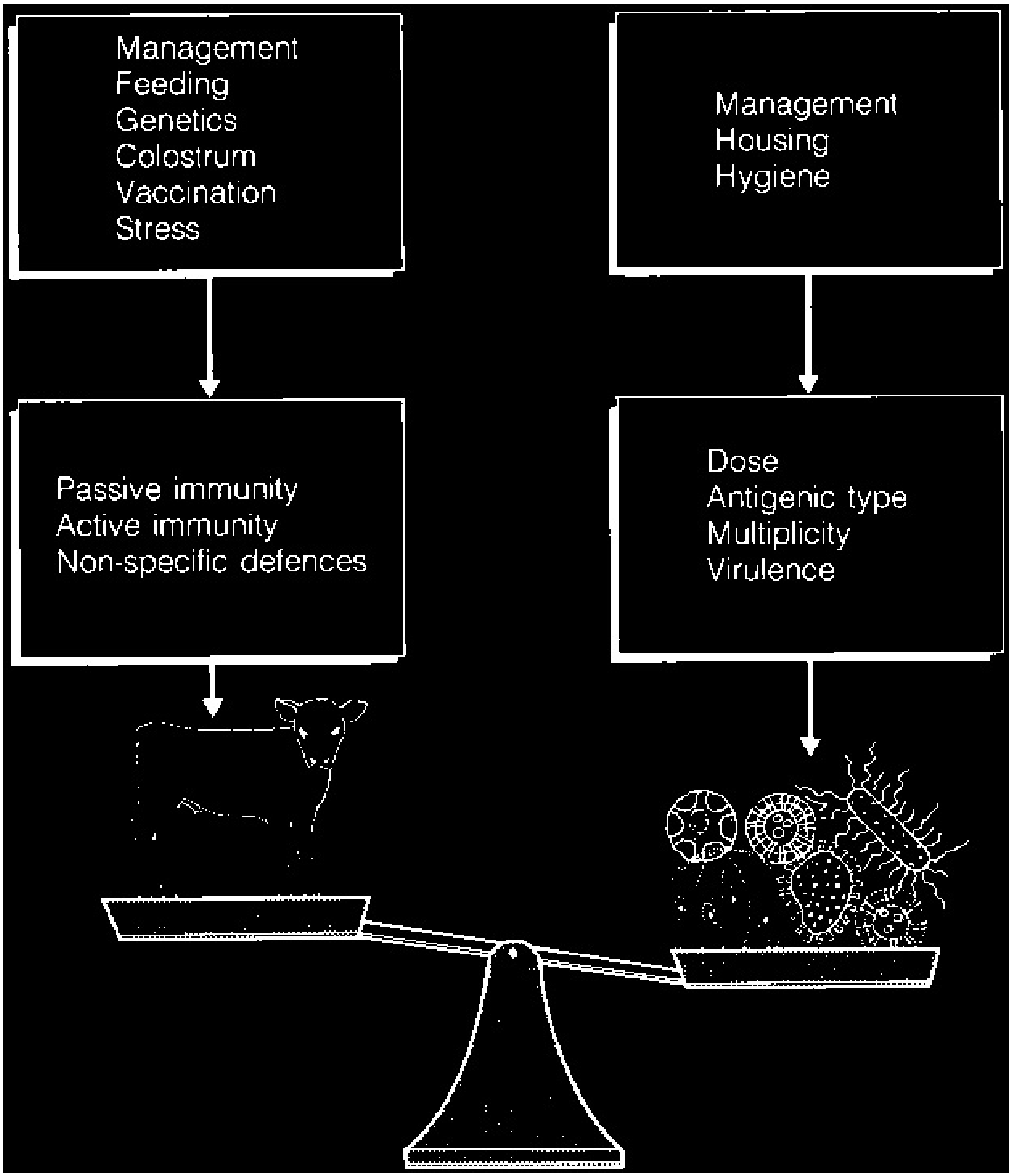
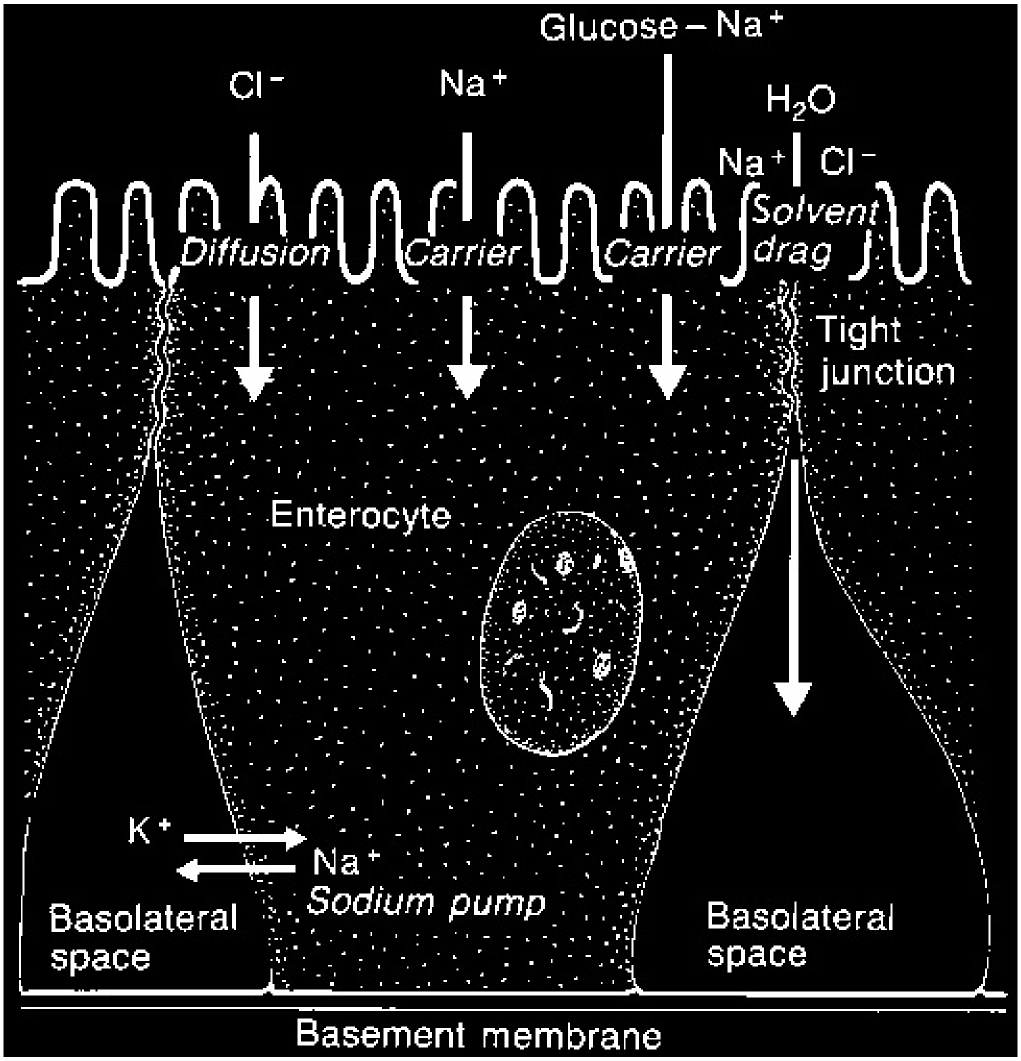
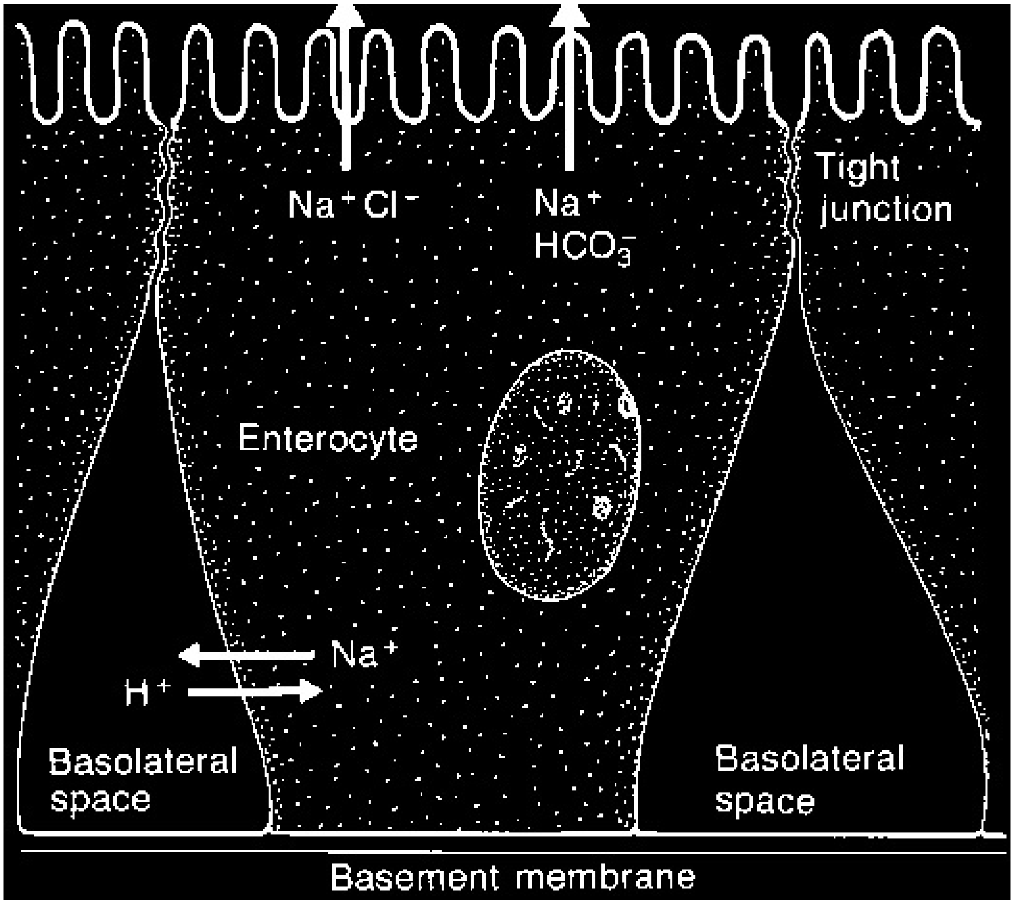




Glucose – Na^+
Cl^-
Na^+
H_2O
Na^+ Cl^-
Diffusion
Carrier
Carrier
Solvent drag
Tight junction
Enterocyte
K^+
Na^+
Sodium pump
Basolateral space
Basolateral space
Basement membrane



Na^+Cl^-
Na^+
HCO_3^-
Tight junction
Enterocyte
Na^+
H^+
Basolateral space
Basolateral space
Basement membrane

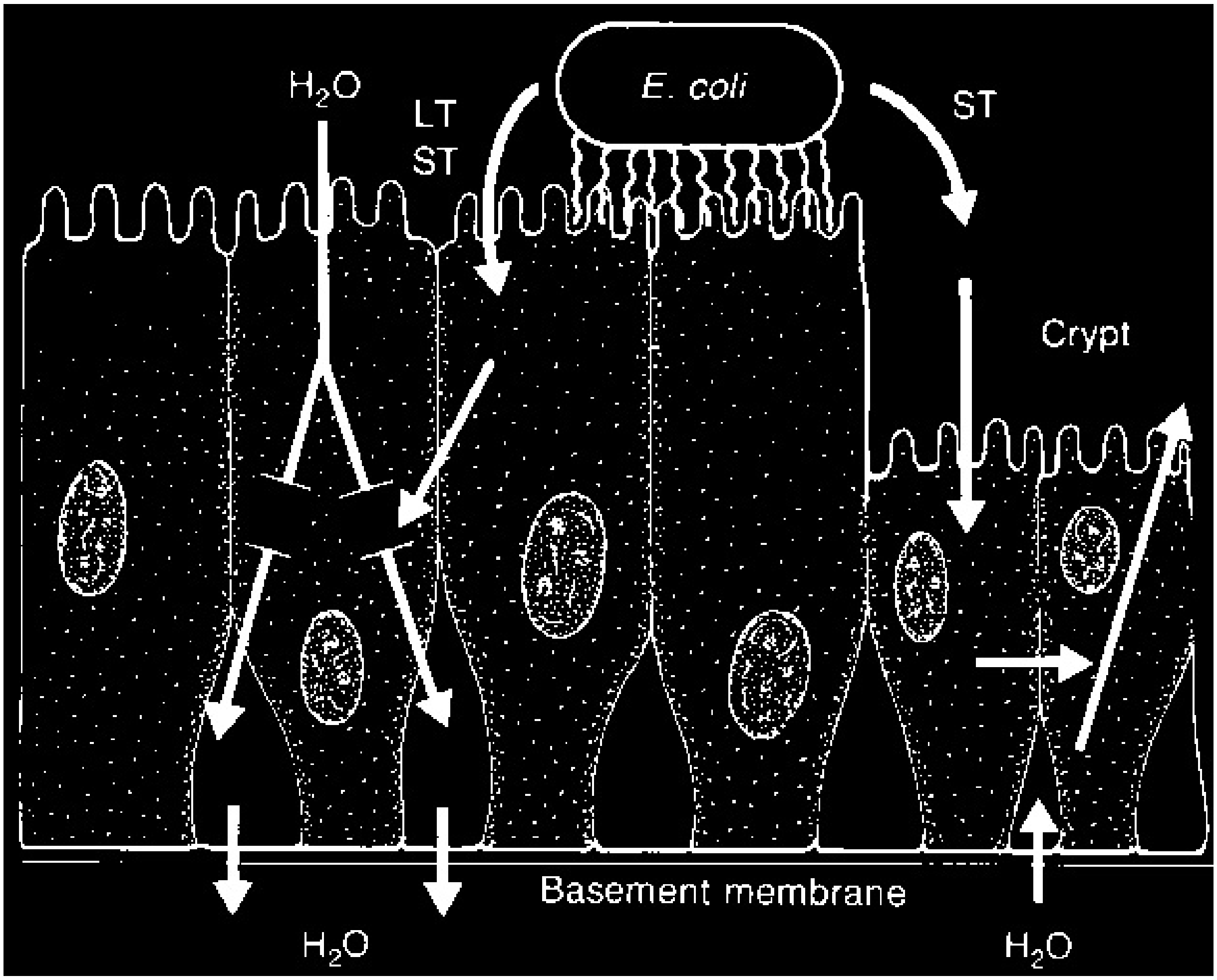


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Fig. 14.3

Line drawing illustrating some mechanisms of sodium secretion by crypt enterocytes. Sodium ions are secreted through the luminal surface and chloride and bicarbonate ions and water are transported within sodium ions.

Fig. 14.1

Interactions between management, the calf and enteric agents. Reproduced from Morgan (1990).

Fig. 14.4

Line drawing illustrating the mechanisms by which

enterotoxigenic E. coli cause diarrhoea. Bacteria are attached to the enterocyte surface by fimbriae and secrete heat-labile

enterotoxin (LT) or heat-stable toxin (ST), which act on metabolic pathways in villous enterocytes to block water absorption and

on metabolic pathways in crypt enterocytes to stimulate water

secretion.

Fig. 14.2

Line drawing illustrating some mechanisms of move-

consequently water absorption is reduced. At the same

ment of sodium and chloride ions and water from the intestinal time secretion of chloride ions, and therefore water, is

lumen into basolateral spaces. The sodium pump expels sodium

stimulated in crypt cells (Fig. 14.6). The heat-stable

ions from the villous enterocyte into the basolateral space.

enterotoxin activates guanylate cyclase, stimulating

Sodium ions diffuse along the electrochemical gradient created intracellular synthesis of cyclic guanosine monophos-by the sodium pump, through the enterocyte luminal surface

membrane, where passage is assisted by glucose-dependent

phate (cyclic-GMP),

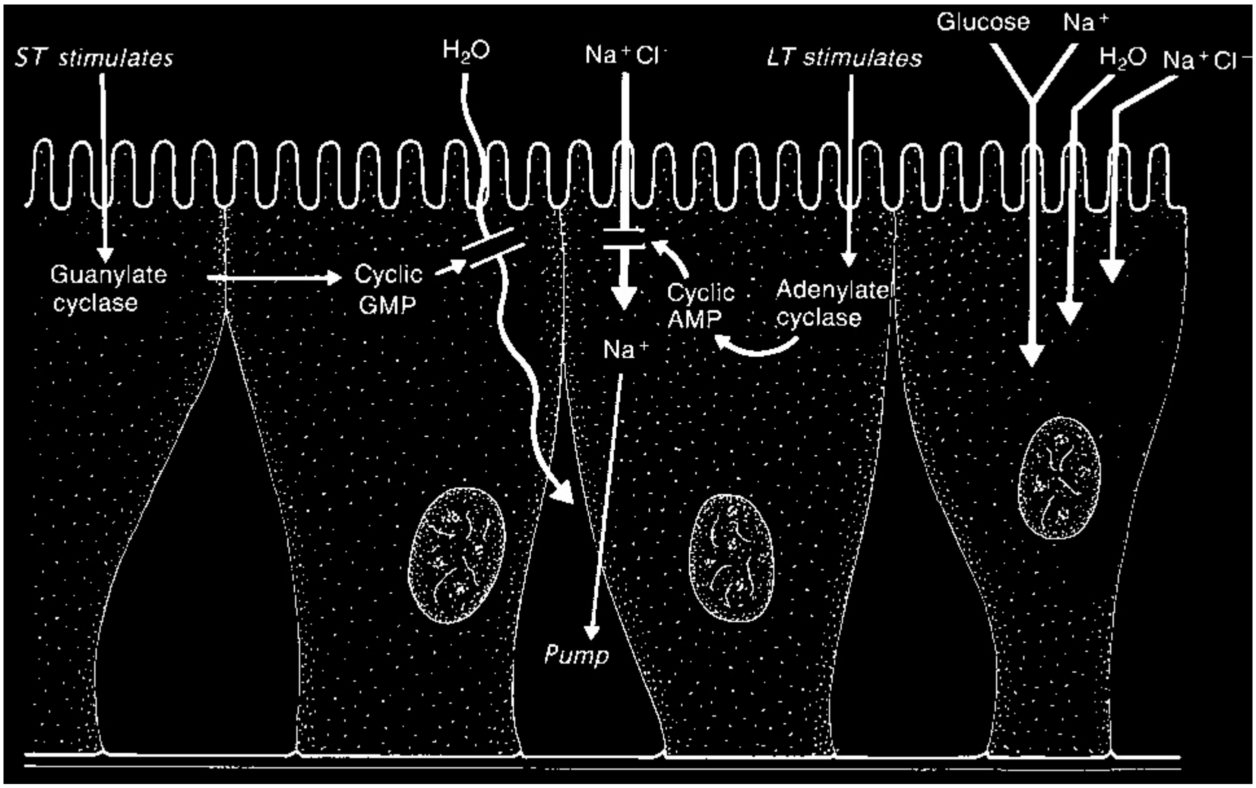
which probably stimulates

and glucose-independent carrier systems. Chloride ions and

secretion and reduces absorption, although the precise

water follow the movement of sodium ions.

mechanisms are not known (Fig. 14.5).



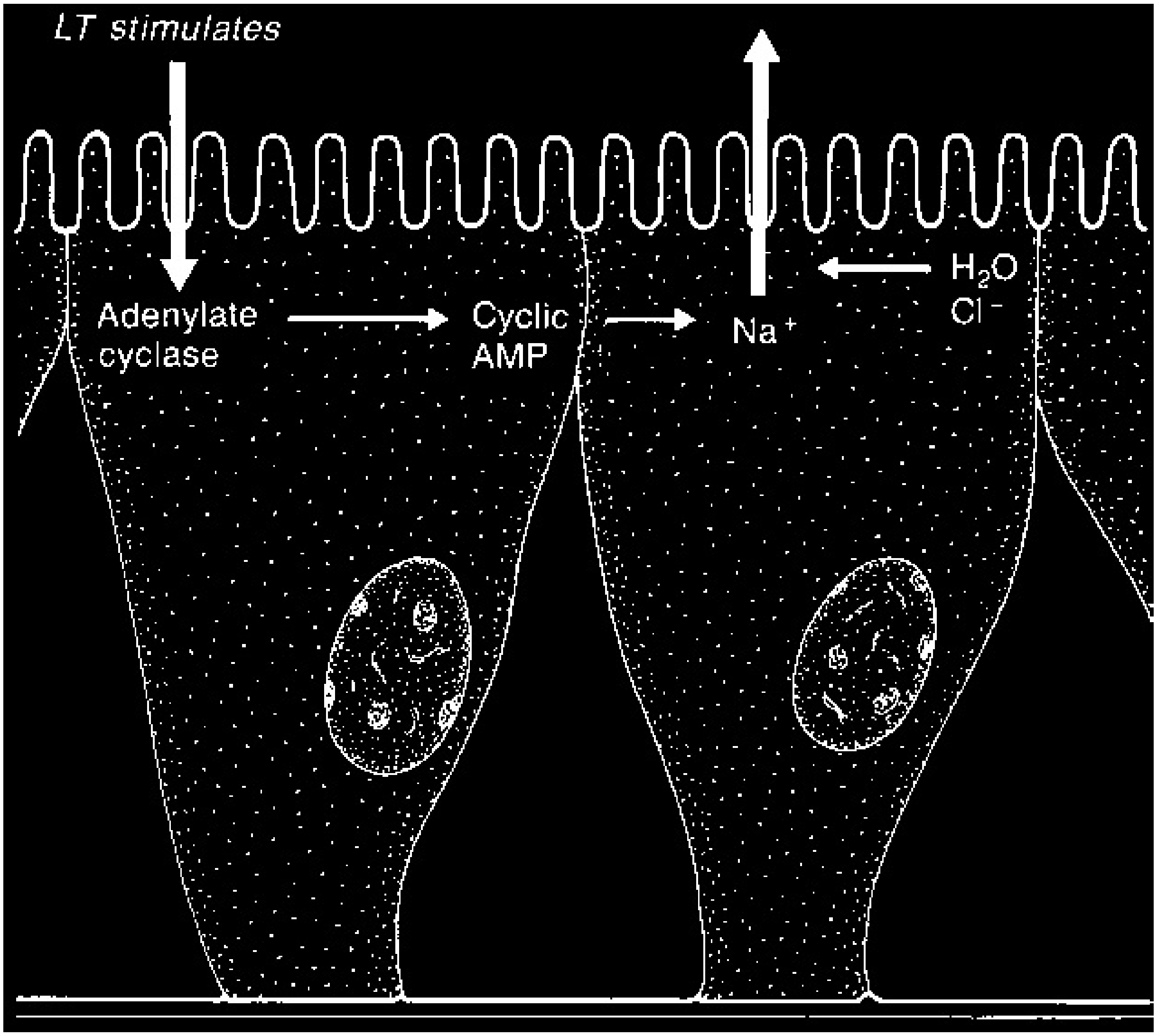


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Fig. 14.5

Line drawing illustrating the effects of heat-stable enterotoxin (ST) and heat-labile enterotoxin (LT) on movement of water through villous enterocytes into *basolateral spaces. ST inhibits water absorption via cyclic-GMP and LT, acting via cyclic-AMP, blocks absorption of sodium ions and water along the glucose-independent carrier system. The glucose-dependent carrier system is not affected by either toxin.*

lumen. Malabsorption also occurs when morphological changes reduce the absorbing surface area. The best example of such morphological change is villus stunting produced by viral enteritis. The mature villous enterocytes can be regarded as the functional compartment of the small intestine, with absorption as one of the principal functions. A substantial reduction in the number of villous enterocytes causes a corresponding loss of function. Furthermore, crypt hyperplasia occurs in viral infections and immature secretory cells migrate onto the villus, increasing secretory capacity. In addition to loss of absorptive capacity there is also loss of digestive capacity, therefore maldigestion occurs, which *can lead to an osmotically induced diarrhoea.*

Intestinal motility

Increased intestinal motility may contribute to the

Fig. 14.6

Line drawing illustrating the effects of heat-labile

development of diarrhoea, resulting in decreased

enterotoxin (LT) on the secretion of sodium ions by crypt ente-transit time and insufficient time for normal absorption.

rocytes. LT increases production of intracellular cyclic-AMP and this stimulates secretion of sodium ions, which carry with them The role of motility is now considered to be less

chloride ions and water.

important than was thought previously.

Osmotic effects

Lactose, the major sugar in cows' milk, is split into

Passive malabsorption

glucose and galactose by the enzyme galactosidase

Diarrhoea may be the consequence of water mal-

(lactase), which is located on microvilli of jejunal ente-

absorption (Fig. 14.7). If malabsorption occurs then

rocytes. These monosaccharides are rapidly absorbed

normal secretory processes and fluid loss due to tissue *and therefore have little osmotic effect. Viral*

hydrostatic pressure will continue and will cause diar-

enteropathogens destroy mature enterocytes, thus

rhoea. Water malabsorption will follow a direct reduc-

creating a transient deficiency of galactosidase. Conse-

tion of active uptake of sodium ions from the intestinal

quently, lactose passes undigested to the colon together

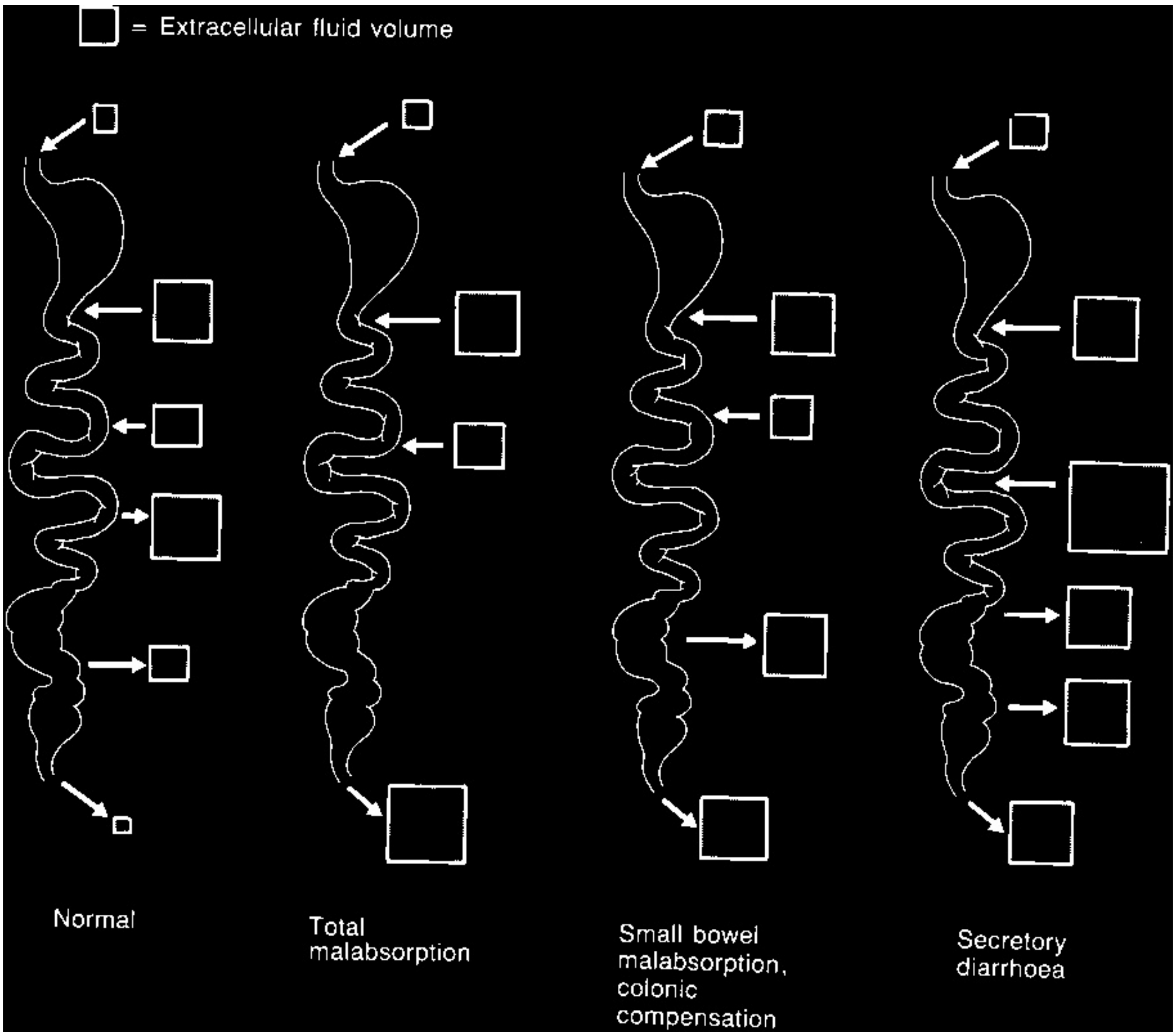


Fig. 14.7

Fluid fluxes in normal

growing pigs (40 kg) and pigs with diar-

rhoea. Volumes of fluid entering and

leaving the intestines are drawn in pro-

portional size to the extracellular fluid

volume shown at the top. Most water is

absorbed by the distal small intestine

and colon in pigs of this age

and colonic compensation is likely

to be much less in neonatal pigs.

Source: Argenzio (1984).

with an osmotic equivalent of water. It may be inferred

Tissue hydrostatic pressure and

from studies of pigs, goats and horses that the conse-

increased permeability

quence of increased lactose in the colon depends on the

Tissue hydrostatic pressure results in a continual

balance between input of lactose and the fermentative

seepage of water from the mucosa into the lumen and *capacity of the colonic microbial flora. If the calf pos-*

this can contribute to the pathogenesis of diarrhoea if

sesses a well-developed colon and colonic microbial

malabsorption is present. Seepage may be increased by

flora and the amount of lactose entering is not exces-

inflammation of the mucosa, which allows greater

sive because of restricted dietary intake and/or slight

leakage of fluid between enterocytes. In very severe

intestinal damage, then the lactose will be fermented to

inflammatory conditions, for example acute salmonel-

short-chain fatty acids. These will be absorbed through

losis, the epithelium may be so extensively damaged as

the colonic mucosa, a process that facilitates the absorp-

to allow erythrocytes to leak from capillaries, through

tion of sodium ions and water by the colonic mucosa.

the epithelium into the lumen; clearly other blood

These processes are 'anti-diarrhoeal' (Fig. 14.8). In a

constituents will be lost also.

young animal, with a poorly developed colon and

colonic microflora, there may be little fermentation of

lactose that remains in the lumen, holding water and *contributing to the diarrhoea (Fig. 14.8). In an animal*

Types of diarrhoea

with a well-developed colonic microflora, dumping of

large amounts of lactose into the colon as a result of ad

Having examined the various pathophysiological

libitum feeding and severe intestinal damage results in processes that can give rise to diarrhoea, two general

hyperfermentation and the production of lactic acid

types of diarrhoea can be recognized.

rather than short-chain fatty acids. Lactate is poorly

absorbed and draws water into the colon by osmosis,

Secretory diarrhoea

exacerbating the diarrhoea. These mechanisms explain

why withholding milk from calves with rotavirus scour

A diarrhoea resulting from net movement of fluid

reduces the severity of the diarrhoea (Fig. 14.8).

into the gut lumen despite fasting. Faeces are

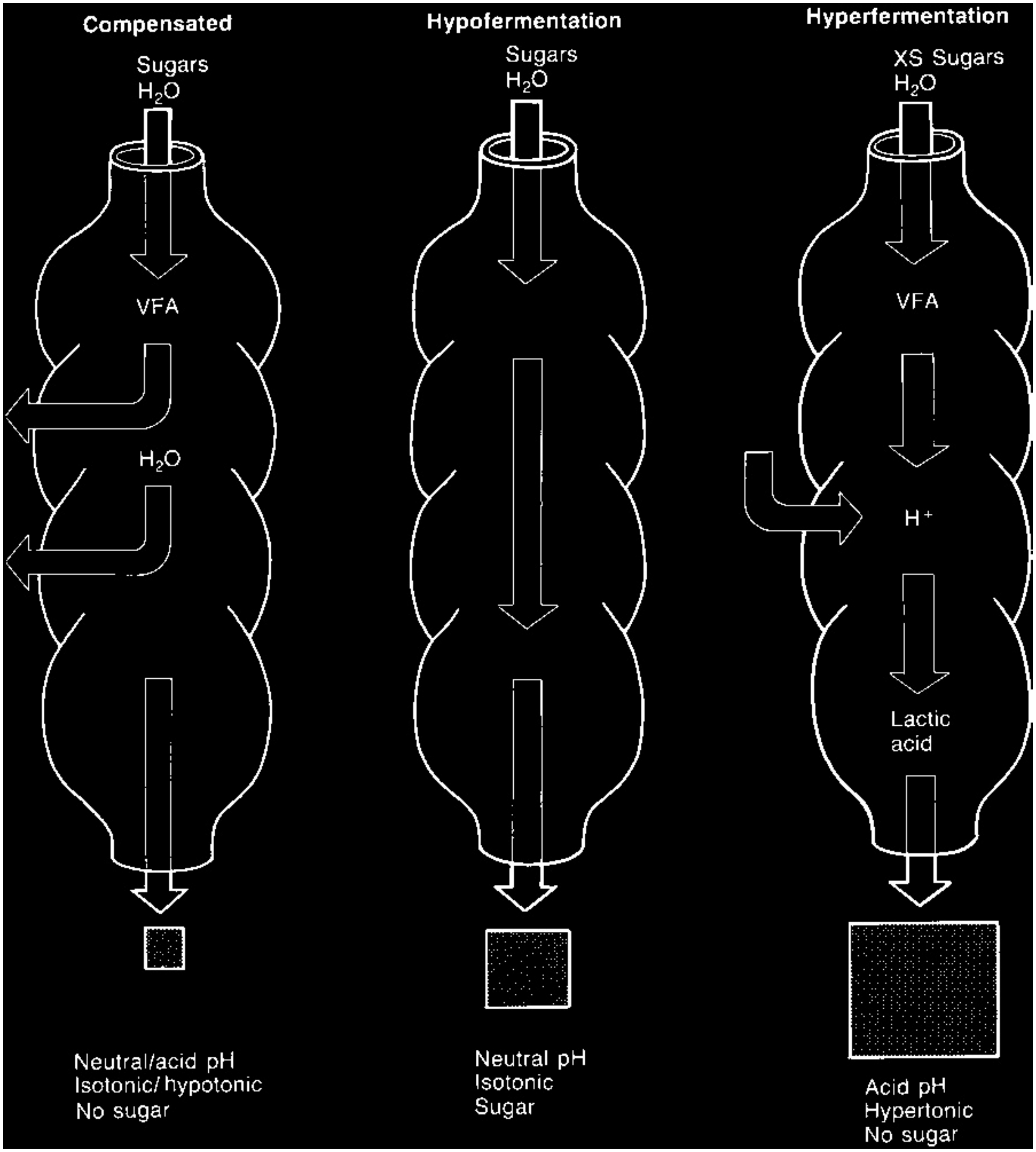


Fig. 14.8

Three alternative conse-

quences of a small intestinal maldiges-

tion and malabsorption, as seen in rotavirus infection. In the 'compensated' situation, the colonic flora is well developed and microbial fermentation of the moderate amounts of malabsorbed carbohydrate yields volatile fatty acids (VFA). These are rapidly absorbed, stimulating water absorption and promoting colonic compensation so that diarrhoea does not occur. If the colon and colonic flora are poorly developed there is hypofermentation and consequently no compensation, and diarrhoea occurs. If the colonic flora is well developed and is overloaded with sugar, hyperfermentation occurs and lactic acid is produced that promotes osmotic diarrhoea. Source: Argenzio (1984).

characteristically isotonic with plasma, watery and alka-

Role of the large intestine

line, and the volumes produced are usually large. The

Most diarrhoea in the calf originates in the small intes-

faeces are alkaline because sodium and bicarbonate

tine and as a result small intestinal function has

ions are secreted by the ileum. In compensation, the

received most study. It is evident that the large intestine,

colon may be exchanging potassium ions for sodium

particularly the colon, is a very important site of

ions. Acute secretory diarrhoea is always caused by a

water absorption and consequently may contribute to

bacterial infection.

the development of diarrhoea if its functional capacity

is overwhelmed or impaired by the fermentative

Osmotic diarrhoea

mechanisms described above. Similarly, its function may

be impaired by infection with Cryptosporidium, coron-

A diarrhoea where the faeces may have high osmolal-

avirus or enterohaemorrhagic E. coli. Ingesta entering ity due to unabsorbed molecules with osmotic activity,

the colon from the small intestine may be damaging.

usually of dietary origin. Faeces may contain undigested *lactose and faecal pH will vary, depending on the*

amount of lactose fermented to short-chain fatty acids

or lactic acid. Osmotic diarrhoea may also be thought

Effects of diarrhoea and

of as a diarrhoea caused by malabsorption and

their clinical signs

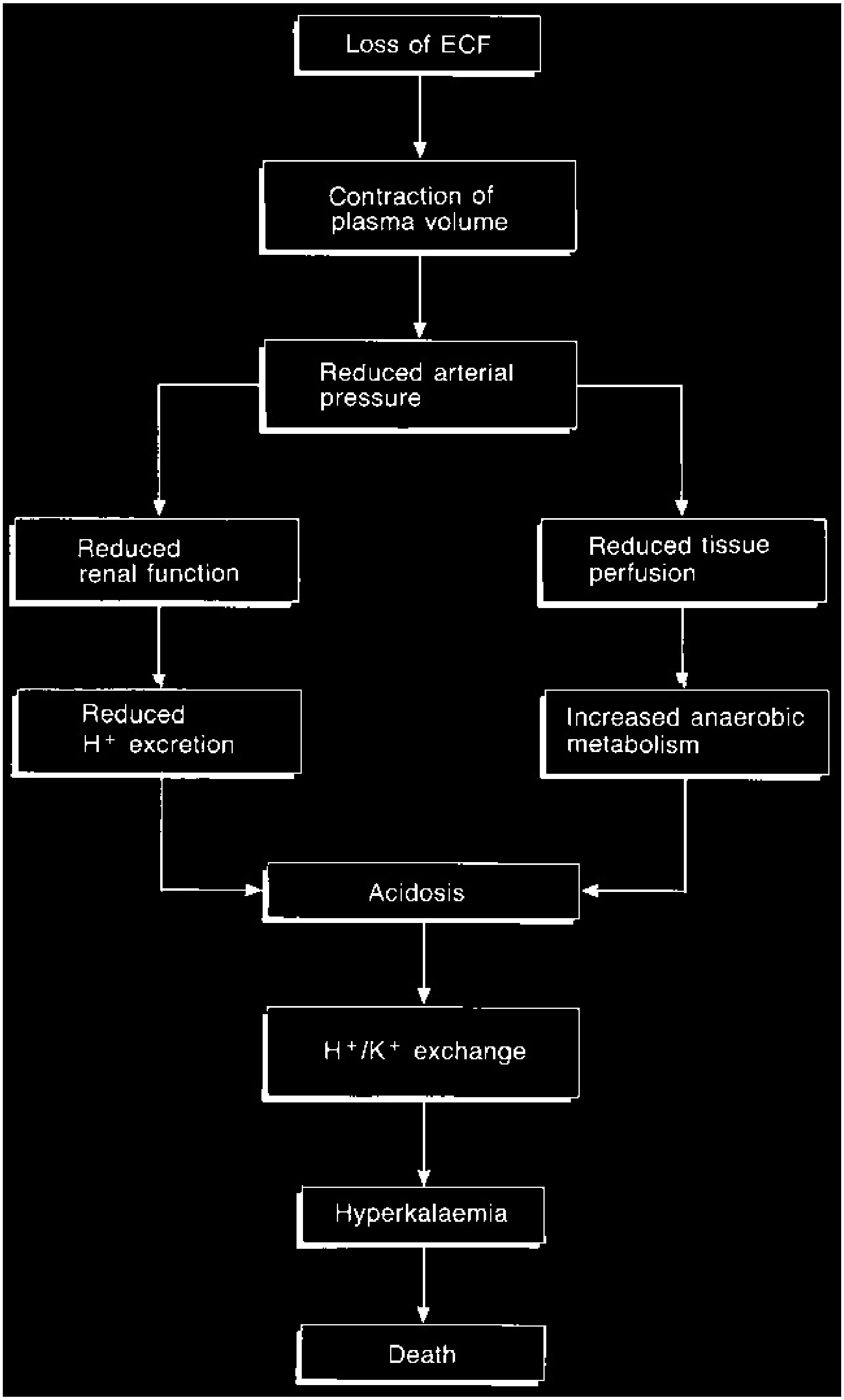
maldigestion. Faecal volume is smaller than in secretory

diarrhoea and the diarrhoea is reduced or abolished by

The systemic effects of diarrhoea, which eventually cul-

fasting. Viruses are one cause of this.

minate in death, are precipitated by a single event, the


Loss of ECF
Contraction of plasma volume
Reduced arterial pressure
Reduced renal function
Reduced tissue perfusion
Reduced H+ excretion
Increased anaerobic metabolism
Acidosis
H+/K+ exchange
Hyperkalaemia
Death

sodium and chloride ions and considerable losses of bicarbonate and potassium ions. There was loss of body weight, 12.7 per cent between onset of diarrhoea and death. Plasma volume decreased by 40 per cent leading to a 39 per cent increase in haematocrit and a 33 per cent increase in plasma protein concentration. The increase in plasma protein concentration was lower, possibly because of protein loss by catabolism or by leakage into the intestinal lumen. Both these values vary widely between individuals and are of little value in assessing severity of fluid loss.

Contraction of plasma volume gives rise to the clinical signs of sunken eyes and 'tenting' of skin folds; it leads to a fall in arterial blood pressure, which stimulates peripheral vasoconstriction. Peripheral vasoconstriction, in its turn, leads to poor tissue perfusion with blood, localized ischaemia and lower metabolic activity so that the temperature of peripheral tissues falls, approaching ambient temperature prior to death; the *extremities, the ears and mouth, feel cold. Rectal tem-*

perature increases until near to death when it falls

rapidly to below normal.

Acidosis is an important consequence of diarrhoea

and a number of factors contribute to its development.

A major factor is loss of bicarbonate ions in faeces and,

additionally, there may be absorption of acids produced

by microbial fermentation of lactose in the large intes-

tine. Loss of extracellular fluid (dehydration) causes

decreased perfusion of the kidney with blood, causing

reduced renal function, which leads to decreased excre-

tion of hydrogen ions by the kidney. Finally, lactic aci-

dosis may develop because of increased production of

lactate following peripheral hypoxia, and decreased uti-

Fig. 14.9

The systemic consequences of diarrhoea. Reduction

lization of lactate due to decreased delivery of lactate

of extracellular fluid volume leads to acidosis, an exchange of to the liver. The ability of the liver to use lactate for glu-extracellular H+ for intracellular K+ leading to hyperkalaemia coneogenesis may be impaired because of increased

causing cardiac failure. Source: Argenzio (1984).

intracellular concentration of hydrogen ions. Indeed, *the liver may become a lactate producer rather than a lactate utilizer. The calf attempts to reduce metabolic acidosis by panting to increase exhalation of carbon dioxide. Intracellular acidosis occurs in parallel with the loss of extracellular fluid. Endogenous secretion into fall in the blood pH. Intracellular production of hydro- the gastrointestinal tract in 24 hours may equal the gen ions increases and hydrogen ions move into cells. extracellular fluid volume. Loss of 7 per cent of the This movement of hydrogen ions into cells forces potas- extracellular fluid volume leads to clinical signs and loss sium and sodium ions to be lost and hyperkalaemia of 30 per cent results in death.*

develops. However, potassium is also lost in the faeces, Diarrhoea causes changes in plasma constituents that so that the plasma concentration may, theoretically, be are similar regardless of the cause of the diarrhoea (Fig. increased, normal or decreased depending on the rate 14.9). When neonatal colostrum-fed calves were experi- of loss from plasma into faeces, and from cells into mentally inoculated with coronavirus, the water and *plasma. In general it is increased. The loss of potassium*

electrolyte losses were severe (Lewis & Philips, 1978).

ions from cells into the interstitial fluid causes levels of

Faecal water loss increased 28-fold, faecal volume

intracellular potassium to fall and levels in interstitial

increased 22-fold and faecal water content increased

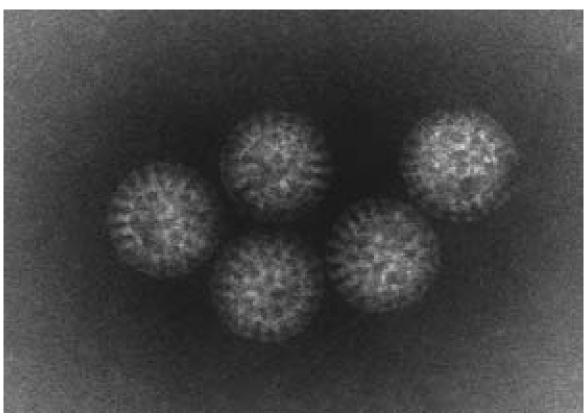
fluid and plasma to rise and, consequently, adjacent to

from 73 to 94 per cent. Renal water loss was reduced to

cells, the ratio of extracellular potassium : intracellular

30 per cent of normal and there were severe losses of

potassium is reduced. This redistribution of potassium



causes a reduction in the resting potential of cell mem-

Bovine rotavirus

branes, which has serious and eventually lethal effects

The agent

on cardiac muscle function. As the concentration of

potassium ions in plasma rises, heart rate falls and there

Rotavirus is a new genus within the family Reoviridae.

is a decreased amplitude, or loss of the P wave. The

The virus contains double-stranded RNA in 11 seg-

activity in plasma of the myocardial enzymes lactate

ments. Particles have a wheel-like appearance; a wide

dehydrogenase isoenzyme 1, creatinine phosphokinase

hub formed by the core, spokes formed by 20 outer cap-

1 and aldolase is raised indicating cardiac damage. Thus

somers and an often ill-defined outer rim (Fig. 14.10).

death from acute severe diarrhoea in the calf appears

Incomplete particles lacking the outer capsid layer are

to be due to potassium cardiotoxicosis.

frequently seen in faeces. Almost all bovine rotaviruses

share a common antigen and have been classified as

group A rotaviruses.

Metabolic and hormonal changes

Hypoglycaemia frequently occurs in acute severe diar-

Epidemiology

rhoea of calves, especially young calves near death.

Bovine rotavirus is universally present in all cattle

Anorexia, decreased absorption of nutrients, minimal

herds but is a more significant problem in single-

glycogen reserves, inhibited gluconeogenesis, increased

suckled beef calves than dairy calves because of the

glycolysis due to reduced tissue perfusion and anoxia

much greater risk from cross-contamination between

and insulin-like effect of bacterial endotoxins on liver

calves, the seasonal nature of the calving pattern and

may contribute to the hypoglycaemia. Signs of hypo-

financial restrictions leading to lower nutritional inputs

glycaemia are weakness, lethargy, convulsions and

during late gestation.

coma. Hypoglycaemia stimulates corticoid secretion;

The incubation period varies from 15 hours to five

plasma concentration of corticosterone and hydrocorti-

days and is followed by virus excretion which com-

sone are elevated in calves with diarrhoea and are

mences in the second week of life. Many infections are

higher in calves that die. Theoretically, corticosteroids

subclinical but a proportion results in severe diarrhoea

help counter hypoglycaemia by stimulating gluconeo-
and even death if not treated promptly. The peak inci-
genesis but their effects may be blocked. Plasma aldos-
dence of diarrhoea occurs at about 10 to 14 days of age.
terone concentrations are increased in calves with
Initially, calves are dull and reluctant to suck. The dam’s
diarrhoea probably due to acidosis, hypovolaemia,
udder becomes distended with milk and may be the first
hyperkalaemia and hyponatraemia. The actions of
indication to the diligent stockperson that the calf is
aldosterone are helpful in that sodium and water reten-
unwell. Diarrhoea develops which is pale yellow or
tion is increased as is excretion of potassium and hydro-
white and may contain mucus; dehydration and meta-
gen ions. There is, however, decreased renal function,
bolic acidosis develop in more severely affected calves
which limits the helpful actions of aldosterone.

Infectious agents

The elucidation of the infectious causes of calf diarrhoea has been a major area of progress over the last 30 years. For many years, salmonellas were the only *known cause, but in 1967 it became clear that a small*

number of strains of E. coli caused a watery diarrhoea and subsequently these came to be known as enterotoxigenic E. coli (ETEC). Rotavirus was the first viral enteropathogen to be recognized, followed by coronavirus, and more recently Breda virus. Approximately

20 years ago, Cryptosporidium parvum was found to

cause diarrhoea in calves. Most recently, E. coli have been identified that cause diarrhoea without producing

enterotoxins; these include strains that infect the large

Fig. 14.10

Transmission electron micrograph of a cluster of

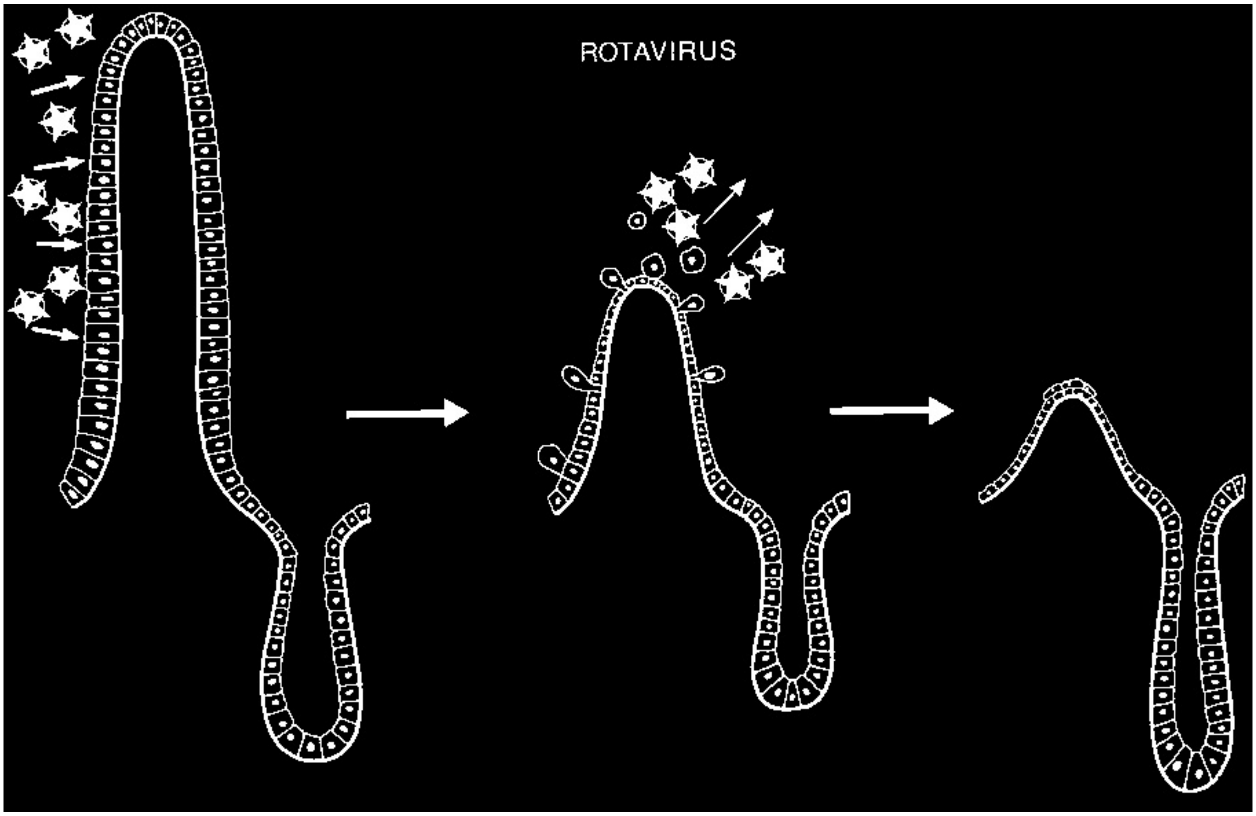
intestine and cause mild dysentery, the enterohaemor-

five bovine rotavirus particles. Visible are the wide hub, spokes rhagic E. coli (EHEC), and strains comparable to

formed by the capsomeres, and the outer rim. (Courtesy of Dr

human enteropathogenic E. coli (EPEC).

J.C. Bridger, Royal Veterinary College, University of London.)



and may be fatal. At this stage the calf may have

et al., 1971). There is variation in pathogenicity between abdominal distension due to fluid sequestration in the

strains; whilst some strains may only damage a limited

small intestine. Excretion of copious amounts of

length of upper jejunum, others may damage the entire

yoghurt-like faeces is typical of rotavirus infections that

length of the small intestine. Some poorly virulent

are uncomplicated by other enteropathogens and the

strains are able to infect enterocytes, replicate within *faeces are thought to have this appearance because*

them and cause enterocyte loss, but not at a sufficiently

they represent the passage of partially digested or

rapid rate to outpace repair mechanisms and cause

undigested milk.

lesions and diarrhoea. The existence of strains of low

Occurrence of pyrexia is variable, but when it occurs

virulence has implications for accurate diagnosis of

it is usually mild (<39.5°C) and may be more suggestive

rotavirus diarrhoea because it may be assumed that

of a focal bacterial infection such as omphalophlebitis

such strains could be excreted by calves with diarrhoea

or polyarthritis.

caused by other enteropathogens. To be confident in a

diagnosis of rotavirus diarrhoea, it is necessary to iden-

tify rotavirus in the faeces of significantly more diar-

Pathogenesis

rhoeic calves than in age-matched, clinically normal

Rotaviruses infect mature enterocytes, located on the

calves on the same farm. On the basis of present knowl-

surface of villi. Particles are detected in the cytoplasm, *edge, groups of four affected and four normal calves are*

usually in dilated cisternae of the endoplasmic reticu-

adequate.

lum. Masses of granular or finely fibrillar virus precur-

The changes in intestinal structure affect its function.

sor (viroplasm) containing virus cores are present

Loss of mature enterocytes with their lactase, and their

outside the cisternae. Particles released from viroplasm

replacement with immature enterocytes containing less

pass into the cisternae; some bud through the mem-

lactase, results in a reduced capacity of the mucosa to

brane of the endoplasmic reticulum and acquire an

digest lactose, especially in the jejunum. Because the

envelope. Viral multiplication within the cells initiates

surface area of the small intestine is reduced, there is

degenerative changes, the cell exfoliates and the rapid

reduced ability to absorb the glucose and galactose that

loss of large numbers of cells leads to fusion and stunt-

is produced from the digestion of lactose. Thus lactose

ing of villi. The columnar epithelium is replaced by

accumulates in the large intestine, where by virtue of its

enterocytes that are cuboidal or squamous and the
hypertonicity it prevents absorption of water from
epithelium contains increased numbers of immature
faeces and contributes to the development of water loss
cells from the crypts (Fig. 14.11). In very severe cases
and dehydration. Bacterial fermentation of the lactose
the villi may be obliterated leading to a totally flat
may increase the osmotic effects. As a result of entero-
epithelium. The pathogenic process may commence in
cyte loss, the population of enterocytes on the villi
the upper jejunum and progress along the small intes-
changes from mature cells with digestive and absorp-
tine to the ileum, producing a wave of damage (Mebus
tive function to predominantly immature cells with

Fig. 14.11

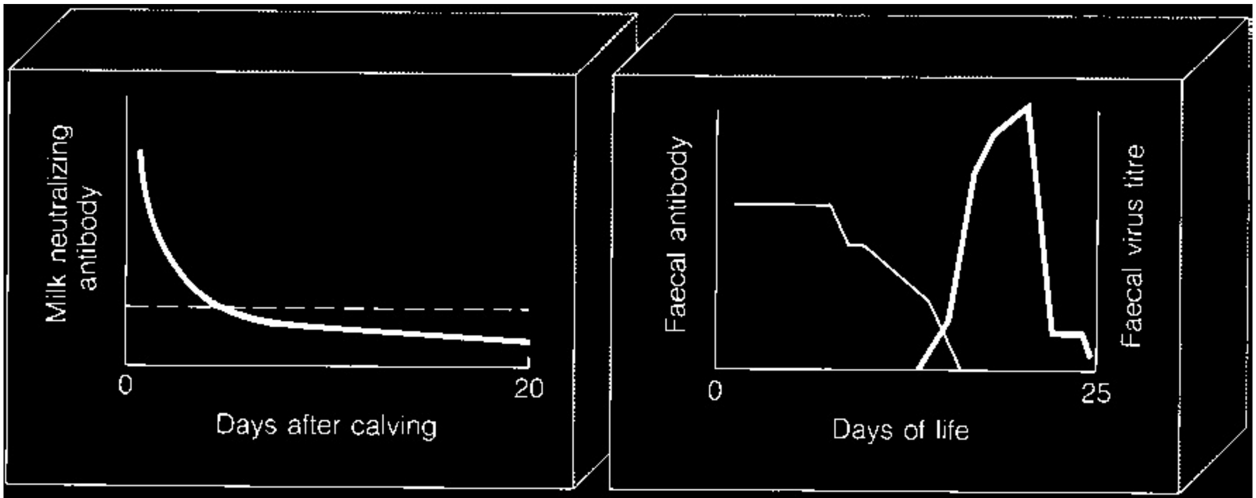
Line drawing illustrating
the development of the small intestinal
lesion in rotavirus infection. Mature
enterocytes are infected and virus repli-
cation causes enterocyte death and
sloughing. Villi stunt and the surviving

enterocytes are cuboidal or squamous.

Mitosis increases in the crypts, which

elongate. The star within a circle repre-

sents a virus particle.



Antibody declines as colostrum turns to milk

Antibody in calf intestine washed out followed by rotavirus injection

secretory function. The number of cells in the crypts

calves by vaccinating dams with commercial combined

(secretory cells) also increases. Thus the functional

inactivated vaccines containing rotavirus, coronavirus

balance may change from absorption to secretion.

and E. coli K99 one to three months before the anticipated calving date. Because rotavirus is endemic in

herds, cows have antibodies to rotavirus in their serum

Prevention

and parenteral administration of a single dose of inac-

Virtually all calves that have sucked colostrum will have

tivated virus absorbed onto aluminium hydroxide gel,

serum antibody to rotavirus, which can be detected by

and the whole emulsified in a light mineral oil, boosts

a number of tests. These antibodies, however, do not

these pre-existing serum antibodies. Consequently, the

protect against infection and disease because for pro-

concentration of antibody in colostrum and milk is

tective purposes neutralizing antibody is required in the

increased and antibody is present in milk for longer

gut lumen. This is because the entire disease process

than in unvaccinated animals. Thus, dam vaccination is

occurs on the mucosal surface and if antibodies are to

essential on those farms which have experienced losses

interfere with the pathogenic process they must be

due to viral diarrhoea in young calves. This system is

present in the gut contents that bathe the mucosal

suitable for both suckled calves, and for artificially

surface; luminal antibodies neutralize virus and prevent

reared calves where hyperimmune colostrum is saved *initial infection and spread of infection from enterocyte*

from the first six to eight milkings and stored in a cool

to enterocyte. There is recent evidence, however, sug-

place and ideally fed at a rate of 2.5 to 3.5 litres per day

gesting that serum antibodies, which originated from

for the first two weeks of life.

the colostrum of hyperimmune cows, can be transferred

It is essential that all calves ingest sufficient good

to the gut where they are protective.

quality colostrum within the first six hours after birth

Following natural infection, calves are immune to

with values equivalent to between 7 and 10 per cent of

disease; this is thought to be the result of an active

bodyweight commonly quoted. Factors that may reduce

mucosal immunity provided by IgA and cell-mediated

the level of specific antibody accumulation in the

mechanisms. Repeated episodes of reinfection without

colostrum differ between beef and dairy cows because

signs occur throughout life, maintaining herd immunity

of the lower nutritional and management inputs in beef

and the virus in the population and environment.

herds and the higher prevalence of metabolic disease in

Colostrum contains antibodies to rotavirus that help

high-yielding dairy cows.

protect the calf against infection and disease. The con-

Problems with sufficient colostrum accumulation in

centration of antibody in colostrum and early milk from

the udder of beef cows include debility of the dam, poor

unvaccinated cows declines rapidly, reaching levels that

nutritional status during late gestation, intercurrent

are thought to be non-protective three to four days

disease such as fascioliasis and chronic mastitis caused

after parturition (Fig. 14.12).

by Arcanobacterium pyogenes (summer mastitis)

Under farm conditions where rotavirus is always

(Chapter 24). Dystokia is more common in beef calves

present, feeding colostrum only immediately after birth

leading to extended intervals to standing and sucking.

delays, rather than prevents, rotavirus excretion and

As a general rule, those calves born following an

calves are susceptible to infection and disease in the

assisted calving should receive 2 litres of colostrum *second week of life. Protection of the calf has been*

within the first two hours of life and be closely super-

achieved by providing enhanced passive protection to

vised to ensure normal sucking behaviour.

Fig. 14.12

Graphical illustration of

changes that occur in neutralizing anti-

body to rotavirus in cows' milk after

calving and faecal antibody to rotavirus

and faecal virus in the early days of a

calf's life. Reproduced from Morgan

(1990).

Recumbency resulting from hypocalcaemia, over-

which alter the clinical presentation, whereby profound

crowding of the calving accommodation, slippery

acidosis is the main presenting feature rather than

underfoot conditions and poor mothering ability, espe-

severe dehydration. The abdomen appears distended

cially in dairy heifers, may delay the ingestion of

and the abomasum and intestines are distended with *sufficient colostrum by the newborn dairy calf.*

fluid and 'slosh' when succussed.

Dam vaccination may not prevent all episodes and

Calves treated with oral rehydration solutions by the

rotavirus diarrhoea may follow stressful events such as

farmer using an oesophageal feeder often have normal

housing and disbudding if undertaken before the calves

hydration status but become severely acidotic, causing

are six weeks old.

profound weakness and depression extending to stupor.

There is no relationship between the degree of dehy-

dration and the severity of the acidosis. The eyes are not

Diagnosis

sunken and the skin tent duration is normal. Fluid dis-

Rotavirus infection produces the complete range of

tension of the abdomen is obvious. The respiratory rate

clinical signs from no observed abnormality through to

is increased above 40 breaths per minute with increased

severe diarrhoea and dehydration with high mortality

depth of expiration. The heart rate is often less than 90

even in treated calves. The incubation period is one to *beats per minute.*

three days depending upon the level of viral challenge.

A thorough clinical examination is essential in all

Isolation of rotavirus from faecal samples does not nec-

young calves with diarrhoea because of the likelihood

essarily indicate a diagnosis of rotavirus diarrhoea

of other focal infections such as early bacterial menin-

because rotavirus can be isolated from a high propor-

goencephalitis, respiratory disease, omphalophlebitis

tion of normal healthy calves without signs of diar-

and possible associated peritonitis, hypopyon and pol-

rhoea. Comparison of faeces samples collected from

yarthritis. Indeed, the diarrhoea reported by the client

healthy and diarrhoeic populations of calves may be

may be the agonal stage of a septicaemia, although such

necessary to determine the precise aetiology but such

peracute infections usually occur in calves less than six

sampling will prove cost-prohibitive in most farm

days old.

situations. Determination of the age of affected calves,

In normal calves more than two days old the um-

and vaccination status of their dams against infectious

bilical remnant is dry and shrivelled, hastened by its

causes of neonatal diarrhoea, will assist in determining

immersion in strong veterinary iodine solution imme-

the aetiology of the disease outbreak, noting that mixed

diately after birth and again six to 12 hours later.

infections are common. For example, Cryptosporidium

Omphalophlebitis manifests as a swollen (>3 cm diam-

spp. often exacerbate the severity of diarrhoea caused

eter), wet and painful umbilicus which may discharge

by rotavirus infection.

pus under digital pressure (see p. 249). Localized peri-

Calves with rotavirus infection during the early

tonitis associated with omphalophlebitis may result in

stages of disease typically show signs of mild depression

the formation of fibrinous adhesions and associated

and salivation, reluctance to stand and suck and profuse

ileus which proves difficult to detect on clinical exami-

diarrhoea when eight to fourteen days old. Disease

nation alone. Abdominocentesis is difficult to perform

rapidly spreads among young calves present on the

on such recumbent calves because of the fluid-dis-
farm when clinical signs may be seen from six days of
tended intestines and the scant fibrinous nature of the
age. There is extensive faecal staining of the perineum
adhesions. Similarly, abdominal ultrasonography fails to
and tail. The faeces are yellow and fluid but without
identify such early adhesions. Calves with peritonitis
blood or mucosal casts. The rectal temperature is
fail to respond to standard fluid therapy and antibiotic
usually within normal limits during the early stages
therapy regimens, with the adhesions identified at
unless there is evidence of focal bacterial infection.
post-mortem examination.

Without oral rehydration therapy the affected calf
Polyarthritis manifests as hot, distended and painful
becomes dehydrated, hypothermic and weak, and
joints, typically the fetlock, hock and carpal joints,
remains in sternal recumbency. The eyes are sunken and
resulting in the tendency for calves to adopt lateral
the skin becomes tight and inelastic, consistent with 8
recumbency rather than sternal recumbency associated

to 10 per cent dehydration within 48 hours, unless

with weakness (see pp. 249, 455).

treated appropriately. As hypovalaemic shock develops,

peripheral vasoconstriction causes the calf's extremities

Laboratory diagnosis of rotavirus

to feel cold. At this stage the calf is often hypothermic

(<38.0°C). Without treatment, death may ensue within

Enzyme-linked immunosorbent assays (ELISA) have

72 hours of the onset of diarrhoea.

been developed for rotavirus and a plate ELISA is used

In most situations diarrhoeic calves have been

by many diagnostic laboratories. Some diagnostic

treated by farm staff with oral rehydration solutions

laboratories use the polyacrylamide gel electrophoresis

method, which has proved to be equally satisfactory.

Example: treatment of diarrhoeic calf under

The diagnostic kits available to practice laboratories in

field situations

the UK are a dot ELISA, a latex method and a plate

The objectives of intravenous fluid therapy include the

ELISA system. The plate ELISA system requires a

correction of extracellular fluid volume, plasma pH,

minimum of equipment and also tests for bovine coro-

blood glucose concentration and plasma concentrations

navirus and K99+ Escherichia coli; a modification to the of sodium and potassium, restoration of cellular

system has permitted the detection of Cryptosporidium

potassium and the provision of nutrients.

spp.

A 10 day-old, 45 kg single suckled beef calf is pre-

The identification of rotavirus particles or antigen

sented with profuse diarrhoea with faecal staining of

in the faeces of calves with diarrhoea does not

the tail, perineum and hind legs. The calf is weak, unable

automatically lead to a diagnosis of rotavirus disease

to rise or remain standing when lifted. It is markedly

in the outbreak. Rotavirus antigen was detected in

depressed with cold extremities. The skin tent is about

50 per cent of faeces from healthy calves aged one

three seconds. The eyes do not appear sunken but

to two weeks in a study in which an ELISA test was *the scleral vasculature is pale. The heart rate is 85*

used. Thus, in order to reach a sound diagnosis, and

beats/minute and the respiratory rate is 45

using that test to identify excretors, it was necessary to

breaths/minute. Two litres of an oral rehyration solution

show that significantly more than 50 per cent of diar-

have been administered by oesophageal feeder twice

rhoeic calves were excreting rotavirus. This was

daily for the past two days.

achieved by examining faeces from four calves with

diarrhoea and four matching normal calves on the farm.

The number of calf faeces that will need to be exam-

Typical laboratory values: Typical laboratory values are ined in an investigation of an outbreak will depend on

listed below for this calf but such analyses are rarely

the ability of the diagnostic test in use to detect

possible under field situations. Excellent clinical recov-

excretion by normal calves.

ery rates for such cases are achieved in general practice

using estimations of the base deficit based upon the

clinical examination

Treatment (see p. 209)

Packed cell volume = 31%

Arterial blood gas

analysis:

Veterinary treatment of calf diarrhoea is generally

Total plasma protein = 68.0 g/l pH = 6.9

limited to collapsed animals which have failed to

Sodium = 128 mmol/l

pCO =

2

46 mmHg

respond to oral rehydration solutions. Administration

Potassium = 7.2 mmol/l

HCO =

3

7 mmol/l

of oral rehydration solutions is frequently made by the

Chloride = 105 mmol/l

Base deficit = 20 mmol/l

farmer using an oesophageal feeder. While this proce-

dure has considerable time savings, it is frequently used

The calf is estimated to be only 5 per cent dehydrated.

for weak recumbent calves without a strong suck reflex

The serum potassium concentration is elevated because

which serves to further delay veterinary involvement to

intracellular K+ ions exchange with H+ and pass into the

the stage where calves are profoundly acidotic when

extracellular fluid. However, the intracellular (and total

presented. In veterinary practice therefore, treatment

body) K+ ion concentrations will be lowered, but this

of calf diarrhoea involves the correction of acidosis

deficit is more safely replaced by the oral rehydration

rather than simple correction of hydration status,

solution rather than the intravenous fluid. Diarrhoeic

although both problems may have to be tackled at the

calves are not markedly hypoglycaemic and nutrients

same time.

are better supplied in the oral rehydration solution, and

Basic animal husbandry is frequently overlooked in

then milk, than in the intravenous fluids.

many modern beef production systems. The diarrhoeic

calf should be isolated in a warm, dry and well-bedded

Intravenous fluid therapy: The fluid requirements are

pen. In beef herds, the dam should be separated from

calculated as:

the calf by a gate which allows visual contact.

45 kg ¥ 0.05 = 2 litres

Hypothermic calves should be warmed and this is

best achieved with convector heaters rather than heat

The daily requirement of 75–150 ml/kg should be added

lamps.

to this deficit. The fluids should be warmed to body

Intravenous fluids are essential because most

temperature before administration and insulated if left

severely affected diarrhoeic calves are profoundly aci-

suspended in a cold environment.

dotic (see example below), with variable degrees of

dehydration depending upon previous oral rehydration

Base deficit: The base deficit is estimated from the

therapy.

clinical findings whereby profoundly weak and

depressed/stuporous calves, in the absence of septi-

rate information on the precise severity of the acidosis,
caemia or bacterial meningoencephalitis, have a base
the farmer can be instructed to spike the intravenous
deficit in the region of 20 mmol/l. As an alternative
fluid with materials left on the farm.
practical guideline, calves able to maintain sternal
recumbency are reported to have a base deficit of
Treatment regimen: Under practical conditions on farm
15 mmol/l, whilst those in lateral recumbeny have a
a 14 gauge (or 16 gauge) catheter should be stitched
deficit of 20 mmol/l (Naylor, 1996). However, such dis-
into a jugular vein as this makes fluid administration
tinction is not necessary to achieve excellent results,
much easier because the calf can be left unattended. A
even under less than ideal practice situations.
5 cm by 5 cm area of skin overlying a jugular vein is
The total base deficit (or negative base excess) can
shaved and aseptically prepared. A stab incision
be calculated as:
through the skin overlying the jugular vein using a 15T
blade greatly facilitates catheter placement. If the calf

base deficit ¥ bicarbonate space ¥ dehydrated calf

is severely dehydrated and cannot be catheterized

weight = 20 ¥ (0.3 to 0.6) ¥ 45 = 270 to 540 mmol

easily, either the first litre of fluid can be administered

bicarbonate

through a 16 gauge hypodermic needle or the calf is

There is considerable debate as to which value should

suspended by its hind legs to distend the jugular veins,

be employed for the bicarbonate space because this

thereby facilitating catheterization.

value is higher in neonates than adults. In practice

A typical treatment regime for a recumbent acidotic

situations, where blood gas analysis is rarely available,

calf would commence with 1 litre of isotonic saline

an estimate of 20 mmol/l for base deficit in recumbent

spiked with 200 mmol bicarbonate (16 g sodium bicar-

stuporous calves is commonly used in conjunction with

bonate) administered intravenously over 20 to 30

an estimate of 0.5 to 0.6 for the bicarbonate space.

minutes. This solution can be administered while the

While it is accepted that there will be errors in such a *veterinary surgeon remains on the farm suturing the*

simplified approach, this regimen has proved very reli-

catheter in position, securing the fluid administration

able in general practice where the rapid response to

set, and possibly attending further calves with diarrhoea

intravenous fluid therapy spiked with bicarbonate is the

or collecting faecal samples as appropriate.

most valuable indicator of success of the fluid therapy

A further 3 litres of isotonic saline solution contain-

regimen.

ing the balance of the estimated bicarbonate deficit

Typically, stuporous calves should be much improved

(approximately 400 mmol) should then be administered

after three to four hours, and be able to stand six to

over the next four to six hours, by which time the calf's

eight hours after the start of intravenous fluid therapy.

demeanour will be much improved. The calf should be

A thorough initial clinical examination will eliminate

able to stand and suck a teat enthusiastically at this

focal and septicaemic infections from the list of differ-

stage. An oesophageal feeder should be used only as a *ential diagnoses. Re-evaluation of the diagnosis and/or last resort to administer oral fluids because the calf's treatment is necessary if the calf's condition has not demeanour and willingness to suck are valuable indi- markedly improved within six hours of commencing cators of the calf's recovery. Indeed, early cases of intravenous fluid therapy. The two most common bacterial meningoencephalitis may be difficult to dif- reasons why the calf's condition has not improved are: ferentiate from profound acidosis, but acidotic calves the extent of the base deficit has been underestimated should respond well within six hours to spiked and insufficient bicarbonate has been infused or, intravenous fluid therapy and suck, whereas those with less commonly, that the calf has bacterial meningo- meningoencephalitis will not and may progress to encephalitits (see pp. 251, 901).*

opisthotonus with spontaneous nystagmus. Alterna- Some practice laboratories use a Harleco apparatus tively, in cases where meningoencephalitis is suspected to determine total CO2, which is a useful index of the *during the veterinary examination, lumbar CSF can be*

severity of the metabolic acidosis. However, determi-

collected under local anaesthesia and inspected visually

nation of metabolic acidosis using either the Harleco or

for turbidity caused by white cell infiltration.

blood gas analysis necessitates hospitalization of the

This approach to fluid therapy of collapsed acidotic

calf with the attendant risks of contaminating the facil-

calves described above has been employed in many

ities with a range of enteropathogens, some of which are

farm animal practices because the calf remains on the

serious zoonoses. While blood samples can be trans-

farm and is visited by the veterinary surgeon, thereby

ported to the practice laboratory for blood gas analysis,

removing the risk of introducing enteropathogens,

such retrospective information may not be so helpful

including Salmonella spp., into the practice hospital because financial considerations frequently preclude

facilities with the potential for disastrous consequences.

a second veterinary visit to correct any estimations

Often only one veterinary visit is possible for each diar-

based upon clinical findings. Alternatively, with accu-

rhoeic calf because of cost limitations, but this system

of intravenous fluid administration works well in

whereby sodium is transported across the gut wall into

practice.

the extracellular fluid and water follows along the

Most diarrhoeic calves are not profoundly hypogly-

osmotic gradient. Other molecules, including acetate,

caemic and the addition of glucose to the intravenous

propionate, glycine and glutamine, also play an impor-

solutions is generally not undertaken. Energy supply is

tant role in sodium transport.

better given as a component of the oral rehydration

The original World Health Organization (WHO) oral

solution therapy (high energy rehydration solution),

rehydration solution was an equimolar solution con-

which often commences within six to eight hours of

taining approximately 100 mmol/l sodium and glucose

the start of intravenous fluid administration. Recently-

and was the basis of the first generation oral rehydra-

introduced oral rehydration solutions have a high

tion solutions introduced into veterinary practice

energy content designed to counter the energy deficit

during the 1970s. Potassium was present to assist in

state caused by witholding milk from the calf's diet. As

restoring any deficits. These solutions contain no bicar-

soon as the suck reflex returns, the calf should be

bonate or precursor and are therefore unable to correct

offered either one litre of oral rehydration solution or

a significant acidosis, but are effective in many cases of

milk at alternate feeds every two hours.

calf diarrhoea associated with dehydration. Viral causes

of neonatal diarrhoea were not reported in the United

Other intravenous fluids: Clinical evaluation of the

Kingdom until the mid-1980s (Snodgrass et al., 1986),

alkalinizing effect of various bases in diarrhoeic calves

and these oral rehydration solutions proved effective

suffering from severe dehydration and acidosis (Kasari

in the treatment of bacterial and nutritional causes of

& Naylor, 1986) clearly demonstrated the advantages in

calf diarrhoea which were not usually associated with *both speed and extent of administering isotonic saline*

severe metabolic acidosis.

solutions containing bicarbonate compared to those

The widespread occurrence of rotavirus-induced

solutions containing either lactate or acetate.

diarrhoea and associated metabolic acidosis led to the

Lactated Ringer's solution should not be used to

development of oral rehydration solutions containing

treat severe acidosis because it contains only 30 mmol/l

80 to 120 mmol/l bicarbonate as a precursor, whether

of lactate, which would necessitate in excess of 15 litres

lactate, propionate or citrate. These solutions have been

to counter severe acidosis in a calf. Furthermore, lactate

referred to as 'second generation' oral rehydration

must be metabolized to yield bicarbonate but the young

solutions. While these solutions are very effective in

calf cannot fully utilize D lactate in the racemic mixture.

meeting the primary objectives of correcting hypo-

Hypertonic (7.2%) saline solutions are not indicated in

volaemia, moderate metabolic acidosis (and associated

the treatment of acidotic calves because of their lack *hyperkalaemia) and hyponatraemia, they fail to*

of alkalinizing effect, although successful treatment of

provide sufficient calorific support and treated calves

mild acidosis in experimental calves has been reported

lose considerable body condition during treatment

using a hypertonic saline solution containing sodium

when milk is withheld from the diet.

bicarbonate (Dupe et al., 1993).

'Third generation' oral rehydration solutions contain

The administration of sterile isotonic saline solutions

much higher concentrations of glucose (up to 375 mmol/l)

spiked with bicarbonate described above has obvious

and sodium (up to 133 mmol/l) to counter the energy

advantages over non-sterile fluids made using tap

deficit which results when milk is withheld from the calf's

water; however, solutions prepared using small water

diet. Such hypertonic solutions do not worsen diarrhoea

purification plants are reported to work well under

due to osmosis or produce hypernatraemia and, when

practice conditions. A typical mixture of salts available

compared to standard oral rehydration solutions, these *in the UK (Electrolyte ED; Vetoquinol Ltd) added to*

'third generation' solutions have reduced the liveweight

5 litres of water yields 141 mmol/l sodium, 4 mmol/l

loss which results from calf diarrhoea.

potassium, and 35 mmol/l bicarbonate, which can then

Further developments in oral fluid therapy ('fourth

be spiked with additional sodium bicarbonate. Extra

generation') include the addition of the amino acid glu-

bicarbonate can be administered either as a 1.3 per

tamine to promote enteric sodium uptake and sustain

cent isotonic solution (65 g sodium bicarbonate to 5

villus form and function. A high-calorie oral rehydra-

litres, yielding 150 mmol/l bicarbonate) or by adding

tion solution with glutamine was more effective in

35 g sodium bicarbonate to yield 400 mmol in addition

correcting plasma, extracellular fluid and blood volume

to the 175 mmol already present in the 5 litre solution

than solutions without (one WHO-type solution and

(Grove-White, 2000).

two high-glucose but glutamine-free solutions) using an

Escherichia coli model (Brooks et al., 1997).

Oral rehydration solutions: There are a large number

In summary, an oral rehydration solution should be

of oral rehydration solutions available but all utilize

judged on the composition of the solution in mmol/l and

the active glucose/sodium-linked gut transport system

not on a dry matter percentage basis. The sodium

concentration should not exceed 130 mmol/l. The bicar-

increased glucose content as energy source should be

bonate concentration (usually as a precursor such as

chosen if the calf is fed only oral rehydration solution

citrate, acetate or propionate) should be in the region

for more than 24 hours (third or fourth generation oral

of 80 to 120 mmol/l. The role of glycine may be over-

rehydration solutions).

stated with respect to sodium transport but it aids

palatability. High-energy-containing oral rehydration

Antibiotics: Antibiotics are frequently employed in the solutions, with glucose concentrations up to 375 mmol/l,

treatment of diarrhoeic calves despite the fact that

limit liveweight loss during diarrhoea and should be *significant bacterial causes are limited to age-specific*

considered if milk is withheld for more than two days.

periods within the first four days (enterotoxigenic E.

The addition of glutamine to the oral rehydration solu-

coli) and at over three weeks old (Salmonella spp.).

tion appears to offer numerous advantages over other

Unsupervised widespread use of antibiotics prescribed

solutions (Brooks et al., 1997).

by veterinary surgeons for the treatment of calf diar-

rhoea has been claimed to result in an increased preva-

Treatment with oral rehydration solutions: As detailed lence of muliple resistant enteropathogens in humans,

above, there is an almost bewildering list of oral rehy-

which cautions against their use except for specific

dration solutions which can be used to treat diarrhoeic

bacterial causes (see also p. 210).

calves, each supported by its own experimental and

Enterotoxigenic E. coli do not display a high degree

clinical database. For veterinary practitioners presented

of antibiotic resistance and the commonly used anti-

with a recumbent calf with severe metabolic acidosis, *biotics such as trimethoprim-sulpha are effective. Such the most critical treatment is appropriate intravenous calves do not develop a bacteraemia and oral antibiotic fluid therapy. No oral rehydration solution will correct administration is preferable. Many Salmonella spp. the moderate to severe base deficit in these profoundly infections result in bacteraemia with localization in the weak and recumbent calves. Within six to eight hours lungs, joints and growth plates. Antibiotic selection of the start of intravenous fluid therapy the calf should should be guided by bacterial isolation and antibiotic be much improved, with return of the suck reflex. This sensitivity testing. Improved biosecurity and hygiene, clinical improvement indicates that the acidosis has and possibly dam vaccination, should all be considered been largely corrected, but to counter ongoing losses 1 to control salmonellosis in neonatal calves, thereby litre of a high-calorie oral rehydration solution with a reducing the need for antibiotic therapy. The use of high alkalinizing ability should be offered eight times fluoroquinolone antibiotics to treat salmonellosis in* *daily (note: this may be twice the recommended rate*

calves should be carefully considered and employed

detailed in the product data sheets). The presence of a

only where there is no alternative antibiotic.

vigorous suck reflex is the best indicator that the calf is

The use of antibiotics in rotavirus diarrhoea is not

recovering and is a more important factor than the con-

indicated, but care must be taken not to overlook focal

tinued production of fluid faeces.

bacterial infections. Indeed, it is possible to overlook

The calf should be returned to a milk diet as soon as

early cases of bacterial polyarthritis and meningoen-

possible, and this should be a complete change. The

cephalitis, but such infections generally appear in calves

milk must not be diluted with an oral rehydration solu-

less than six days old whereas rotavirus infection

tion. Typically, when milk is added to the diet, the calf

causing recumbency and stupor occurs in calves more

will continue to have profuse diarrhoea for a few days

than eight days old with a history of diarrhoea for the

but it will possess a strong suck reflex, be bright and *past two days or more.*

alert with no signs of weakness. Assessment of the calf's

Following intravenous fluid therapy it is important

recovery based upon demeanour, activity and appetite

that the catheter is removed within 24 hours to reduce

is more important than the negative aspect of the

the risk of thrombophlebitis; parenteral antibiotics

continued production of fluid faeces.

should not be necessary simply because the jugular vein

Traditionally, milk was withheld from diarrhoeic

has been catheterized.

calves until solid faeces were passed, which often did

not occur until after four or more days of administra-

tion of only oral rehydration solutions. This calorific

Non-steroidal anti-inflammatory drugs: Non-steroidal

deprivation led to considerable body condition loss and

anti-inflammatory drugs (NSAIDs) such as flunixin

a protracted convalescence. Some clinicians recom-

meglumine and ketoprofen have been recommended

mend that milk and an oral rehydration solution are

for diarrhoeic calves but have not been fully evaluated *alternated every two to four hours during the early con-*

as a supportive treatment. Some reports refer to

valescent phase, thereby largely overcoming the calorie

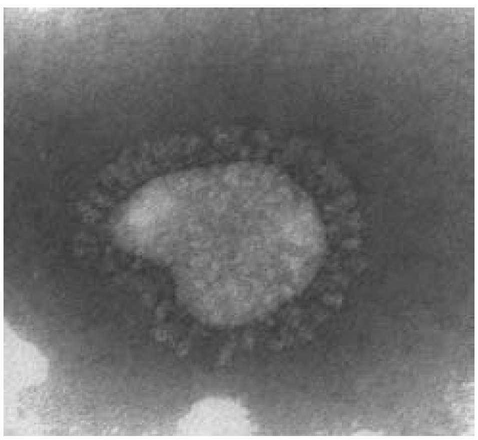
reduced severity of scouring following flunixin injection

deficit but still retaining the benefits of the oral rehy-

while other clinicians comment that dehydrated calves

dration solution. Oral rehydration solutions with an

must not be given NSAIDs.



Protectants: Protectants, e.g. kaolin and pectin mix-

units rearing purchased calves. Pens should be cleaned

tures, are used as an adjunct to treatment but their value

between batches, steamed, disinfected and allowed to

in serious cases is doubtful.

dry.

Disinfectants that have been reported to be effective

against rotavirus are 0.25 per cent formaldehyde, 2 per

Convalescence

cent phenol, 1 per cent sodium hypochlorite, 0.25 per

Convalescence from rotavirus-induced diarrhoea is

cent propiolactone, quaternary ammonium compounds

often protracted because of physical loss of absorptive

and iodophores. Mixing calves of different ages should

capacity of the small intestine. The villus epithelial cells

be avoided and stress should be limited by staggering

are lost, resulting in stunted villi (Fig. 14.11). These

management interference such as castration, disbud-

lining cells are intially replaced with undifferentiated

ding and changing of accommodation.

squamous and cuboidal cells, and only later replaced by

specialized aborptive columnar cells. Extended oral

Bovine coronavirus

administration of certain antimicrobials may prolong

this delay to normal absorptive capacity.

The agent

Bovine coronavirus (BCV) is a member of a group of

Management

viruses with a characteristic morphology seen in the

electron microscope (Fig. 14.13). The virions, which

The management of an outbreak of rotavirus diarrhoea,

contain single-stranded polyadenylated RNA, are

once it has been diagnosed, should be based on the twin

pleomorphic spherical particles 70 to 220 nm in diame-

concepts of reducing exposure to infection and enhanc-

ter with a corona of widely spaced club-shaped surface

ing resistance to infection by ensuring passive transfer

projections (peplomers), which are 20 nm long. Bovine

of specific antibody induced by timely vaccination of

coronavirus has two types of peplomer of different

the dam (see p. 1006). Good hygiene will not be suc-

length. There is only one serotype of bovine

cessful in controlling spread of infection because

coronavirus.

rotavirus is endemic and highly infectious, but it will

help to reduce the build-up of infection throughout the

calving period and thus reduce the infectious challenge

Signs

to which calves are exposed; several studies have

Calves usually become infected with coronavirus when

recorded beneficial results from good hygiene.

they are between one and three weeks old, although

Unlike dairy herds, most beef cattle have a seasonal

disease may occur in calves up to three months of

calving pattern with over 90 per cent of the cows calving

age. Transmission of infection is by the faecal–oral

during a nine week period, which presents problems

route. Calves develop diarrhoea in a manner virtually

with stocking levels in farm buildings and calving

accommodation. Beef cattle should calve outdoors

wherever possible. Newly-calved cows and their calves

should be moved to clean pastures as soon as possible

after birth. The stocking density on these pastures

should be kept as low as practicable to prevent envi-

ronmental contamination and build-up of infection.

Problems with rotavirus diarrhoea usually appear

during the second half of the calving period and are

often associated with adverse weather conditions

during early spring or late autumn, when young calves *are crowded in sheltered areas of the field facilitating*

build-up of infection. Infection builds up rapidly in

housed beef herds where poor building design and lack

of sufficient straw bedding material aggravate over-

stocked conditions. The provision of a dry, well-bedded

creep area for calves may reduce the level of challenge

but is not sufficent to prevent disease.

To assist good hygiene, calving accommodation and

Fig. 14.13

Transmission electron micrograph of a single parti-

calf pens on dairy farms should be designed for ease of

cle of bovine coronavirus. The particle has an irregular shape cleaning and with adequate drainage. An 'all-in, all-out'

and is covered by a corona of peplomers. (Courtesy of Dr J.C.

policy should be adopted where possible, especially in

Bridger, Royal Veterinary College, University of London.)

identical to rotavirus; studies of experimental inocula-

coronavirus and are used by diagnostic laboratories.

tions suggest that the incubation period is 20 to 30

The existence of bovine coronavirus excretion by clini-

hours. Generally, coronavirus diarrhoea is more watery

cally normal calves is recorded, although it is not seen

and of greater severity than rotavirus diarrhoea, leading

as commonly as is rotavirus.

more rapidly to dehydration and acidosis. The severe

diarrhoea also leads to substantial losses of sodium,

Management

potassium, chloride and bicarbonate ions. Fluid yellow

faeces are passed at first and these turn to a yellow

An outbreak of BCV diarrhoea should be managed in the

liquid containing milk clots and mucus.

same way as an outbreak of rotavirus diarrhoea; that is,

aim to reduce exposure to infection and enhance resist-

ance to infection by vaccination of the dam and ensuring

Pathogenesis

adequate passive antibody transfer (see p. 1006).

Bovine coronavirus infects mature enterocytes located

Sick calves should be moved to isolation facilities to

on the surface of villi and epithelial cells of the upper

help prevent a build-up of infection and to facilitate the

respiratory tract. The small intestine is severely

provision of rehydration therapy. Diarrhoea induced
damaged due to sloughing of infected cells, especially
by BCV is often more watery than that caused by
the ileum, and cells on the surface and in the crypts of
rotavirus, possibly because the colon is less able to
the large intestine are also killed. Infection of the upper
absorb water because it is damaged by the infection.
respiratory tract does not appear to cause lesions. Virus
The watery diarrhoea is likely to lead to severe
particles are assembled in the cytoplasm by a budding
dehydration and rehydration therapy as outlined for
process through the rough endoplasmic reticulum. They
rotavirus is indicated (see pp. 195–6).
are subsequently transported through and accumulate
in the Golgi complex and are released from the cell by

Calici-like virus (Newbury agent)

lysis. The range of lesions seen in the small intestine is
identical to those produced by rotavirus and repair can
Particles of calf calici-like virus measure approximately
occur rapidly because small intestinal crypt cells are
33 nm in diameter and have an indefinite feathery

largely unaffected. Virus damage to colonic crypt cells
outline with dark hollows on the surface. Some parti-
results in atrophy of the mucosal ridges and dilated
cles have a 10-spiked sphere morphology. The virus was
crypts containing dead exfoliated cells. The mechanisms
first detected in faeces of calves with diarrhoea and the
by which the intestinal damage caused by bovine coro-
pathogenic process has been studied in gnotobiotic
navirus results in diarrhoea are thought to be the same
calves. As far as is known, the disease is confined to the
as described for rotavirus. The presence of severe
unweaned calf, although a gnotobiotic calf aged 60 days
lesions in the ileum, caecum and colon, areas of the
was susceptible to infection and disease. In gnotobiotic
small and large intestine that absorb water, may
calves, clinical signs of enteric disease are identical to
account for the more watery nature of the diarrhoea
those seen in rotavirus infections and the lesions are
seen in BCV infections. It is not clear whether or not
comparable to those produced by rotavirus and BCV.
strains of BCV vary in virulence, as is seen in bovine

Two antigenically distinct isolates of Newbury agent

rotaviruses.

have been identified and infection with either virus did

not protect against clinical illness following infection

with the other virus three weeks later. There are no spe-

Prevention

cific diagnostic tests for the calf calici-like viruses, other There are two inactivated vaccines available in the UK

than electron microscopic examination of faeces con-

which combines coronavirus, rotavirus and E. coli K99

centrated and purified by ultracentrifugation. They

to provide protective antibody in colostrum and early

might be suspected as the aetiological agent in cases

milk. The vaccines are administerd 12 to 13 weeks

that appeared clinically similar to rotavirus, but are

before the anticipated calving date.

negative for rotavirus and other enteropathogens.

Calves with diarrhoea caused by a calici-like virus may

be managed as though they were infected with rotavirus.

Diagnosis

Bovine coronavirus is universally present on all cattle

Astrovirus

farms, as indicated by the presence of antibodies in all

adults. Diagnosis of coronavirus disease, like that of

Astrovirus is a descriptive name for viruses with a star-

rotavirus disease, is based on the detection of virus or

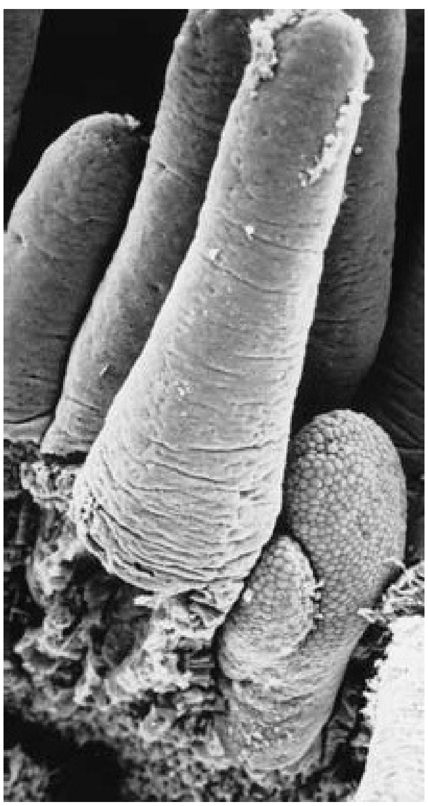
like pattern on their surface in the electron microscope.

virus antigen in intestinal tissue or faeces. Assays using

They have a diameter of 28–30 nm and contain single-

ELISA have been developed for detection of bovine

stranded RNA. Astroviruses have also been detected in



faeces of lambs with diarrhoea where the virus infected

Breda virus

enterocytes causing mild villus stunting in the mid small

This virus was first described as causing calf diarrhoea

intestine. Astroviruses have been detected in calf faeces

in the USA in 1982. Lesions were similar to those pro-

in association with diarrhoea but experimental infec-

duced by coronavirus. Jejunal and ileal villi were

tion of gnotobiotic calves with astrovirus did not cause

stunted and there were crypt abscesses in the small

diarrhoea. Nevertheless, antibodies to astrovirus are

intestine and particularly in the colon. There were areas

widespread in cattle sera, having been found in 11 out

of necrosis of the surface epithelium of the colon.

of 22 herds in the UK and in 30 per cent of cattle sera

There are no tests available commercially which

examined in the USA. Recently, astroviruses were

detect Breda virus in faeces. Electron microscopy of

shown to infect and damage the specialized epithelium

faeces and thin sections through ultracentrifuge pellets

of the dome villi (Fig. 14.14) in the Peyer's patches of *may be used in the research laboratory and, because all calves. These calves did not develop diarrhoea, but isolates of Breda virus possess common antigens, anti-severe diarrhoea occurred in mixed infections of astro-bodies to these can be used in an immunofluorescent virus and rotavirus or astrovirus and Breda agent. It is test of intestinal sections and in an ELISA test. Ex-probable that astrovirus are not pathogenic on their amination by ELISA of over 200 faeces from UK calves own, but may increase the severity of the disease pro-with diarrhoea failed to detect Breda virus. However, duced by other enteropathogenic viruses. There are no in a separate study, antibodies to Breda virus were routine tests to detect astroviruses in faeces, but in the detected in 55 per cent of cattle sera.*

research laboratory they can be identified by electron microscopic examination of faeces concentrated by centrifugation.

Escherichia coli

Three groups of E. coli have been identified that appear to cause diarrhoea in calves. Strains that elaborate a *heat-labile enterotoxin or a heat-stable enterotoxin are called the enterotoxigenic E. coli (ETEC). A second collection of strains exists that colonize the small intestinal mucosa and cause diarrhoea, but do not elaborate enterotoxins. Characteristically, these strains attach closely to the luminal surface of enterocytes, often in cup-shaped depressions or on cytoplasmic protrusions, described as 'pedestals'. This attachment of bacteria to the enterocyte surface usually results in the microvilli being effaced and the lesion has been named the 'attaching and effacing' (AE) lesion (Fig. 14.15). Comparable strains cause diarrhoea in children and are called enteropathogenic E. coli (EPEC). It is appropriate to use this term for equivalent calf strains, but care is required because the term enteropathogenic E. coli has been used in the veterinary literature for many years to describe strains associated with diarrhoea, regardless of their pathogenic mechanism.*

A third group of strains colonizes the surface of the large intestine and causes a mild dysentery. These strains also cause AE lesions but because they cause *blood to be lost into the lumen of the large intestine,*

they are called enterohaemorrhagic E. coli (EHEC);

once again comparable strains cause a similar disease

in children. Some EPEC and EHEC, but not all,

produce a toxin that kills Vero cells in vitro and is called Verocytotoxin (VT) or Shiga-like toxin (SLT). This

Fig. 14.14

Scanning electron micrograph of calf small intestine

toxin does not cause AE lesions, but is probably

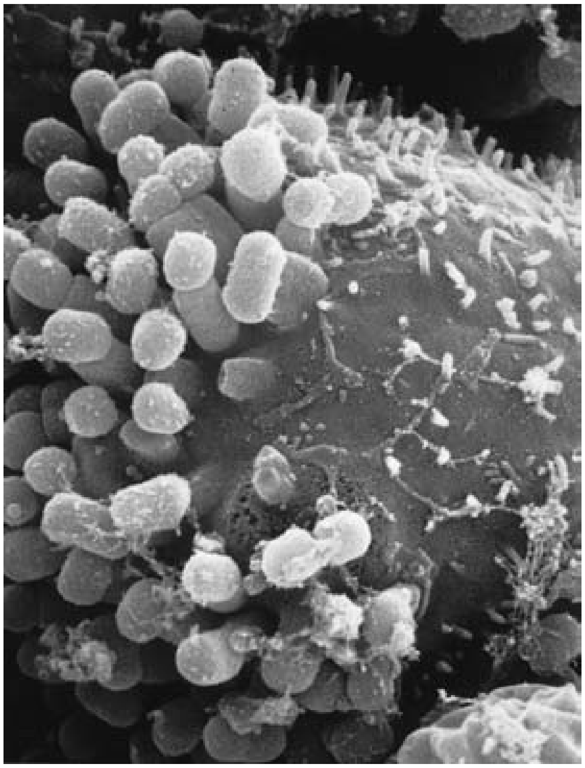
illustrating absorptive villi and a dome villus covered by a characteristic epithelium, which is thought to be specialized for

involved in the pathogenic process. Escherichia coli that antigen uptake and which has been shown to be susceptible to

produce VT are referred to as VT+ E. coli or VTEC.

infection and damage by bovine astroviruses.

VTEC have been isolated from calves with diarrhoea,



Enterotoxigenic E. coli possess two virulence attributes (determinants) that distinguish them from non-pathogenic strains: ability to adhere to the mucosal surface of enterocytes and, as mentioned previously, ability to produce enterotoxins (see Fig. 14.4). Adhesion is mediated by filamentous protein structures called fimbriae, sometimes called pili or adhesins, which bind to specific receptors on the enterocyte cell membrane. Adhesion mediated by fimbriae does not bring the bacterium in close contact with the enterocyte *luminal surface as is the case of EPEC and EHEC. The microvilli are unaltered and 'cups' and 'pedestals' are not seen. The presence of receptors is affected by age, and susceptibility to infection is greatest in the newborn calf when expression of receptors is greatest. These fimbriae are antigenic and so many of them are known by their antigenic name (e.g. K99, F41). Their adhesive ability allows ETEC to overcome the peri-stalsis of the small intestine by sticking to the mucosal surface. The adhesion antigens commonly found in ETEC of calves are K99 and F41; they often occur together but may be present independently. K99+ strains are also capable of inducing diarrhoea in pigs, foals, lambs, goats and possibly other ruminants. Adhe-sion of the bacterium to the enterocyte surface confers another advantage to the bacterium because entero-*

Fig. 14.15

Scanning electron micrograph of an enterocyte in

toxins are released close to their receptor sites. The

the colonic mucosa of a gnotobiotic calf inoculated experimen-

ability of ETEC to produce fimbriae and enterotoxins *tally with an enterohaemorrhagic E. coli (strain S102–9). Bacte-is determined by genes that are usually carried on a*

ria are attached closely to the surface of the enterocyte, often single plasmid and thus occur together. It is adequate,

on 'pedestals' (arrow) and the microvilli have been effaced.

therefore, to diagnose ETEC infection by detecting

either the enterotoxin or the adhesin.

Detection of adhesins forms the basis of the diag-

nostic tests for ETEC because they are easier to detect

but they may also be present in the faeces of healthy

than enterotoxins. Special culture media may be

calves. In an epidemiological study, they were found to

required to encourage ETEC to express adhesins

be as common in the faeces of healthy calves as in the

because, in general, K99 and F41 are poorly produced

faeces of calves with diarrhoea. Therefore, designation

by bacteria in vitro, although they are readily produced of an E. coli as a VTEC may not necessarily define it as by bacteria growing in the gut. Once expressed they can

an isolate capable of causing diarrhoea and demon-

be detected using specific antisera in agglutination,

stration of a VTEC in the faeces of a calf or calves with

haemagglutination or ELISA tests.

diarrhoea does not constitute a diagnosis of the cause
It is helpful to understand the mechanisms of absorp-
of the diarrhoea.
tion and secretion in the small intestine before consid-
ering how the enterotoxins produced by ETEC cause
diarrhoea. Absorption occurs through the activity of
Enterotoxigenic E. coli
the mature villus enterocyte. Sodium ions are trans-
Enterotoxigenic E. coli most commonly cause diar-
ported out of enterocytes through the basolateral cell
rhoea in calves under four days old. In experimentally
membranes into the basolateral spaces by an energy-
infected newborn calves the incubation period is 12 to
dependent mechanism, the sodium pump. This creates
18 hours. Calves are depressed and anorexic and rapidly
a concentration gradient extending from the lumen into
dehydrate and die. In calves ETEC diarrhoea can be
the enterocyte. Sodium ions, followed by chloride ions,
diagnosed clinically because it causes disease in very
diffuse along the concentration gradient from the
young calves and because it produces a very profuse

lumen through the microvillous surface, assisted by a

and much more watery diarrhoea than any other of the

brush border carrier system. The osmolality in the

calf enteropathogens.

basolateral spaces increases and water passes from the

lumen along the osmotic gradient (see Fig. 14.2). There

because adhesion is an important component of the

are several carrier systems that assist the entry of

pathogenic process.

sodium ions; one system does not utilize the products

It is possible to recognize clinically an outbreak of calf

of digestion, another utilizes glucose, which is specifi-

diarrhoea caused by ETEC because of the severity and

cally absorbed through the luminal surface of entero-

age group of calves affected. An outbreak characterized

cytes and each molecule of glucose carries with it a

by the rapid onset of severe, very watery diarrhoea,

molecule of sodium. Chloride ions and water follow and

which quickly causes dehydration and collapse and

this flow of water traps additional sodium and chloride *which is frequently fatal and occurs in calves that are*

ions by solvent drag (Fig. 14.2). Carrier systems for

less than 96 hours old, is likely to he caused by ETEC.

amino acids and citrate also transport sodium ions and

In some circumstances, calves may die before there is

water through the intestinal mucosa. These carrier

evidence of profuse diarrhoea. There is rapid and severe

systems, particularly the glucose carrier system, are par-

dehydration. The calf quickly becomes recumbent.

ticularly important in oral rehydration therapy. Secre-

Sequestration of fluid in the abomasum and intestines

tion occurs from crypt cells; sodium passes into the

gives the abdomen a bloated appearance which 'sloshes'

intestinal lumen taking chloride and bicarbonate ions

on succussion. The rectal temperature may be elevated

and water with it (Fig. 14.3). Cyclic-AMP stimulates this

in the early stages but rapidly falls to subnormal.

secretory activity.

Affected calves are rarely acidotic. Faecal bacteriology

The heat-stable enterotoxin (ST) is the enterotoxin

will confirm the diagnosis. ETEC diarrhoea is not *usually produced by ETEC strains from calves.*

common in the UK (less than one per cent of calf diar-

Two forms of ST occur (STA, and STB), but only STA

rhoea outbreaks), but outbreaks have been associated

occurs in calves. Both forms stimulate guanylate

with poor housing and management at calving.

cyclase activity within enterocytes, causing increased

There are a number of possible causes of recumbency

levels of intracellular cyclic-GMP, which inhibits

in neonatal calves which must be excluded from the

absorption by villous enterocytes but has no effect on

differential diagnosis list, including congenital heart

secretion.

defects, rupture of liver/spleen following dystokia and

The heat-labile enterotoxin (LT), rarely produced by

bilateral femoral nerve paralysis. Atresia coli/ani cases

calf ETEC strains, is made up of two subunits. Subunit

present with increasing abdominal distension, progres-

A stimulates adenylate cyclase activity within entero-

sive weakness and dehydration leading to recumbency.

cytes. Subunit B assists entry of subunit A into entero-

Septicaemia and bacterial meningoencephalitis are also

cytes. Adenylate cyclase raises the levels of cyclic-AMP

commonly encountered in calves less than four days

in mature villous enterocytes and crypt cells. In mature

old. Congenital neosporosis has also recently been

villous enterocytes, cyclic-AMP inhibits the independ-

reported as a cause of recumbency in neonatal calves.

ent pathway for the absorption of sodium ions and

The immediate response must be rapid isolation and

therefore of chloride and water (see Fig. 14.5). In crypt

treatment of sick calves by rehydration with an elec-

cells, it stimulates sodium secretion, which takes with it

trolyte solution. Acidosis is not a feature of diarrhoea

chloride and water (see Fig. 14.6).

in calves less than six days old and spiking intravenous

Although the main mechanism for the pathogenesis

fluids with bicarbonate is not indicated in calves with

of diarrhoea is attributed to enterotoxins, which do not

enterotoxigenic E. coli infections. Rehydration may

cause visible damage to the gut, experimental infections

be given by intravenous infusion if the calf is unable *of gnotobiotic and conventional calves, both colostrum*

to feed; intravenous infusions may be changed to oral

fed and colostrum deprived, have revealed a pathology

administration as the calf recovers strength. Less

associated with ETEC infections that probably con-

severely dehydrated calves may be treated only by oral

tributes to the development of diarrhoea. Villi become

rehydration. The biochemistry of oral rehydration

stunted and fused together and the enterocytes change

has been discussed earlier (pp. 197–8). Oral antibiotics

shape from columnar to cuboidal. These cells are prob-

should be administered to all calves at birth in the face

ably immature enterocytes and these changes indicate

of an outbreak until the vaccine administered to all

an increased rate of enterocyte loss.

remaining pregnant cattle can provide protective

Immunoprophylaxis against ETEC-induced diar-

immunoglobulins in the colostrum. Antibiotic resist-

rhoea is based on the use of immune colostrum. Dam

ance is not a problem in such outbreaks thus antibiotic

vaccination is used to stimulate high levels of antibody *selection is not critical to a successful outcome. Fluid*

in the colostrum and this approach is particularly suc-

therapy is the first priority because calves may die of

cessful because calves are susceptible to this disease for

dehydration before any beneficial effects are obtained

only the first few days of life when colostrum is fed.

from antibiotic therapy.

Vaccines containing the K99 fimbriae, or dead bacteria

Following immediate management of an outbreak

with the K99 antigen expressed on the surface, are used

with fluid therapy and antibiotics, it is essential to

introduce dam vaccination (see p. 1006). It should be

is little risk of spinal meningitis. Selection of a narrow

possible to eliminate the infection from the herd with

gauge hypodermic needle, and removal of only 1 to 2

the use of antibiotics, dam vaccination and good

ml of CSF, will greatly reduce any risks associated with

hygiene. ETEC with the K99 antigen are absent from

sudden release of CSF pressure.

most farms and disease prevention should concentrate *on exclusion of the infection by good herd biosecurity.*

Campylobacter spp. *(see p. 852)*

The related campylobacters, Campylobacter jejuni and

Enteropathogenic E. coli , enterohaemorrhagic

C. coli, have been recognized recently as important

E. coli and verocytotoxin-producing E. coli

enteric pathogens in humans. They are the most

common cause of diarrhoea in developed countries and

There are no specific clinical signs of diarrhoea caused

they are one of the three most common causes of

by EPEC and VTEC although a yellow watery diar-

human diarrhoea in developing countries; E. coli and

rhoea has been reported. The mean age of calves with

rotavirus are the other two enteropathogens of major

diarrhoea caused by EHEC was 15 days. Calves main-

importance. Recognition of the importance of campy-

tained a normal appetite and did not develop pyrexia,

lobacters followed marked improvements in culture

but a mild diarrhoea containing blood was seen. In pro-

techniques that improved isolation and identification

longed cases there was dullness, signs of abdominal *from faeces. They have been isolated from healthy and*

pain, dehydration and weight loss.

diseased domestic animals and poultry for many years

Although the EPEC, EHEC and VTEC are capable

and, not unexpectedly, the most common sources of

of causing diarrhoea in calves and have been associated

infection in human outbreaks are fresh poultry, minced

with outbreaks of disease, it is difficult to diagnose their

meat and unpasteurized milk.

specific involvement. Presence of frank blood in the

The recognition of animal products as the source of

faeces is suggestive of EHEC, especially if salmonellas

human infection has prompted a reassessment of the

and cryptosporidia are not isolated from faeces. The

importance of C. jejuni and C. coli in causing enteric presence of these enteropathogens will be suggested by

disease of farm animals. Since the 1930s, campylobac-

the failure to find other agents and possibly by the

ters have been thought of as the cause of an enteric

finding of E. coli in association with the mucosa of the disease of housed adult cattle in the winter–syndromes

small or large intestine.

referred to as 'winter dysentery', 'winter scours', 'vibri-

onic enteritis'. The above association has, however,

been questioned and more recently a coronavirus has

Clinical signs of septicaemia

been implicated as the cause of winter dysentery (see

In many situations it can prove difficult to differenti-

p. 852). The association of campylobacters with calf

ate the cause of the calf's depression, lethargy and

diarrhoea has been examined in experimental infec-

weakness between profound acidosis or early

tions and in case-control studies of field outbreaks. The

septicaemia/bacterial meningoencephalitis. Most septi-

results have shown that C. jejuni is present on all farms caemic calves are less than six days old and this age

and most case-control studies have failed to demon-

prevalence differs from the typical occurrence of viral-

strate an association between excretion of this organ-

induced diarrhoea and acidosis (more than eight days

ism and calf diarrhoea. In the majority of experimental

old). Septicaemic calves usually present with episcleral

studies, inoculation of calves with C. jejuni, even using injection, toxic mucous membranes and evidence of *high doses, resulted in colonization without diarrhoea.*

multi-organ system involvement such as joints, respira-

Campylobacter jejuni may be detected in up to 80 per

tory tract and eyes. Pyrexia above 39.5°C is not a con-

cent of weaned calves, indicating that isolation of this

sistent finding in septicaemic calves while diarrhoea is

organism from calves with diarrhoea does not consti-

often only present during the terminal stage of illness.

tute a diagnosis. Campylobacter coli is less commonly Lumbar cerebrospinal fluid (CSF) collection and

isolated from cattle and experimental inoculations and

visual inspection of the turbid sample on farm enables

case-control studies indicate clearly that it is non-

immediate diagnosis of bacterial meningoencephalitis

pathogenic. Campylobacter fetus subsp. fetus and C.

and appropriate aggressive antimicrobial therapy

hyointestinalis are also commonly isolated from cattle (Scott & Penny, 1993). This sampling procedure is rec-of all ages, but most evidence suggests that they are not

ommended in those cases where the clinician is unsure

a cause of intestinal disease.

of the diagnosis. On-farm collection of lumbar CSF in *depressed calves is a simple procedure which only*

Cryptosporidium parvum *(see p. 286)*

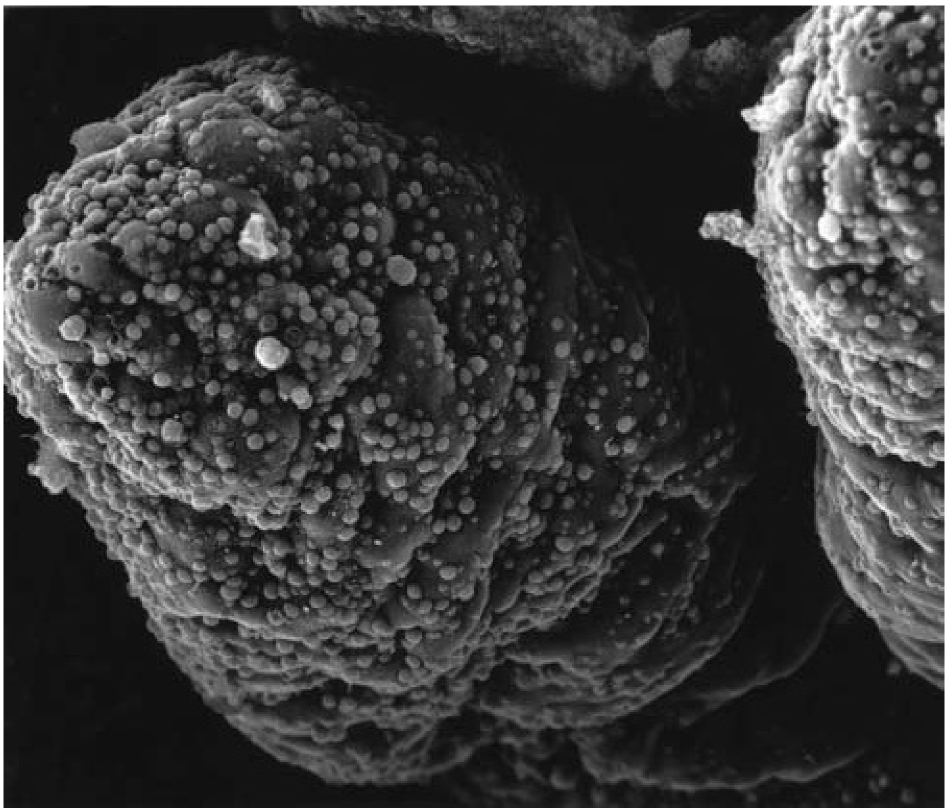
requires a knowledge of the bony landmarks and an

appropriate length hyopdermic needle without stylette

Cryptosporidium parvum is an enteric coccidia recog-

(see p. 896). With appropriate aseptic precautions, there

nized commonly in calves and lambs and is a zoonosis.



The organisms are spherical or ovoid parasites that

similar to that seen with rotavirus and not similar to

adhere to the microvilli of enterocytes, particularly in *that seen in Eimeria spp.*

the ileum, but also in the large intestine. Cryptosporidia

Cryptosporidiosis is seen in neonatal calves, usually

exhibit three important differences from other enteric

when they are aged one to two weeks (peak 11 days old),

coccidia: excreted oocysts are directly infective to new

at about the same time as they develop rotavirus diar-

hosts, cryptosporidia are not host specific so that infec-

rhoea. Most calves appear to become infected, but not all

tion can spread between mammalian species, including

develop diarrhoea. Subclinical infections are not thought

man, and finally they are unaffected by most existing

to be the result of passive protection by colostral anti-

anticoccidial drugs (see pp. 206, 1029).

bodies because experiments have shown that antibodies

The life cycle commences with the ingestion of

that are fed are not protective; subclinical infections

oocysts containing sporozoites, which become tropho-

remain unexplained. Experimental infections indicate

zoites. In the asexual phase of the life cycle the tropho-

an incubation period of two to five days and close associ-

zoites mature to schizonts containing eight merozoites,

ation between occurrence of diarrhoea and excretion of

which are liberated and infect new enterocytes to form

oocysts. Depression and anorexia accompany the

a second generation of merozoites. In the sexual phase,

profuse watery green diarrhoea, which contains mucus

macrogametes fuse with microgametes and give rise to

and occasionally blood. Diarrhoea may be intermittent

zygotes, which form oocysts. Sporozoites form within

and lasts two to 14 days (usually about seven) and causes

oocysts in the intestinal lumen or whilst they are still

dehydration which often requires treatment with oral

attached to the surface of enterocytes so that oocysts

rehydration solutions. Morbidity is usually high and mor-

excreted in the faeces are directly infective to new hosts

tality low,although some outbreaks have been associated

without an obligatory period of maturation outside the

with high mortality.

host body. Consequently, infection can spread rapidly

Infected mucosae (Fig. 14.16) are congested and villi

within a group of calves and the pattern of spread is *are stunted in the ileum. Enterocytes in the small and*

Fig. 14.16

Scanning electron micrograph

of the ileal mucosa of a calf naturally

infected with Cryptospordium parvum. The

surface of the villi is heavily infected and

partially exfoliated enterocytes are present

at the tip of the villus.

large intestines become cuboidal or squamous and

and before treatment commences and should be exam-

crypts may become dilated and filled with exfoliated

ined for rotavirus, coronavirus, Cryptosporidium and

cells and neutrophils. The lamina may become infil-

Salmonella spp. Samples from very young calves with

trated with mononuclear inflammatory cells, neu-

watery diarrhoea should be tested for K99+ E. coli.

trophils and eosinophils. Cryptosporidia appear to

Faeces should be collected from affected calves and

cause diarrhoea by destroying mature enterocytes, but

age-matched healthy calves on the farm, a minimum of *by an unknown mechanism. The population of mature*

four calves in each category. Faecal collection should

enterocytes is reduced in size and numbers of immature

continue if the outbreak persists to monitor for changes

cells are increased. Mucosal lactase activity is markedly

in enteropathogens being excreted.

depressed and there is reduced ability to digest and

Where a problem persists, or no diagnosis has been

absorb food. Intestinal secretion may be enhanced due

reached, samples may be sent to a research laboratory

to the increased numbers of secretory cells in the

for examination by electron microscopy or for the

mucosa. The self-limiting nature of natural and experi-

detection of EPEC, EHEC and VTEC. A post-mortem

mental infections and the widespread detection of anti-

examination of a calf submitted alive to a laboratory

bodies indicate that immune responses occur that are

may help to elucidate the significance of results of

protective. No further information is available on

faecal examination and indicate the presence of other

immunity.

agents not detected by faecal examination. Laborato-
Cryptosporidiosis can be diagnosed by detection
ries are frequently asked to assist in the diagnosis of
of oocysts in faecal smears but more reliable results
the aetiology of calf diarrhoea outbreaks on the basis
are obtained from stained gut sections. However, such
of samples submitted from one or two calves only.
material is rarely available due to the low mortality.
Clearly this is pointless, because diagnosis of disease
Several staining methods are available, of which the
caused by an endemic agent is based on the detection
Giemsa stain, the modified acid fast method and
of the agent in a higher percentage of the faeces of
auramine are the most widely used. Alternatively,
calves with diarrhoea than in healthy calves on the same
mucosal smears of ileum may be stained with Giemsa
farm. Where data are not available from healthy calves
or histological sections of ileum stained by haema-
on the same farm, results from other studies may be
toxylin and eosin. The histological method is of little
considered. Rotavirus and cryptosporidia have rarely

value if autolysis is advanced because the enterocytes

been found in more than 50 per cent of randomly

will have sloughed from the mucosal surface. The most

selected healthy calves and coronavirus is usually

reliable method is to make and stain smears of oocysts

detected in less than 25 per cent. Figures above these

concentrated from faeces using flotation techniques.

values may be taken as a tentative diagnosis.

Management of an outbreak presents problems;

Salmonellas, which may be suspected clinically, are

although a large number of chemotherapeutic agents

often only detected qualitatively. Merely isolating these

have been tested for efficacy against Cryptosporidium, bacteria is relatively meaningless; quantitative bacteri-only halufiginone has been found to be effective. Most

ological techniques should be used to demonstrate

workers recommend high levels of hygiene as the best

excretion of large numbers of bacteria from calves with

approach to control, but oocysts are extremely resistant

diarrhoea. It is only worth looking for K99 adhesins

to a variety of disinfectants, including iodophor, cresylic

where the outbreak is suggestive of ETEC, i.e. if calves *acid, sodium hypochlorite, benzylkonium chloride,*

under four days of age are affected and there is severe

sodium hydroxide and aldehyde-based disinfectants.

watery diarrhoea.

Ammonia and formalin are effective disinfectants. The

organism is susceptible to freezing and thawing and to

temperatures over 50°C. Steam cleaning is strongly

Epidemiology

recommended.

On a farm basis, the infectious agents that have been

associated with neonatal calf diarrhoea can be divided

Investigating an outbreak of

into three groups: those infections that are usually

calf diarrhoea

absent but may be introduced and cause an outbreak of

disease (ETEC, Salmonella spp.); the ubiquitous agents The investigation should start with a farm visit to

(rotavirus, coronavirus, and cryptosporidium) that are

examine the calves clinically and establish a picture of

invariably present on every farm; and those agents for

calf husbandry and of the outbreak. Enterotoxigenic E.

which inadequate epidemiological data are available

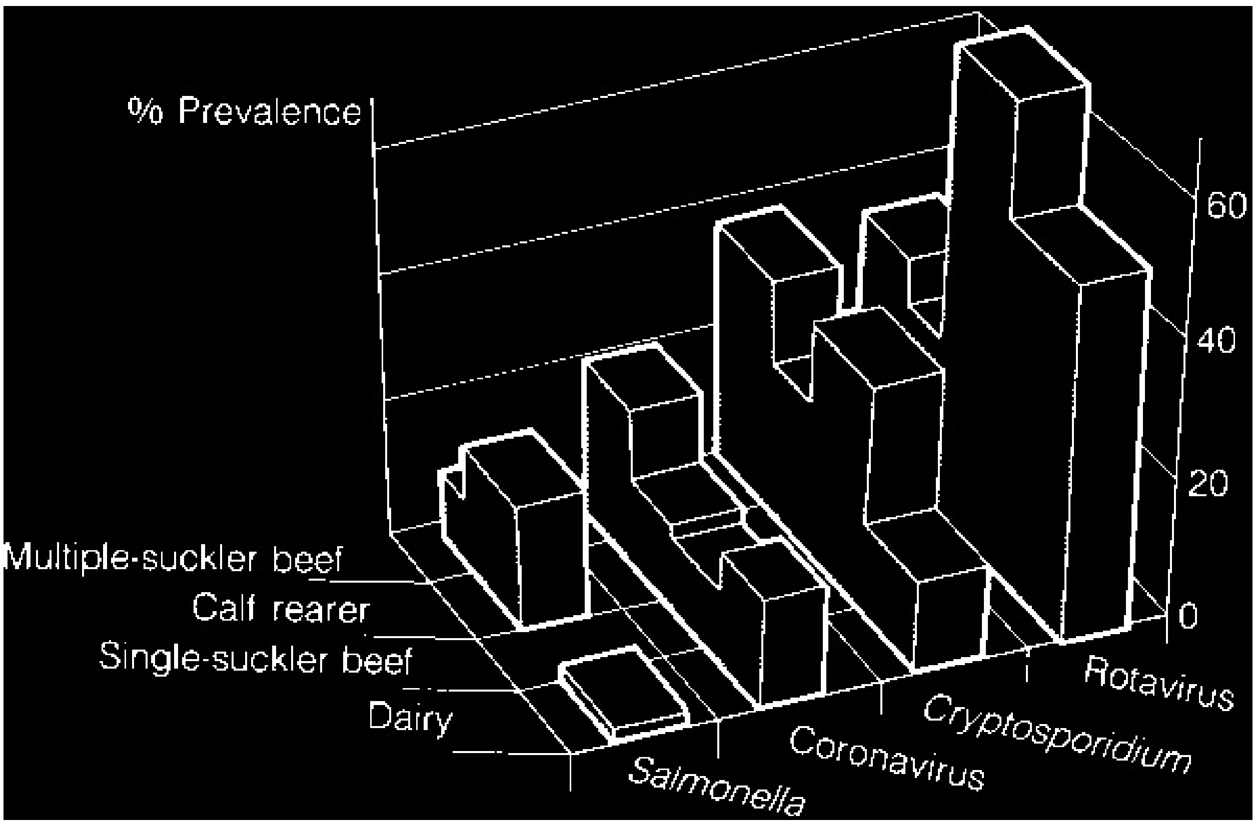
coli diarrhoea can be suspected on the basis of age of (Breda virus and VTEC). Although there is evidence to

affected calves. Faeces, not rectal swabs, should be col-

support the view that all the above infectious agents are

lected as soon as possible after the onset of diarrhoea

able to cause diarrhoea in calves, it is clear that their



detected rarely in clinically normal calves and it was

Cryptosporidium

Rotavirus

Salmonella

invariably associated with disease, usually in outbreaks

with high mortality. Results of two surveys show that

VT+ E. coli

diarrhoea caused by ETEC was uncommon in the UK

No diagnosis

at that time; this may still be the situation. Intermittent

Coronavirus

excretion of ETEC may occur throughout life, often

K99+ E. coli

unassociated with diarrhoea, making interpretation of

diagnostic findings difficult and emphasizing the need

Calici-like virus

for quantitative bacteriology.

Fig. 14.17

Prevalence of pathogenic agents in calf diarrhoea.

These survey data have been reproduced by numer-

ous monitoring organizations over the past 15 years

which clearly indicates the important role of rotavirus

and coronavirus in neonatal enteritis. Vaccination is

highly effective against these viral causes of diarrhoea *but the need for annual vaccination and perceived high cost have resulted in many beef calves remaining unprotected.*

Mixed infections

With the recognition of enteropathogenic agents and the development of diagnostic tests, it has been possible to look at outbreaks of diarrhoea and at individual animals to assess the importance of mixed infections. Results of surveys of faeces of calves with diarrhoea indicate that although single infections may result in

Fig. 14.18

Correlation of farm type with prevalence of pathogens in calf diarrhoea. Reproduced from Morgan (1990).

diarrhoea, the likelihood of diarrhoea occurring increases with the number of enteropathogens present. When 21 moribund calves with diarrhoea were examined in detail by necropsy, two or more

presence in the intestinal tract does not inevitably lead

enteropathogens were detected in 19 calves (Hall

to disease and they are not all equally important in the

et al., 1988). The most common combination of *aetiology of calf diarrhoea.*

enteropathogens revealed by these studies has been

The prevalence of these agents in calves with diar-

rotavirus and cryptosporidia and the way in which these

rhoea in southern Britain, as determined from 45

infections can overlap in rearing pens is illustrated in

outbreaks of calf diarrhoea, is shown in Fig. 14.17

Figs 14.19 and 14.20. Studies of distribution of infection

(Reynolds et al., 1986); another survey examined out-

of the gut mucosa with these two agents and the sever-

breaks in northern England and southern Scotland

ity of the lesions have shown that either agent, as a

(Snodgrass et al., 1986). Rotavirus was associated most single infection, might not cause sufficient intestinal

frequently with calf diarrhoea and was most common

damage to cause diarrhoea, but together they could. A

on dairy farms and single-suckler beef units (Fig. 14.18).

study of the intestinal pathology of normal calves that

Cryptosporidia oocysts were associated with calf diar-

were excreting rotavirus showed that there were severe

rhoea slightly less often than rotavirus and were more *lesions in the anterior small intestine and mild lesions*

common in beef suckler units than in dairy farms. In

in the mid small intestine, but the lower small intestine

southern England, salmonellas occurred in 25 per cent

and large intestine were normal (Reynolds et al., 1985).

of outbreaks and were most often a problem for rearers

Cryptosporidia, however, infect and damage the

of calves bought in from markets. Enteropathogens

lower small intestine and the large intestine, so that in

were not detected in 31 per cent of faeces of calves with

a combined infection the cumulative damage would be

diarrhoea. Rotavirus and cryptosporidia were excreted

sufficient to cause diarrhoea (Fig. 14.21). Similarly, if

by up to 50 per cent of normal calves, and on the basis

simultaneous infection with coronavirus and either

of this evidence an outbreak of rotavirus-induced or

rotavirus or calici-like virus occurred there would

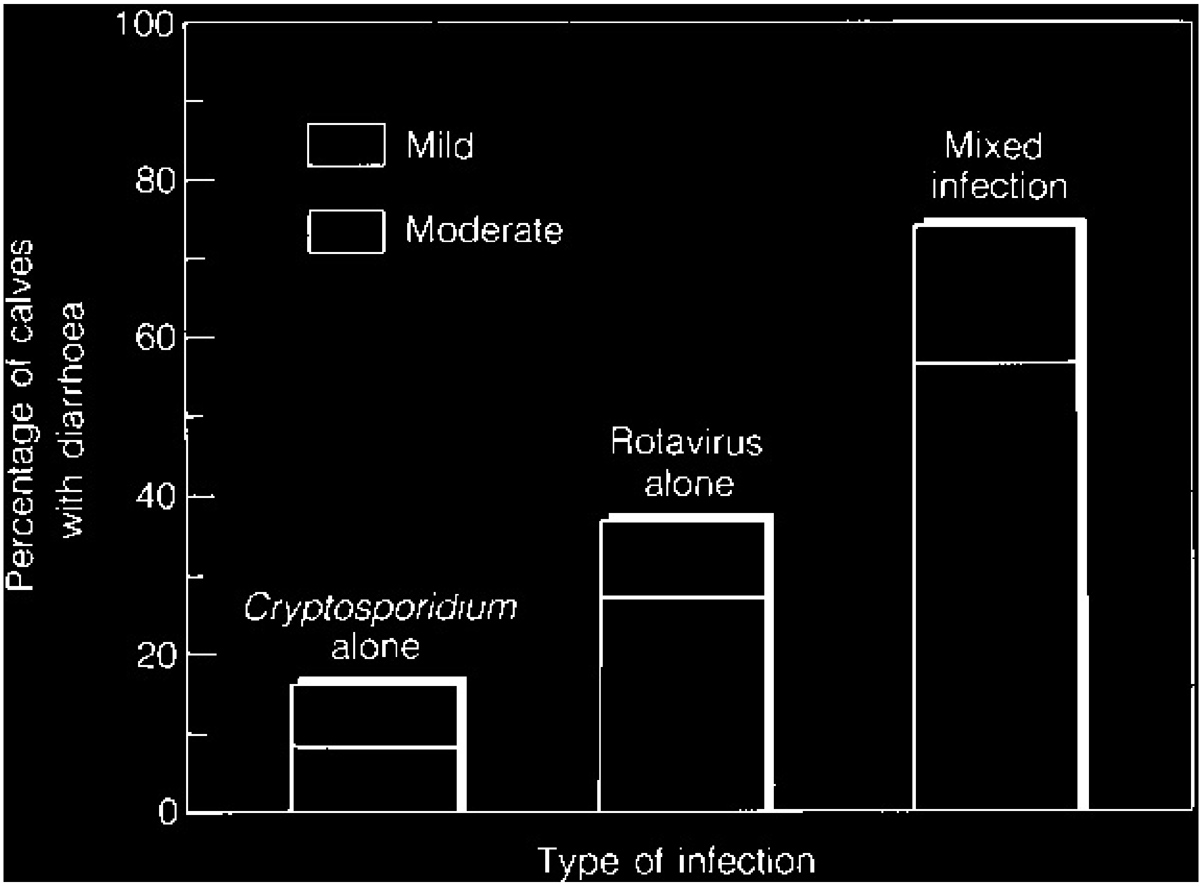
cryptosporidia-induced diarrhoea should only be diag-

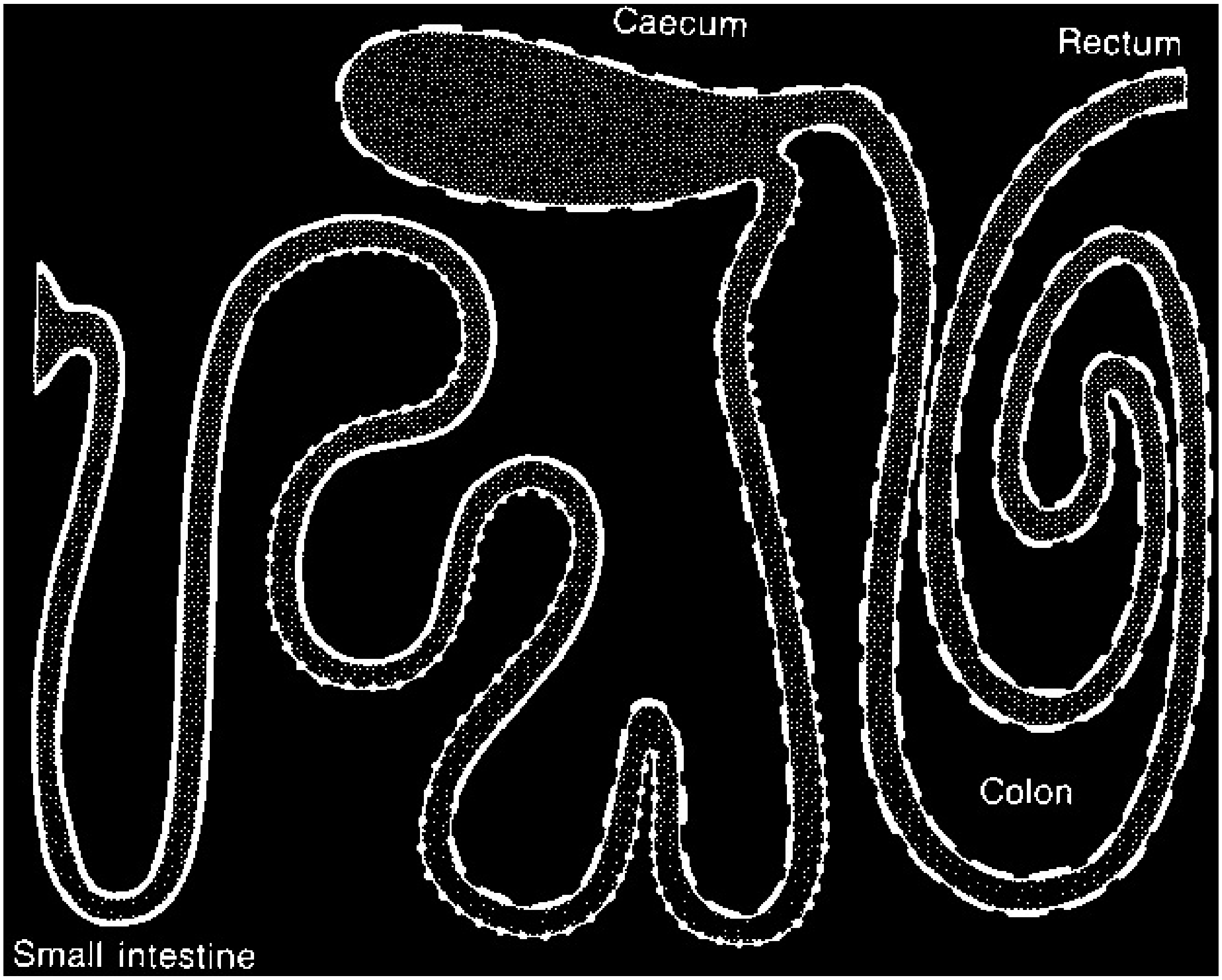
be cumulative damage because the former infects and

nosed if more than 50 per cent of calves with diarrhoea

damages the lower small intestine and large intestine, *are excreting either enteropathogen. Coronavirus was*

whilst the latter infects and damages the upper small




Caecum
Rectum
Colon
Small intestine

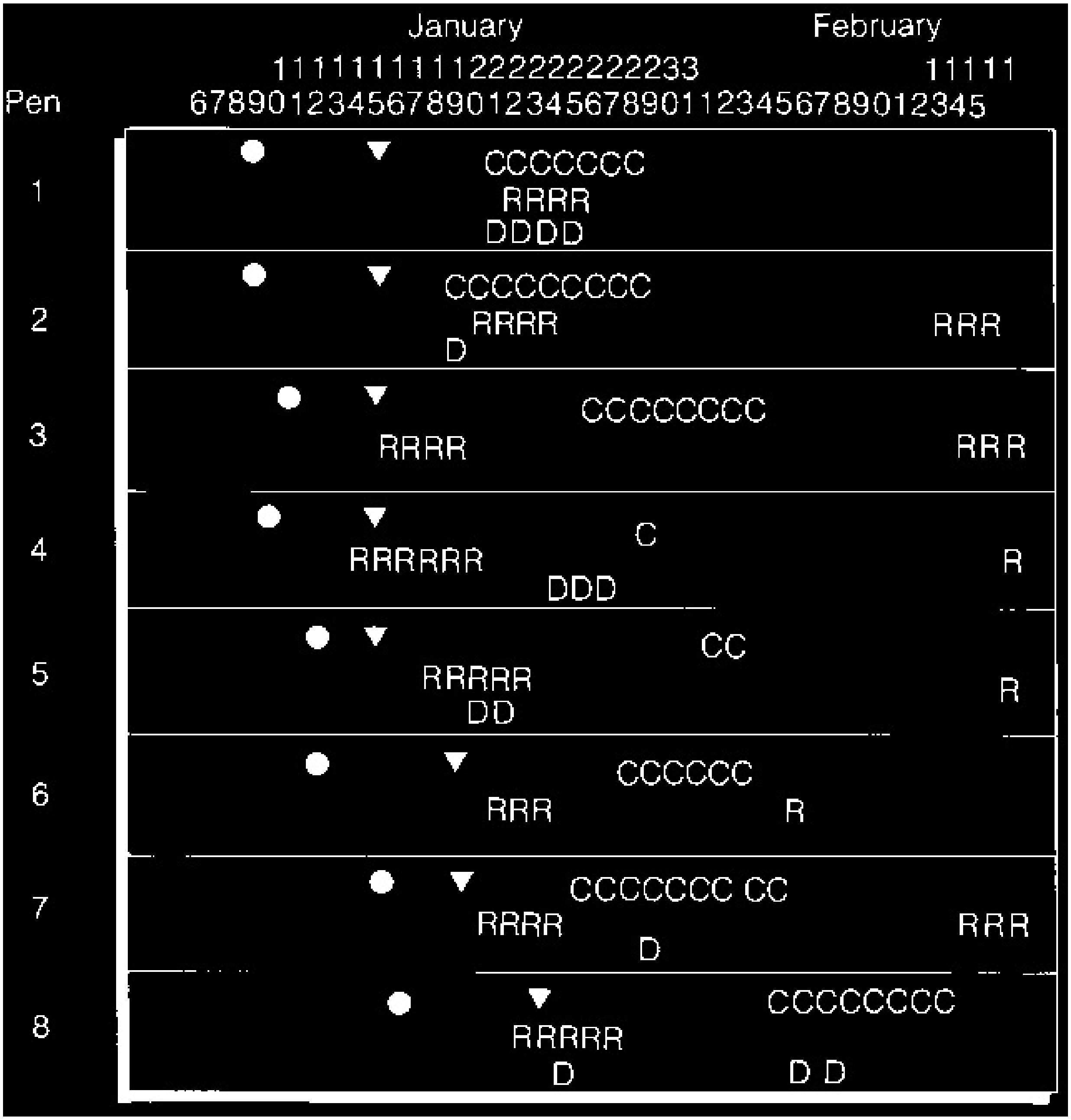


Fig. 14.21

Line drawing illustrating the small and large intes-

tines of the calf and indication of those parts susceptible to infection by rotavirus (. . .) and those susceptible to infection by Cryptosporidium spp. (---). Reproduced from Hall (1989).

Fig. 14.19

The spread of rotavirus and Cryptosporidium

between calves in adjacent pens. (粽) Day of birth, (彅) day of

Many of the recognized enteropathogens infect

move to rearing pens. C, Cryptosporidium excretion; R, rotavirus and damage the small intestine and coronavirus, Breda

excretion; D, day of diarrhoea. Reproduced from Morgan (1990).

virus, EHEC and cryptosporidia also damage the large

intestine. However, assuming that diarrhoea is more

likely to occur when both the small and large intestines

are damaged, there is a need to study the infectious

agents that damage the large intestine. Diarrhoea was

often associated with infections and lesions throughout

the small and large intestines in a study of the pathol-

ogy of 21 calves with diarrhoea in southern Britain

(Hall et al., 1988); coronavirus and bacteria adherent to the mucosal surface were associated with the lesions in

the large intestine. The results indicate that these bac-

teria, some of which were EHEC, were contributing

to the development of diarrhoea. Evidence from field

studies also suggests that mixed infections are impor-

tant in the development of diarrhoea. In a longitudinal *study of calves, from birth to weaning, only 15 per cent*

of calves that excreted Cryptosporidium sp. and 37 per ***Fig. 14.20***

Occurrence of diarrhoea in farm calves infected with

cent of calves that excreted rotavirus experienced diar-

either rotavirus or Cryptosporidium and in mixed infections.

rhoea, but in calves in which the two infections occurred

together, 75 per cent developed diarrhoea (Fig. 14.20).

Rotavirus and ETEC were the infectious agents first

intestine. The concept that mixed infections involving

identified as able to cause diarrhoea in calves and, as

rotavirus, cryptosporidia, and coronavirus cause cumu-

a result, combined inoculations with these agents were

lative damage in the small and large intestines is based

studied by several groups. The interaction between

on information presently available concerning the

these two agents was studied despite the fact that

predilection sites of these pathogens. There is, however,

ETEC cause diarrhoea in calves that are less than

evidence that different strains of rotavirus and coron-

48 hours old, whereas the mean age of calves with

avirus may have different predilection sites within the *rotavirus diarrhoea is ten days. The conclusions reached*

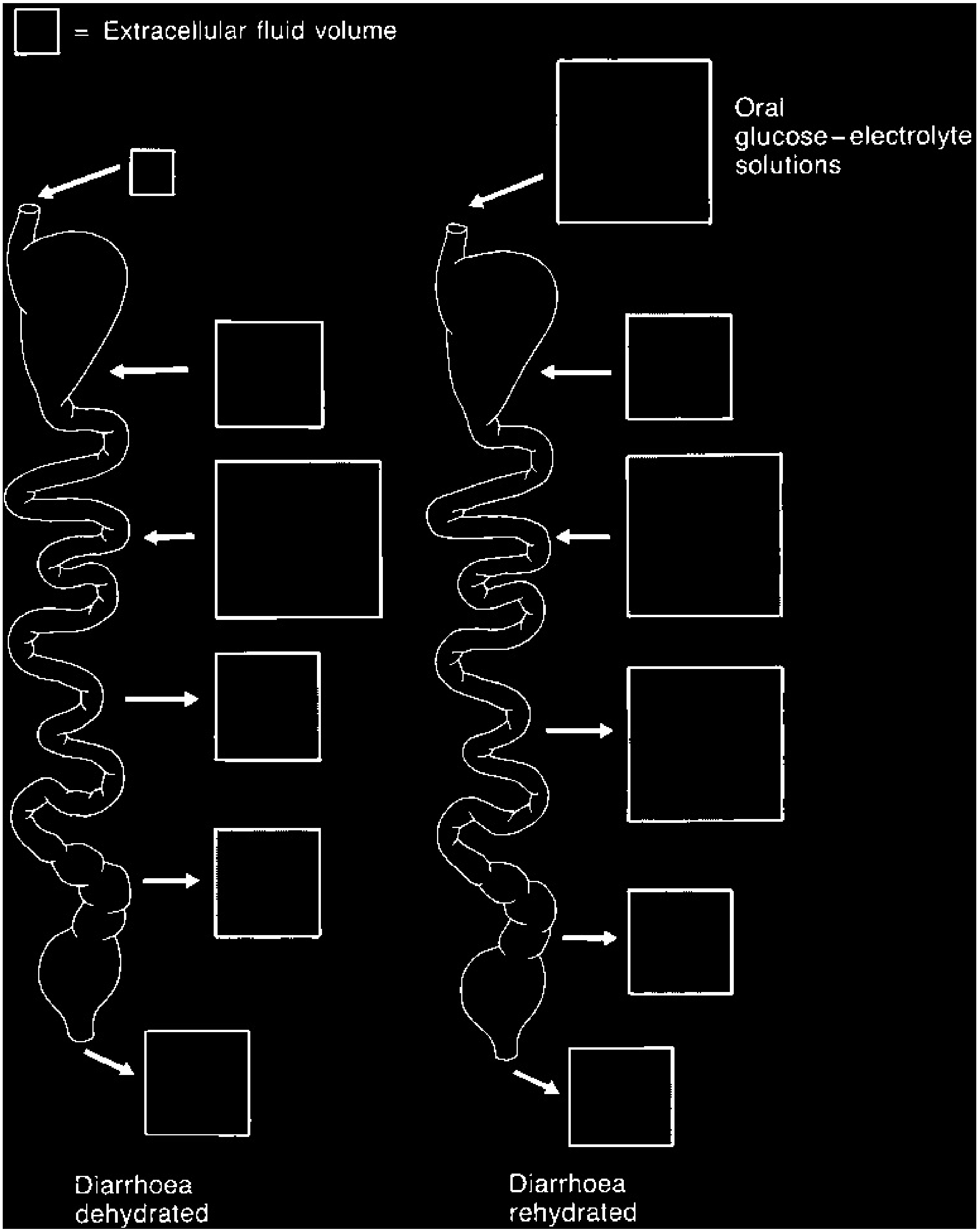
small intestine and this could affect the development of

from these studies were that combined infections were

cumulative damage.

more severe, although it was unclear whether this was

due to additive effects or synergism.


= Extracellular fluid volume
Oral
glucose – electrolyte
solutions
Diarrhoea
dehydrated
Diarrhoea
rehydrated

Management of diarrhoea

tion containing glutamine, a simple amino acid and high

levels of glucose has also recently been introduced with

The first priority is to treat fluid depletion, i.e. restore

the claim that this combination will have a beneficial

extracellular fluid volume so as to counter shock and

effect on mucosal architecture by reducing the severity

acidosis.

of villous atrophy and promoting repair. Commercially

prepared oral rehydration solutions are sophisticated

formulations and should always be used.

As a rule of thumb, if the calf is weak and presents

Rehydration *(see also p. 195)*

in lateral recumbency, use intravenous therapy; if it

Oral fluids are very satisfactory in the less severely

can lift its head but has no suck reflex, use intravenous

affected animals. They are usually isotonic with plasma

therapy. If the calf can drink, offer electrolyte solution

and contain sufficient K^+ and HCO^-

3

to replace faecal

by teat and bottle as reluctance to suck may be the first
losses and Na+ and glucose in equimolar amounts. Such
indicator of septicaemia/bacterial meningoencephalitis.
preparations are formulated to utilize the pathways of
The calf should be fed every two to four hours and care-
absorption of glucose, amino acids and citrate, which
fully monitored; loss of an active suck reflex indicates
carry water with them. These formulations have been
deterioration of the calf's condition and veterinary
improved by inclusion of 80 to 100 mmol/l bicarbonate
attendance is necessary without further delay.
as a precursor, usually citrate, which is catabolized to
The efficacy of oral rehydration varies with the type
give bicarbonate ions which helps to counter metabolic
of diarrhoea. In secretory diarrhoea, the sodium
acidosis. Energy is supplied as glucose and citrate. More
glucose absorption system is unaffected by bacterial
recently, oral rehydration solutions have been intro-
enterotoxins and glucose/electrolyte solutions are very
duced which contain up to 375 mmol/l glucose in an
effective in rehydrating the animal. Nevertheless, the

attempt to counteract the energy deficit when milk is

diarrhoea continues and this should be stressed to the

removed from the calf's diet. An oral rehydration solu-

client (Fig. 14.22). The small intestine may be so

Fig. 14.22

Effect of orally administered glucose/

electrolyte solution of fluid fluxes in secretory diar-

rhoea in the pig. Where glucose/electrolyte solution is

not given, there is a net loss of water and dehydra-

tion develops. Where glucose/electrolyte solution is

given, the diarrhoea continues but there is a net gain

of fluid by intestinal absorption and rehydration

occurs. Source: Argenzio (1984).

severely damaged in very severe viral infections that

Microbial environment

oral electrolyte solutions are ineffective. In less severe

The enteropathogens that have been discussed are all

viral infections, for example many rotavirus infections

excreted in faeces in very large numbers by clinically

of calves, sufficient functional surface may remain for *sick calves. It is clear, therefore, that once an outbreak*

oral electrolytes to be effective.

is established the major source of infection is faecal

contamination of the environment by clinically affected

Nutrition

calves. Other animal sources or reservoirs of infection

have been described; rotavirus and coronavirus are

The energy requirements of a newborn calf are approx-

excreted by calves and cows with subclinical infections

imately 2500 kcal/day, equivalent to 600 g of glucose.

and similar situations could be expected for the other

The glucose content of 10 litres of an oral glucose/elec-

enteropathogens, which have been investigated less

trolyte solution containing 80 mmol glucose is 144 g,

well. Studies of dairy systems (Greene, 1983; McNulty

which does not supply sufficient energy but this can be

& Logan, 1983) have shown the value of cleansing,

largely overcome by feeding an oral rehydration solu-

disinfection and use of the 'all-in all-out' system in the

tion containing 375 mmol/l. A rational approach is to

control of diagnosed and undiagnosed calf diarrhoea.

feed electrolyte solution alone for one to two days and

Calving accommodation and calf pens should be

subsequently alternate feeds of milk and electrolyte

designed for ease of cleaning, steaming and disinfection

solution. While mixing electrolyte solution and milk

and with adequate drainage. Pens should be well venti-

does not appear to interfere with clotting of milk in the

lated, but draught free. Pens and utensils should be kept

abomasum, this method is to be avoided if possible.

clean, and pens kept dry with adequate straw.

With suckled calves, separate the calf and the cow, feed

The same principles apply in beef systems (Radostits

electrolyte and then allow the calf to suck the cow for

& Acres, 1980). Firstly, it is important to remove the

approximately five minutes.

source of infection from the calves' environment, or

minimize it. Measures that can be adopted include the

following.

***Drugs** (pp. 189, 229)*

• Avoid confining the herd, especially at calving.

In severe dehydration, rehydration must be the first pri-

Avoid using calving paddocks in which mud and

ority. There are two situations where the use of anti-

faeces soon predominate and where animal density

biotics is indicated: infections with Salmonella spp. or is high.

with pathogenic E. coli (ETEC, EHEC and VTEC).

• Regularly change the pastures that the herd grazes.

Broad-spectrum antibiotics and antimicrobials have

• Do not calve cows and heifers on the pasture on

been used widely as a primary form of treatment of

which they have been held during winter; move

calves with neonatal diarrhoea, without sound reason

them to clean areas just before calving.

in many cases. Most therapeutic trials for treatment of

• Do not calve on the same area year after year.

diarrhoeal calves with antibiotics have been uncon-

Avoid calving in barns and sheds where infection

trolled or used small numbers of animals and have not,

builds up rapidly, and ventilation and sunlight are

therefore, been convincing.

restricted, encouraging survival of infection.

The disadvantages of using antibiotics are that some

• Choose a calving ground that is sheltered and well

directly damage the intestinal mucosa, delaying repair,

drained. Avoid creating local areas within calving

and may contribute to the development of diarrhoea.

grounds where animals congregate and infection

Antibiotics add significantly to production costs, they

builds up, i.e. restricted feeding or watering areas.

may contribute to the problem of resistance factors in

• Calving areas should be cleaned up and left vacant

the enterobacteria, they may result in residues in meat

during summer.

and antibiotic use may result in the carrier state in

• Isolate calves, as far as is possible, from the con-

Salmonella infections.

taminated environment by removing calves from

areas contaminated by diarrhoeic calves. Reduce

crowding of calves by dividing the calving herd into

Environment

small subgroups and dispersing newborn calves

with their mothers soon after birth.

The impact of environment on the pathogenesis of calf diarrhoea may be discussed under the follow-

Immunological environment

ing headings: microbial environment, immunological

environment, nutritional environment and physical

Neonatal calves are more resistant to enteric infec-

environment.

tions when suckled than when fed artificial feeds,

regardless of whether or not there is absorption of

been shown to protect calves from ETEC, probably

colostral immunoglobulins. This suggests that compo-

by anti-adhesive activity. Absorbed colostral antibody

nents of colostrum and milk that are not absorbed have

may also influence enteric infections because IgA is

an intestinal role in protecting the neonate. The other

absorbed along with IgG1 and some is resecreted onto

quite distinct protective function provided by the

mucosal surfaces.

immune components of mammary secretions is their

Studies of the concentration of immunoglobulins in

absorption to provide passive circulating antibody,

the blood of diseased calves showed that calves with the
which prevents invasion of micro-organisms.
lowest levels of immunoglobulin had highest mortality;
colisepticaemia was the major killer, either rapidly or
via abscesses in the umbilicus, liver and joints. Calves
Specific protective systems in colostrum and milk
with low levels of immunoglobulins may also show a
(see p. 1002)
greater incidence of diarrhoea.
Immunoglobulins are concentrated from the cow's
Colostral antibodies, if they are to be absorbed effec-
serum into colostrum from five weeks prepartum.
tively or if they are to have a protective function in the
The classes of immunoglobulins that are present in
gut lumen, must resist rapid degradation. The mecha-
colostrum and milk are IgA, IgG1, IgG2 and IgM.
nisms that protect colostrum from degradation in the
IgA and IgG2 each comprises 5 per cent of colostral
gastrointestinal tract are the low activity of pancreatic
immunoglobulins and IgM comprises approximately 7
protease in the neonatal calf, the presence of a trypsin

per cent. The majority of colostral immunoglobulins (80

inhibitor in colostrum, the high buffering capacity of

to 90 per cent) are IgG1 and the concentration of IgG1

colostrum, the reduced secretion of acid in the aboma-

in colostrum is three to twelve times that of maternal

sum in the first three days of life and the resistance of

serum, because of selective secretion by the acinar

IgG1 to proteolysis by chymotrypsin. The enterocytes

epithelial cells of the mammary gland.

of the newborn calf are specialized for non-selective

Colostral proteins are absorbed very rapidly and effi-

macromolecule absorption by pinocytosis and vesicle

ciently by the small intestine of the newborn calf. The

transport. This process results in rapid and effective

small intestinal villi are covered by highly vacuolated

uptake of antibodies (IgG1) because these are the major

enterocytes, which are specialized in the uptake of

macromolecules in colostrum.

macromolecules by pinocytosis. The ability to absorb

There are, in addition to protective immunoglobulins,

macromolecules may persist for up to 24 hours after *non-specific protective systems in colostrum and milk*

birth and its disappearance is known as ‘closure of the

(Reiter, 1978; see also Chapter 58). Lactoferrin, an iron-

gut’. Although the gut may remain ‘open’ for up to 24

binding protein present in colostrum and milk, inhibits

hours, closure occurs rapidly after ingestion of the first

bacterial growth, possibly by reducing availability of

feed. If the first feed is colostrum, all is well, but if

iron to bacteria. There are appreciable amounts in

the first feed is milk, the gut will ‘close’ and colostrum

bovine colostrum but little in bovine milk. Citrate, also

fed subsequently will not be absorbed. Thus, IgG1 is

present in colostrum, competes for iron, making it avail-

absorbed into the blood of the calf in large amounts

able for bacteria. Therefore, normal colostrum is not

during the first 24 hours of life. All macromolecules pre-

bacteriostatic for E. coli, but once the citrate is removed sented are absorbed but IgG1 is predominant and there-colostrum is bacteriostatic. Conditions in the calf small

fore it is absorbed in greatest amounts. IgA in milk

intestine apparently favour the action of lactoferrin

provides a passive intestinal humoral immunity in other *because citrate is rapidly absorbed from the calf small*

species. In ruminants the predominance of IgG1 in milk

intestine and bicarbonate, which assists binding of iron

suggests that it has a similar function. Determination

and lactoferrin, is secreted into the small intestine. The

of passive antibody transfer can be easily achieved by

antibacterial action of lactoferrin is enhanced by spe-

measuring total plasma protein concentration using

cific antibodies in colostrum. The lactoperoxidase/thio-

a refractometer where values greater than 65 g/l are

cyanate/hydrogen peroxidase system is inhibitory or

considered optimum and concentration below 50 g/l

lethal to bacteria via the production of an oxidation

inadequate.

product.

Lactoperoxidase is synthesized by the

The immune components of mammary secretions

mammary gland, thiocyanate ions are present in milk

have two functions.

Firstly, colostral antibodies

and are secreted into the calf stomach and cow’s milk absorbed into the circulation of the neonate provide

contains glucose and glucose oxidase, which provide

passive circulating antibody, which prevents invasion

hydrogen peroxide; hydrogen peroxide is also produced

of micro-organisms (e.g. septicaemic E. coli). Secondly, by lactobacilli, which are the predominant bacteria in

colostral antibodies that are not absorbed due to gut

the flora of the stomach and small intestines of newborn

closure, and milk antibodies, act within the gut lumen,

calves. Thus, all the components of this protective

providing passive local immunity. Milk antibody has

system are present in the calf in vivo.

The absorption of colostral immunoglobulins is influ-

• Encourage outdoor calving in warm weather; it is

enced by several factors and 20 to 50 per cent of calves

more likely to lead to higher levels of serum im-

attain inadequate serum IgG levels. The time of the first

munoglobulins.

colostrum meal is an important determinant of serum

immunoglobulin concentration; late feeding leads to

Methods of measuring the concentration of

lower levels. Also, first-milk colostrum has the highest

immunoglobulins in calf serum include the following:

concentration of immunoglobulins, therefore prepar-

turient leaking or milking leads to poorer quality post-

• *Single radial immunodiffusion: convenient, accu-*

parturient colostrum. Colostrum is secreted prepartum

rate and capable of measuring IgG1, IgG2 and IgA.

and once removed is not replaced. The amount of

• *Zinc sulphate turbidity test: depends on the selec-*

immunoglobulin absorbed varies with its concentration

tive precipitation of immunoglobulin by zinc

in the colostrum and this is more important than the

sulphate; there is good correlation between zinc

quantity of colostrum consumed.

sulphate turbidity and total immunoglobulin

Maternal nutrition may affect colostrum production.

content of serum.

Poor nutrition does not, apparently, influence the

• *Sodium sulphite precipitation method.*

concentration of immunoglobulin in colostrum but

• Refractometry: measures total protein.

decreases the amount of colostrum produced, there-

fore sucking calves achieve lower levels of serum

The immunoglobulin content of colostrum can be

immunoglobulin; heifers produce less colostrum than

assessed simply and accurately with a hydrometer

cows. A second feed of colostrum increases the

(Fleenor & Stott, 1980) and one designed specifically

absorption of immunoglobulin from the first feed,

for the purpose is available in the UK.

presumably because the second feed displaces

colostrum from the upper gastrointestinal tract into the

jejunum.

Nutritional environment

The presence of the dam improves the efficiency of

Skim milk powders, which have been severely heat

absorption of immunoglobulins by the calf by up to 80

treated, and some non-milk proteins (e.g. soya) do not

per cent. Lower serum levels are obtained if the calf and

coagulate well in the abomasum. This may result in

dam are separated at birth and colostrum is fed by

gastric stasis and reduced secretion of gastric acid and
bucket. The dam licks and cleans the newborn calf in
enzymes, which causes increased escape of undigested
the order: thorax, back, abdomen, head, neck and per-
protein into the duodenum and reduced secretion of
ineum. The placenta is then eaten. Suckling does not
pancreatic enzymes. These events result in diarrhoea.
occur unless the licking process occurs. An easy partu-
Soya initiates immune-mediated intestinal damage in
rition leads to early licking. Beef cows mother better
some calves and heated soya may contain substances
than dairy cows; they lick longer and stand better to be
that are directly damaging to the intestinal mucosa.
sucked. The speed at which calves stand is important
Some feeding methods may upset the balance between
because they then start to seek the teats. If cows have
the calf and the infectious agents to which it is exposed,
calved standing then sucking is likely to start earlier.
thus precipitating diarrhoea. These include feeding cold
Field-born calves have higher levels of serum
milk, bucket feeding, high-fat diets and skim milk.

immunoglobulins than box-born calves. The cow is

Alternatively, feeding methods that are said to alleviate

likely to be the primary object of teat-seeking attention

diarrhoea include use of acidified milk and fermented

but in a box the walls may confuse the calf. Low

colostrum, even though it is less well absorbed than

pendulous udders delay successful sucking.

fresh colostrum.

Farmers should be encouraged to ensure that all

calves receive a minimum of 2 1itres of colostrum

soon after birth, certainly within 4 to 6 hours. Practical

Physical environment

recommendations to enhance colostrum uptake include

the following:

Hypogammaglobinaemia is more common in single-

suckled beef herds where the stocking density is high,

• Do not separate dam and calf until 24 hours

presumably due to poor mothering and supervision.

postpartum.

Calf mortality is less if the person who looks after the

• Provide bedding to allow the calf to stand easily.

calves is the farmer, or a member of his or her family.

• Encourage early feeding, which is very beneficial.

Single penning helps reduce the spread of infection,

The calf may need assistance to ensure this.

as do solid walls between pens. Aspects of the physical

• Keep a supply of frozen colostrum for use after

environment that contribute to the development of

prepartum leakage.

diarrhoea by stressing calves are inclement weather,

particularly snow and rain, cold wet bedding and

minal ileum and colon. Abomasal lesions range from dis-

overcrowding.

crete 1 to 3 cm diameter oval ulcers to large confluent areas

of ulceration and necrosis in the pyloric region. Haemor-

rhagic or necrotic lesions overlying gut-associated lym-

Necrotic enteritis *(See p. 238)*

phoid tissue (Peyer's patches) are common.

Necrotic or necrotizing enteritis is the term used to

describe a distinct clinicopathological syndrome char-

References

acterized by severe diarrhoea, pyrexia and neutropae-

nia in two to three month-old beef calves (Penny et al., Argenzio, R.A. (1984) Pathophysiology of neonatal diarrhoea.

1994). The disease has been reported to occur in the

*Agri-Practice, **9**, 25–32.*

same beef herd for four consecutive years, affecting

Brooks, H.W., White, D.G., Wagstaff, A.J. & Michell, A.R.

approximately 5 per cent of calves when seven to 12

(1997) Evaluation of a glutamine-containing oral rehydra-

weeks-old (Penny et al., 1994). Despite intensive sup-

tion solution for the treatment of calf diarrhoea using an

portive and antibiotic therapy approximately 25 per

*Escherichia coli model. The Veterinary Journal, **153**, 163–70.*

Dupe, R., Bywater, R.J. & Goddard, M. (1993) A hypertonic

cent of affected calves died after five to 10 days of

infusion in the treatment of experimental shock in calves

illness. The clinical presentation of necrotic enteritis is

*and clinical shock in dogs and cats. Veterinary Record, **133**, not dissimilar to coccidiosis but the morbidity is much*

585–90.

lower and the findings more severe in nature.

Fleenor, W.A. & Stott, G.H. (1980) Hydrometer test for

Affected calves are dull and depressed and do not

estimation of immunoglobulin concentration in bovine

suck. These calves are moderately (5 to 7 per cent) to

*colostrum. Journal of Dairy Science, **63**, 973–7.*

severely (8 to 10 per cent) dehydrated, and pyrexic

Greene, H.J. (1983) Minimise calf diarrhoea by good hus-

(39.5 to 42.0°C) with pale mucous and oral membranes.

bandry: treat sick calves by fluid therapy. Annales de

Sudden onset profuse dark green diarrhoea containing

*Recherches Vétérinaires, **14**, 548–55.*

fresh blood is a consistent feature. Tenesmus is also a

Grove-White, D. (2000) Intravenous fluid therapy in the

common feature and becomes more prominent during

*diarrhoeic calf. UK Vet, **5**, 56–61.*

Hall, G.A. (1989) Mechanisms of mucosal injury: animal study.

the latter stages of the disease and may cause tem-

In: Viruses and the Gut, Proceedings of the Ninth BSG:

porary rectal prolapse. There is rapid loss of body con-

SK&F International Workshop, 27–29.

dition and affected calves have a gaunt appearance with

Hall, G.A., Reynolds, D.J., Parsons, K.R., Bland, A.P. &

a tucked-up abdomen. This syndrome has many clinical

Morgan, J.H. (1988) Pathology of calves with diarrhoea in

features of mucosal disease but oral erosions and

southern Britain. Research in Veterinary Science, **45**, 240–50.

ulceration are observed in less than 50 per cent of

Kasari, T.R. & Naylor, J.M. (1986) Clinical evaluation of

calves, and there are no interdigital lesions.

sodium bicarbonate, sodium lactate and sodium acetate for

Muco-purulent ocular and nasal discharges, com-

the treatment of acidosis in diarrhoeic calves. Journal of the monly seen in mucosal disease, are not observed in

American Veterinary Medical Association, **187**, 392–7.

necrotic enteritis.The age-specific occurrence of necrotic

Lewis, L.D. & Philips, R.W. (1978) Pathophysiologic changes enteritis differs from mucosal disease which more

due to coronavirus-induced diarrhoea in the calf. Journal of the American Veterinary Medical Association, **173**, 636–42.

commonly affects yearling cattle although BVD/MD

McNulty, M.S. & Logan, E.F. (1983) Longitudinal survey of

persistently affected cattle may die of intercurrent

rotavirus infection in calves. Veterinary Record, **113**, 333–5.

disease, especially bacterial pneumonia, from two

Mebus, C.A., Stair, E.L., Underdahl, N.R. & Twiehaus, M.J.

months old. BVD antigen has not been detected

(1971) Pathology of neonatal calf diarrhoea induced by a

in blood samples from affected calves nor from fresh

reo-like virus. Veterinary Pathology, **8**, 490–505.

tissue samples. No recognized enteropathogen has

Morgan, J.H. (1990) Epidemiology, diagnosis and control of

been isolated from faecal examinations. There is mild to

undifferentiated calf diarrhoea. In Practice, **12**, 17–20.

severe anaemia and profound leucopaenia caused pre-

Naylor, J.M. (1996) Neonatal ruminant diarrhoea. In Large

dominantly by a severe non-regenerative neutropaenia.

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The administration of oral and/or systemic antibiotics

Mosby, St Louis, p. 404.

has no effect on the outcome of necrotic enteritis.

Penny, C.D., Scott, P.R., Watt, N.J. & Greig, A. (1994) Necrotic enteritis of unknown aetiology in young beef calves at

Supportive therapy comprising oral and intravenous

pasture. Veterinary Record, **134**, 296–9.

fluids, and flunixin meglumine, may effect a temporary

Radostits, O.M. & Acres, S.D. (1980) The prevention of epi-improvement but does not alter the prognosis.

demics of acute undifferentiated diarrhoea of beef calves in

Erosion or ulceration of the hard palate is common but

*western Canada. Canadian Veterinary Journal, **21**, 243–9.*

no oesophageal ulceration has been recorded. Consis-

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tent findings are necrotizing lesions in the abomasum and

*antimicrobial systems in milk. Journal of Dairy Research, **45**, small and large intestine, particularly involving the ter-131–47.*

Reynolds, D.J., Hall, G.A., Debney, T.G. & Parsons, K.R.

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significance of viral enteritis in Dutch dairy cattle. In

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animals and humans. In Practice, ***9****, 47–9.*

tion. In Practice, ***8***, *239–40.*

Chapter 15

Salmonellosis

P.W. Jones, P.R. Watson and T.S. Wallis

Introduction

215

of three major syndromes: a peracute systemic infec-

Classification

216

tion, an acute enteritis or a chronic enteritis. In humans,

Resistance to antibiotics

217

this ranges from the generalized typhoid infection,

Epidemiology of salmonellosis in cattle

218

through the less severe paratyphoid infections to a

The carrier state

219

mild gastroenteritis. The majority of serotypes produce

Pathogenesis

220

a mild to severe gastroenteritis that only rarely be-

Initiation of infection

220

comes generalized and severe infections are most often

Interaction with the intestines

221

Systemic spread and persistence

224

encountered in very young, old or immunologically-

Signs of disease

225

compromised patients. It is generally accepted that

Adults

225

Salmonella gastroenteritis is a zoonotic disease, mainly Calves

226

contracted by consuming large numbers of salmonellas

Diagnosis of salmonellosis

226

in food of animal origin or foods contaminated with

Control measures and vaccination

227

animal products in which the salmonellas have pro-

Vaccination

228

liferated. There is, however, convincing evidence not

Antibiotic therapy

229

only that infection can be a sequel to the consumption

Summary

230

of small doses but that direct person-to-person contact

is involved in many outbreaks.

The disease in cattle differs from the disease in

Introduction

humans, where the majority of cases in the developed

world represent self-limiting intestinal infections, but

Salmonellosis is a collective description of a group of

which occasionally have a high mortality even when

diseases caused by bacteria of the genus Salmonella

treated.

with signs that vary from severe enteric fever to mild

Until recently salmonellosis in animals in the UK

food poisoning. One of the characteristics of Salmonella

was characterized by the large proportion of infec-

is that different serotypes vary in the range of animals

tions caused by the 'host-specific' and 'host-restricted'

that they can infect and cause disease. For example, S.

serotypes: S. choleraesuis in pigs , S. abortusovis in sheep, typhimurium and S. enteritidis have a very broad host S. pullorum and S. gallinarum in poultry, and S. dublin in range and infections with these serotypes have been

cattle. Recently, apart from the latter, these serotypes

associated with virtually all warm-blooded animals.

have virtually disappeared in the UK although they

In contrast, other serotypes have a more limited host

remain important in other parts of the world.

range and this has been interchangeably referred to as

Salmonellas may be carried by animals in the absence

host specificity, restriction or adaptation. The highly

of clinical signs and this is probably the normal situation

host-specific serotypes infect only phylogenetically

in pigs and poultry, although S. enteritidis (phagetype 4) closely-related host species; for example S. typhi infects became associated with clinical disease in the latter.

only human beings, S. abortusovis infects only sheep

The cycle of infection between man and farm animals

and goats and S. gallinarum infects only poultry. Other is often called the ‘ Salmonella cycle’, which is shown in serotypes are predominately associated with disease

Fig. 15.1. Some of the links in the cycle are tentative and

in one species but may also infect a limited number of

the main source of infection for humans is animal prod-

other host species. For example, S. dublin is usually ucts and the principal sources of infection for domestic

associated with cattle, but natural infection by this

animals are other animals of the same species and

serotype may occur in other animals, including human

contaminated feed.

beings and sheep .

Whilst it is accepted that infections in the human

Salmonellosis as a disease of human beings, cattle,

population are usually associated with the consumption

sheep, pigs and poultry is manifested clinically by one

of animal products such as eggs, meats and milk, it is

Wild animals

Imported

(mammals, birds,

human food

insects)

Animal

products

Imported

FARM

MAN

animals

ANIMALS

Animal

waste/slurry

Animal

Domestic

feed

pets

Infected

pasture

Contaminated

water

Imported

Sewage,

protein

sludge and

effluent

Fig. 15.1

The ‘ Salmonella cycle’.

not always realized that it is possible for the farm

strains are auxotrophic, e.g. S. typhi requires tryptophan animal population to become infected by direct contact

for growth, S. dublin requires nicotinic acid and S.

with man or the waste products of man such as sewage

choleraesuis requires cysteine.

and sewage-polluted waters. It is further complicated

The genus is subdivided into serotypes (or serovars),

by the possibility of the spread of disease by wild

which in some classifications are grouped into sub-

animals such as rodents, birds and insects and by the

genera on the basis of their biochemical reactions.

recycling of animal products and wastes from one

Subgenus I contains the ‘typical’ salmonellas isolated *animal species to another. Thus an understanding of sal-*

mainly from warm-blooded animals, and these are the

monellosis and the eventual solution of the current

bacteria which normally cause disease in cattle. The

disease problems may only arise from an interrelated

serotypes (or serovars) within a subgenus cannot, with

study of the disease in all groups of animals and of the

rare exceptions, be distinguished biochemically and dif-

manner in which the bacteria responsible contaminate

ferentiation is on the basis of the possession of somatic

the environment and pass from one animal to another.

(O) antigens and diphasic flagellar (H) antigens in the

Kauffmann–White scheme. The antigenic formula

consists of three parts delimiting the O antigens and the

Classification

H antigens which may occur in two phases. O antigens

have arabic numbers and H antigens have letters in

Strains of the genus Salmonella obey the definition

phase 1 and letters and numerals in phase 2, since

of the family Enterobacteriaceae: they are straight

the same antigens may occasionally occur as phase 1 or *rods, usually motile with peritrichous flagella (S.*

phase 2 in different serotypes. Thus the common cattle

pullorum/gallinarum which cause disease in poultry are pathogen S. dublin has the antigenic formula 1,9,12:gp:-; the non-motile exceptions), facultatively anaerobic,

this denotes that it is distinguished by the presence

ferment glucose usually with the production of gas (S.

of O antigens 1, 9 and 12 and H antigens g and p. It

typhi and some strains of S. dublin are the exceptions) does not have a second phase. The other common cattle

and reduce nitrate to nitrite. Most are prototrophic

pathogen S. typhimurium, which is diphasic, has the

(grow in artificial media with glucose as the sole source

formula 1,4,5,12:i:1,2. When initiated the scheme

of carbon and energy and ammonium ions as a

comprised 44 serotypes and varieties organized in five

nitrogen source). Most host-specific and host-restricted

O groups (A–E), but it has since expanded to include

Table 15.1

The antigenic formulae (Kauffmann–White scheme)

and S. enterica subsp. indica). The names of serotypes of Salmonella serotypes commonly isolated from cattle in the UK.

are not considered as species names and are not printed

in italics. The species name is usually S. enterica and ***Serotype***

Antigens

the serotypes are written, for example, as S. enterica

(sometimes subsp. enterica) serovar typhimurium or

Somatic

Flagella

S. enterica serovar dublin.

Phase 1

Phase 2

S. saintpaul

1,4,[5],12

e,h

1,2

Resistance to antibiotics *(see p. 1038)*

S. derby

1,4,[5],12

f,g

–

S. agona

1,4,12

f,g,s

–

A feature of salmonellosis in cattle during the last four

S. typhimurium

1,4,[5],12

i

1,2

decades has been the development of strains resistant

S. agama

4,12

i

1,6

to one or more antibiotics. This has occurred most com-

S. bredeny

1,4,12,27

l,v

1,7

monly in a relatively small number of phagetypes of S.

S. heidelberg

1,4,[5],12

r

1,2

typhimurium and has been the subject of considerable

S. indiana

1,4,12

z

1,7

debate on the use of antibiotics prophylactically,

S. stanleyville

1,4,[5],12, 27

z4,z23

[1,2]

therapeutically and as growth promoters in calves. It is,

S. montevideo

6,7, 14

g,m,[p],s

[1,2,7]

however, generally accepted that resistance is develop-

S. virchow

6,7

r

1,2

ing under the selective pressure of the indiscriminate

S. infantis

6,7, 14

r

1,5

S. mbandaka

6,7, 14

z

use of antibiotics. This is thought to be particularly true

10

e,n,z15

S. newport

6,8

e,h

1,2

both of the use of mixtures of antimicrobials for therapy

S. enteritidis

1,9,12

g,m

[1,7]

without diagnosis and antimicrobials mixed into animal

S. dublin

1,9,12,[Vi]

g,p

–

feeds. The problem was first recognized in the 1960s

S. panama

1,9,12

l,v

1,5

when the number of antibiotic-resistant strains isolated

S. anatum

3,10

e,h

1,6

from cattle rose from less than 3% at the beginning

S. give

3,10

l,v

1,7

of the decade to more than 60% by 1965 and most of

S. havana

1,13,23

f,g,[s]

–

the isolates belonged to one phagetype (DT29). This

phagetype disappeared at the end of the decade and the

–, flagella antigens occur in first phase only.

proportion of antibiotic-resistant isolates declined, but

[], not always present.

1, 14, 27, phage-determined, not always present.

by the end of the next decade the proportion had again

risen to approximately 60%. This was due to the emer-

gence of two closely related types (DT193 and DT204)

and was associated with the development of chlo-

over 2400 serotypes organized in 48 O groups. The anti-

ramphenicol resistance. Although these two phagetypes

genic formulae of serotypes commonly involved in

also subsequently declined, they were replaced during

disease in cattle are shown in Table 15.1.

the 1980s by the closely related phagetype DT204c.

The names given to the serotypes do not follow the

This phagetype became endemic, particularly amongst *usual rules of nomenclature. The first serotypes to be*

market-purchased calves and in the calf-rearing

identified, such as S. typhi, S. choleraesuis, S. abortuso-trade. It subsequently declined and was replaced by

vis and S. typhimurium, were given names that indi-phagetype DT104. This multiply-resistant phagetype

cated the disease with which they were associated or

also became established in sheep and pigs.

their common animal host, and these names, which have

Strains of S. dublin isolated in the UK, unlike S.

become accepted by clinical microbiologists, continue

typhimurium, have remained comparatively sensitive to

in common use. Serotypes isolated subsequently are

antibiotics. In contrast, strains isolated in Holland,

named after the town or region in which they were first

Belgium, Germany and the USA are usually resistant

isolated, such as S. dublin, S. liverpool, S. crossness and to a number of antibiotics. The reason for the difference

S. bareilly, or are designated solely by their antigenic between British isolates and those from North America

formulae. As an aid to epidemiological studies many of

and Europe has not been explained satisfactorily but is

the commonest serotypes have been further subdivided usually attributed to the selection pressure of antibi-

into phagetypes, biotypes, plasmid types, etc.

otics in animal feed. Presumably the same pressure is

In alternative classifications which are increasingly

exerted in the UK as elsewhere and is equally applied

being used Salmonella is considered as one or two

on S. dublin as on S. typhimurium. Multiply-antibiotic-species (with subspecies S. enterica subsp. enterica, S.

resistant strains of S. dublin resistant to chlorampheni-enterica subsp. salamae, S. enterica subsp. arizonae, S.

col began to be reported in the UK from 1979 and the

enterica subsp. diarizonae, S. enterica subsp. houtenae chloramphenicol resistance was transmissible, although

located on R plasmids distinct from those carrying the

epidemic of S. enteritidis phagetype 4, which replaced S.

same resistance genes in S. typhimurium.

typhimurium as the predominant serotype in poultry

and the human population in the 1980s and 1990s, will

follow the same course. It is always possible, therefore,

Epidemiology of salmonellosis

for the relative importance of S. typhimurium and S.

in cattle

dublin to change and the relative importance of these two serotypes in cattle should not be judged on the

In cattle the disease, which has been recognized for two

basis of isolations over only a few years.

centuries, has a world-wide distribution and has been

Salmonellosis occurs in calves in all months of

associated primarily with S. dublin and S. typhimurium.

the year but there is a peak of disease associated with

Other serotypes infect cattle more sporadically and

all serotypes between October and December, with a

these 'exotic' serotypes have become more common in

low incidence in June and July. This is associated with

the UK during the past 50 years, although during the

calving patterns rather than a true seasonal increase

last 20 years approximately 100 serotypes other than S.

and reflects the distribution of calvings in dairy herds

dublin and S. typhimurium have accounted for only and may change. Similarly, since the source of calves

about 10 per cent of incidents. The number of outbreaks

sold through markets to fattening units is bull calves

caused by the 'exotic' serotypes has declined in the last *from dairy herds and surplus cross-bred heifer calves*

few years. There was a dramatic rise in the incidence of

from dairy and beef units, there is also a seasonal

salmonellosis in cattle between 1960 and 1969 due to an

incidence in fattening units since most outbreaks in

increase in isolations of S. dublin. This was followed by calves occur within a few weeks of purchase from

an equally dramatic decline in both S. dublin and total markets.

incidents and a slight rise in S. typhimurium. Over the The importance of salmonellosis as a disease of

last 20 years the incidence has remained about the same

calves was demonstrated by a survey carried out

and at present S. dublin and S. typhimurium are isolated by researchers at the Institute for Animal Health,

at about the same frequency, with the former being

Compton, and is described in detail later in this chapter

more common in adults and the latter more common in

(p. 219). In this survey samples of faeces from diar-

calves.

rhoeic calves on 45 farms in the south of England were

Recent estimates would suggest that approximately

examined for the presence of a variety of putative

20 per cent of UK cattle herds may be infected with sal-

enteropathogens including salmonellas, rotavirus, calici-

monellas at any one time, although obvious disease is

like viruses, coronavirus, E. coli, cryptosporidia and a much rarer event. Serological surveys have suggested

campylobacters. Salmonellas were isolated from 12 per

a history of infection in up to 75 per cent of UK dairy

cent of diarrhoeic calves in 24 per cent of diarrhoea out-

herds. In the UK approximately 400 to 500 incidents

breaks. In 37 of the outbreaks, samples were taken from

(outbreaks in a single herd) of salmonellosis in cattle

normal calves of similar age to the calves with diarrhoea

are reported annually. This is almost certainly an under-

and a comparison between isolation rates from healthy

estimate since disease outbreaks often are not reported

and diarrhoeic calves was prepared. Salmonellas were

and carriage in the absence of disease is common.

isolated from 12 per cent of diarrhoeic calves compared

The distribution of salmonellas in cattle in other parts

with only 3 per cent of normal calves, thus showing a

of the world is similar to the UK. S. dublin is endemic clear association of the organism with disease. Salmo-in northern Europe and western North America *and S.*

nellas were associated with an outbreak of severe

dublin and S. typhimurium tend to be present in most dysentery on six farms while single cases of typical sal-advanced dairying areas and intensive cattle rearing

monellosis occurred in three outbreaks, and salmonel-

regions. In the rest of the world occurrence is more

las were detected with other agents as part of a

sporadic and serotypes other than S. dublin and S.

diarrhoea problem in two outbreaks where dysentery

typhimurium are commonly involved.

and pyrexia were not recorded. This highlighted the

A feature of Salmonella infections in all species,

problem of arriving at a diagnosis in an outbreak of

however, is a continual fluctuation in the proportions of

enteritis when several organisms may be involved as

the serotypes involved. It is common for a serotype to

part of a disease syndrome. Since salmonellas may be

be introduced to the country and to establish in one or

carried by apparently healthy animals, isolation of the

more species, possibly as the predominant serotype, and

organism, unless it is present in large numbers (>105 per *then to decline without any apparent reason or without*

gramme of faeces), is not proof of the cause of disease.

the intervention of public health or veterinary authori-

There was a correlation between the type of farm and

ties. The predominance of S. hadar in poultry and

the isolation of salmonellas from diarrhoeic calves.

the human population in the 1970s to 1980s is a good

Diarrhoea was more likely to be associated with sal-

example and it may possibly be predicted that the

monellas in units (calf-rearer, multiple-suckler) where

large numbers of calves were purchased from markets,

ronmental contamination the organism was not

although a large number of isolations were also made

isolated from the calves on arrival. Subsequent batches

from calves on dairy farms.

of calves (20 or 30 per batch) were examined on arrival

The source of most outbreaks is probably animal-to-

and three further serotypes, S. typhimurium, S. agama animal contact, although there are distinct differences

and

S.

binza, were isolated .

Salmonellas were

in the epidemiology of the disease in adults and calves,

subsequently isolated from 20 per cent of calves that

and between serotypes. The main sources of infection

developed diarrhoea on the farm.

for cattle herds are probably bought-in cattle, contam-

Both of these surveys amply demonstrate that infec-

inated feed, contaminated animal wastes spread on

tion in a limited number of calves can spread rapidly in

pasture, human sewage sludge spread on pasture, con-

young, susceptible animals subjected to the stress of the

taminated water courses, birds, particularly gulls,

marketing and rearing systems and once established

rodents, insects and human contact. Infected cattle may

it may be difficult to remove the organism from an

excrete up to 108 salmonella/g of faeces and con-

infected environment. It may also be possible that

tamination of the environment in the proximity of other

salmonellas, which cannot be recovered on normal *cattle by excreting animals will obviously be a potent*

bacteriological media may, although non-recoverable,

source of infection. In an outbreak of S. saintpaul infec-remain viable and infective for animals.

tion in two large dairy herds, infection rapidly spread

The manner in which animals in previously unin-

from cows to their calves, presumably by contact with

fected dairy herds become infected is more problemat-

the contaminated environment of calving barns, and all

ical, and the source of infection may vary from serotype

calves that eventually became infected were excreting

to serotype. Most outbreaks are probably associated

salmonellas within 72 hours of birth. Dairy calves may

with the introduction of infected stock or contaminated

thus become infected by contact with their dam, other

feed but polluted water supplies, the spreading of

calves or the contaminated environment. The collection

contaminated animal manures and human sewage

of calves for intensive rearing, which involves transport

sludge on pasture, and contamination of pasture or feed

to markets and dealers' premises, produces an ideal

by scavenging birds may also be involved. Outbreaks environment for dissemination. When salmonellosis have also been described where the probable source of gains a foothold in calves subjected to this treatment it infection was direct human contact. Insects may also be spreads so rapidly that entire herds in rearing premises involved in mechanical transmission since it is difficult may become infected.
to contain salmonellosis outbreaks when animals are There have been several reports that demonstrate the kept in units that are not insect-proofed and similar importance of salmonellas in market-purchased calves difficulties have been described in rearing Salmonella-and in rearing units. One of these was a survey of almost free pigs unless fattening units were rendered fly-proof. 600 market-purchased calves supplied to 11 rearing The epidemiology of S. dublin in dairy herds differs units. Frequent swabbing of the calves indicated that from that of other serotypes. Salmonella dublin has less than 1 per cent were infected when they arrived at a precise geographical distribution. The organism has

the rearing units but within the next six weeks over half

remained established in adult cattle in Wales and in

the calves became infected. The calf units examined

southwest and northwest England. It is thought that

in this survey were cleaned and disinfected between

this distribution may, in part, be due to an association

batches of calves and yet salmonellas could still be

between S. dublin and Fasciola hepatica, although this isolated from the environment after cleaning in over

may be fortuitous and merely indicate that both

half of the units. In a similar study of a calf unit in

are influenced by similar climates and survive better in

Berkshire, UK, which bought calves from local markets,

wet conditions. Salmonella dublin probably persists on 250 calves were examined over a two-year period and

farms in these areas because recovered animals remain

51 were shown to be infected with one of four different

infected and excrete the bacteria in their faeces, either

phagetypes of S. typhimurium. Phagetype DT204c,

continuously or intermittently. Elsewhere in the UK the

which was multiply-antibiotic-resistant, was isolated

disease is predominantly one of calves in calf-rearing *at the beginning of the survey. This was eventually*

units rather than adults and it is introduced to the units

removed by destocking and a rigid hygiene programme.

with the introduction of infected animals.

The calf units were steam-cleaned, after which S.

typhimurium DT204c was still isolated from environ-

mental samples. Following further steam-cleaning and

The carrier state

washing with disinfectant the organism was no longer

detectable in the environment but was detectable

Animals which excrete salmonellas continuously

from the next batch of calves introduced to the units.

('active carriers'), usually in concentrations of greater

Although it is not certain that this was the result of envi-

than 105/g of faeces, can be detected by bacteriological

examination which will also detect 'passive carriers',

particularly from field studies, would favour the latent

animals that ingest salmonellas in their feed and

carrier hypothesis.

pass them in their faeces without actual infection of

In contrast to S. dublin, infection with other serotypes the intestine or the mesenteric lymph nodes. When

does not appear to result in active or latent carriers.

removed from an infected environment these latter

Adult cattle usually excrete for a maximum of a few

animals stop excreting. Active excretion is usually a

weeks following infection and excretion that is detected

sequel to clinical enteritis or septicaemia and infected

for longer periods probably reflects recontamination

animals may excrete for many years and perhaps for

from the environment, although the establishment of

life. It may also develop in animals that have not shown

some 'exotic' serotypes such as S. saintpaul for up to a clinical signs, although this probably occurs only in

year has been reported. Similarly, S. saintpaul has been cases of concurrent fascioliasis. In such cattle, S. dublin shown to be retained in the tissues of calves for up to

is characteristically present in the gall-bladder and

eight weeks after excretion had apparently ceased.

alimentary contents without necessarily colonizing the

rest of the animal. However, although active (persist-

Pathogenesis

ent) excretors are an obvious source of infection for *other cattle, and although the source of calf infection is*

An overview of the main stages involved in Salmonella

assumed to be adult cattle, field studies have shown that

pathogenesis is presented in Fig. 15.2.

the majority of calves infected with S. dublin are home-bred on farms where there is no clinical evidence of

Initiation of infection

adult salmonellosis. This is characteristic of the disease

and has led to a search for other sources of infection.

Cattle are probably infected with salmonellas by the

Many of the infections occur in closed herds; other

oral route, although respiratory and conjunctival infec-

sources of infection such as feed are not appropriate

tion may also occur. The dose required to initiate infec-

to a 'host-restricted' serotype such as S. dublin and tion is thought to be high and will be dependent on the

although contaminated streams may be implicated, this

age, immunity and dietary status of the animal and vir-

gap in the epidemiology is usually explained by the exis-

ulence of the infecting strain. However, it is probable

tence of 'latent carriers'. These are animals that have

that animals are infected naturally by much smaller *salmonellas somewhere in their tissues or alimentary*

doses since factors such as concurrent parasitism (par-

tract but only rarely excrete the organisms in their

ticularly fascioliosis), ketosis, metritis, mastitis, cystitis, faeces. It has been suggested that infection with S.

pneumonia, viral infection, dietary changes, pregnancy,

dublin is mainly latent, but is activated by stress,

food and water deprivation and other stress factors

particularly at parturition, and the birth of congenitally

such as freezing, wet weather or worming may lead to

infected calves to latent carriers or to cows that excrete

increased susceptibility. In calves, colostrum, whether

S. dublin would only intermittently explain the occur-normal or immune, is particularly important and

rence of disease in calves on farms where searches for

animals that have either not received colostrum or have

active carriers are unsuccessful. It is possible to detect

received insufficient amounts are particularly suscepti-

greater numbers of excretors by bacteriological exami-

ble. Natural infections have been described where

nation of faeces taken at calving and surveys have

animals may have been infected with very small doses, *revealed animals which, although found to be infected*

particularly from infected feed. In one such outbreak

with S. dublin at necropsy, were not detected as carri-dairy cattle were infected from a component of feed

ers by previous faecal sampling. It has not proved pos-

containing less than three S. mbandaka/g and the

sible, however, to create such animals experimentally

infection spread to their calves. The experimental infec-

and serological tests for their detection have been

tious oral dose for calves has been variously estimated

singularly unsuccessful.

as between 105 and 1011 organisms, although doses in

Serum agglutination tests (SAT) may detect a

excess of 108 are normally required. The dose for adult

proportion of actively infected animals but they do not

cattle is approximately 1011 orally and greater than 108

detect latent carriers and so far other immunological

intravenously.

tests are equally unsuccessful, although they may be

Gastric acidity is responsible for eliminating a large

useful in detecting active carriers and infected herds.

proportion of ingested organisms in both monogastric

Delayed hypersensitivity skin tests can distinguish sys-

animals and ruminants. In ruminants, survival of sal-

temically infected animals but they may, unfortunately,

monellas is further reduced by the high concentration

also detect convalescent and recovered animals. It

of short-chain fatty acids in rumen fluid and conse-

is possible that many unexplained outbreaks may be the

quently salmonellas disappear rapidly from the rumen

result of human contact or extended survival of the

of regularly fed cattle. Factors which alter the acidity and

organism in the environment, although most evidence,

composition of rumen fluid, such as starvation and

Bacterial virulence

Host defence

properties

Ingestion

Survival in

Acid adaptation

Gastric acid, normal flora

stomach/rumen

Fimbriae

Colonisation of intestinal

Mucus, intestinal motility

lipopolysaccharide

epithelium

Fluid secretion,

TTSS-1 secreted

Invasion of intestinal

inflammation phagocytosis,

effector proteins

epithelium

complement activation

TTSS-2 secreted

Evasion of host

Macrophages, neutrophils

effector proteins

defences

TTSS-1

secreted

Induction of

Systemic

Iron-binding proteins

effector

enteritis

spread

proteins

Genes not

identified

TTSS-2, virulence plasmid,

Systemic

iron-binding proteins, SodC,

Pyrexic response

Fig. 15.2

A tentative overview of the

salmonellosis

endotoxin

pathogenesis of salmonellosis. TTSS =

For description see pp. 220–25

type three protein secretory system.

refeeding, achlorhydria or administration of antacid,

the intestines may also be inhibitory to infection and *increase susceptibility to infection. Salmonellas that*

the absence of a fully developed intestinal flora may

survive passage through the stomach(s) will probably

in part account for the comparative lack of resistance

be phenotypically altered. Experiments in vitro have

of young animals to salmonellosis. Despite these host

shown that exposure to low pH and/or short-chain fatty

defences, salmonellas are able to associate rapidly with

acids results in the induction of expression of up to 50

the intestinal epithelial monolayer. Bacterial motility

proteins. This correlates to increased bacterial resistance

and chemotaxis may aid this process by allowing

to further exposure to low pH. Several bacterial genetic

the bacteria to move more freely within the intestinal

loci have been shown to regulate this acid-

lumen, to sense the presence of the epithelial mono-

adaptation response. Three of these genetic loci, rpoS, layer and to penetrate the overlying mucus layer.

fur and phoP/phoQ, have previously been implicated in The interaction between salmonellas and the intes-regulating virulence in the mouse model of systemic

tinal mucosa is highly dynamic. Salmonellas are rapidly

salmonellosis and mutation of several of the other genes *able to mediate their own uptake into epithelial cells*

has also suggested a link between acid adaptation,

and this is associated with a dramatic, but temporary,

survival within murine macrophages and virulence in

'ruffling' of the apical membrane of the epithelial cell

mice. To date, there have been no studies on the effect of

at the site of bacterial entry (Figs 15.3 and 15.4). The

acid adaptation on pathogenesis in bovine salmonellosis.

main initial site of entry is probably the distal ileum.

This may be because the intestinal contents are held

within the distal ileum for some time before entry into

Interaction with the intestines

the caecum and it may also be partly due to the rela-

After passage through the stomach(s), surviving

tively high number of M cells (specialized epithelial

salmonellas must be able to resist several host innate

cells overlying the Peyer's patches) in the distal ileum.

defences, including lysozyme and lactoferrin, and to

In mice M cells are interspersed between enterocytes

prevent their removal from the intestines in the normal

and salmonellas can clearly be seen preferentially *movement of food by peristalsis. The bacterial flora of*

interacting with the M cells. In calves, M cells form a

Fig. 15.3

Scanning electron micrograph of uninfected bovine

ileum showing a group of typical M cells (M) on a domed villus.

The cells have characteristic microfolds with a central area of short microvilli.

Fig. 15.5

Scanning electron micrograph of uninfected bovine

ileum showing the normal morphology of villi.

homogeneous monolayer over the dome villi (villi asso-

ciated with the Peyer's patches) and so the relative *interaction of salmonellas with M cells and enterocytes is more difficult to assess. It appears, however, that salmonellas will initially interact with the M cells (within 10 minutes of direct inoculation into the distal ileum) and are not taken up by the enterocytes until slightly later (approximately 20 minutes after inoculation). The mechanism of Salmonella invasion has been extensively studied. The bacterial genes involved in invasion are clustered together at one site on the chromosome, which has been named Salmonella pathogenicity island 1 (SPI-1). SPI-1 encodes a type 3 protein secretion system (TTSS-1: so called after comparison to two previously described secretion systems), regulatory*

Fig. 15.4

Scanning electron micrograph of bovine ileum after

genes and several effector proteins which are secreted

infection with S. typhimurium. The peripheral microfolds of by TTSS-1. TTSS-1 can be viewed as a protein-the M cells are ruffled and bacteria (arrowheads) are being

aceous microsyringe that spans the bacterial inner and

engulfed by the membrane ruffles.

outer membranes. The main function of TTSS-1 is the

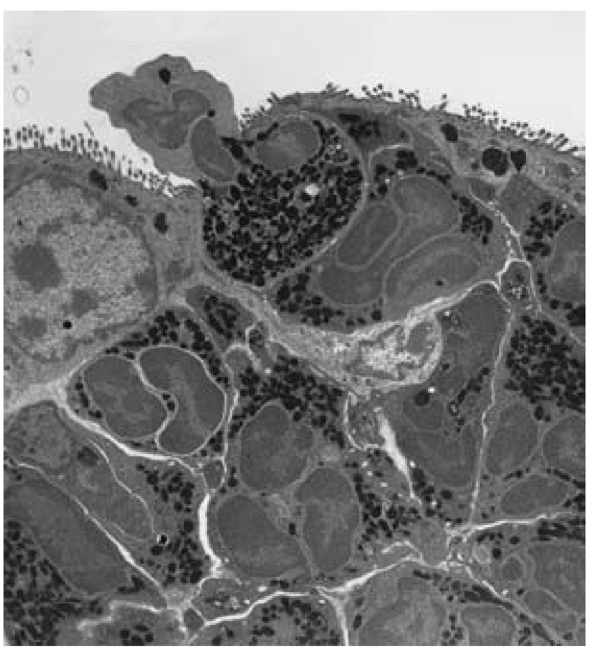

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Fig. 15.7

Transmission electron micrograph of dome villus

after infection with S. typhimurium. There are a large number of PMN leucocytes, one of which appears to be crossing the

epithelial monolayer.

to several strains can be quantified in a single animal,

Fig. 15.6

Scanning electron micrograph of bovine ileum after

thus dramatically reducing the number of animals

infection with S. typhimurium. The villi are shortened and there required for such experiments. In infected ileal loops

is an abnormal extrusion of enterocytes.

there is an increase in the rate of epithelial cell

shedding, which could be viewed either as a bacterial

cytotoxic activity, allowing further invasion, or as a host

defence mechanism to eliminate infected cells rapidly.

co-ordinated secretion of specific bacterial proteins, not

An inflammatory response is initiated in the

only out of the bacterial cell, but also directly into the

intestines by the production of cytokines and other

target epithelial cell. The translocated proteins interfere

pro-inflammatory mediators by infected host cells. It is

with specific components of the host cell signalling

unclear whether this is a generalized host response to
pathways and cytoskeleton, resulting in bacterial
invading bacteria, which will release pro-inflammatory
uptake and potentially influencing the subsequent
molecules such as endotoxin, or if it is the result of
induction of enteropathogenic responses.
the direct action of specific bacterial proteins acting on
Infection of the intestines by Salmonella may result
epithelial cells without necessarily requiring bacterial
in several pathological changes (Figs 15.5–15.7). These
invasion. It results in a large influx of inflammatory
can be studied using the calf ligated ileal loop model,
cells, particularly polymorphonuclear (PMN) leuco-
which has been developed by researchers at the Insti-
cytes, into the intestinal mucosa and lumen. However,
tute for Animal Health, Compton. Results from this
salmonellas are relatively resistant to the bactericidal
model correlate well with those from orally-inoculated
activity of PMN leucocytes and their influx may cause
animals. Short sections of the ileum are sealed in situ
considerable damage to the mucosa by disrupting

by surgical silk to form individual loops and each loop
cellular junctions and releasing the contents of their
is directly inoculated with up to 109 salmonellas. This is
granules extracellularly. The most striking pathological
an appropriate inoculum size, since faeces from infected
change is the increase in net fluid secretion by infected
calves may contain up to 108 salmonellas/g. The main
mucosa. By 12 hours after inoculation with either S.
advantage of this model is that pathological responses
typhimurium or S. dublin, as much as 30 to 40 ml of fluid

may have accumulated in a 6 cm ligated ileal loop. This
in orally inoculated calves. The mechanisms of bacter-
fluid secretion may initiate the physiological response
ial spread from the epithelial monolayer and the way in
of the infected host to eliminate infecting bacteria, but
which intracellular persistence contributes to enteritis
it will also be advantageous to the bacteria, because it
are not known. Several of the host responses to inva-
mediates their dispersal into the environment.
sive bacteria may contribute to enteritis. For example,

This characteristic secretory response has led many

loss of epithelial cells will reduce the absorptive capac-

investigators to look for enterotoxin activity associated

ity of the intestines; the associated increase in crypt cell

with salmonellas. Despite numerous reports of entero-

mitosis will alter electrolyte balance, and hence water

toxic activity in various extracts from salmonellas and

movements, and the PMN leucocyte influx and associ-

using various enterotoxin assays, there is no conclusive

ated vasodilation and mucosal damage may alter

evidence that Salmonella produce a classical entero-

absorptive function, as well as allowing further bacter-

toxin. A Salmonella gene has been cloned on the basis ial spread. The relative importance of these host

of its homology to the cholera toxin gene from Vibrio

responses compared to the direct action of bacterial

cholerae. However, mutation of this gene in either S.

proteins, such as SopB, on epithelial cell function is not

typhimurium or S. dublin did not reduce fluid secretion known.

into infected ligated ileal loops in calves. Despite the

lack of evidence that Salmonellae produce a classical

Systemic spread and persistence

enterotoxin, there is growing evidence that they do

produce proteins with enterotoxin activity, but which

Salmonellas are able to spread rapidly to systemic sites,

lack a receptor-binding domain and therefore require

particularly the liver, lungs and spleen. In experimen-

viable bacteria to translocate them into target host cells.

tally infected calves this may occur within 6 hours after

The best characterized of these proteins is called SopB,

oral inoculation. The most probable route of spread is

and it is dependent on TTSS-1 for translocation into

via mesenteric lymph nodes, the efferent lymph drain-

epithelial cells. SopB affects inositol phosphate eukary-

ing these nodes, and subsequent entry into the general

otic cell signalling, which may lead to interference with

circulation via the thoracic duct. Cannulation of

chloride channel function and hence affect movement

efferent lymphatic vessels draining bovine mesenteric

of electrolytes and water. Mutation of SopB in S. dublin

lymph nodes has demonstrated that S. dublin leaves the significantly reduces fluid secretion and the influx of *nodes in efferent lymph. In general, the growth of S.*

PMN leucocytes in calf ligated ileal loops. SopB is

typhimurium and S. dublin in the bovine liver and located within a small Salmonella pathogenicity island spleen appears to be relatively well controlled and in

called SPI-5 and mutation of the other genes within

calves infected experimentally it is unusual to recover

SPI-5 also reduces enteropathogenic responses in

more than 105 bacteria/g of tissue, even at the peak of

bovine ligated ileal loops, although the biochemical

disease. However, the bovine infection model most

basis of this is not known.

commonly used (four-week-old Friesian calves) usually

Elucidation of bacterial factors involved in the inter-

results in a predominantly enteric disease and may not

action of Salmonella with the intestines is advancing be an appropriate model for the systemic disease occur-rapidly, but there is still a lack of knowledge as to how

ring in some very young calves or adult cattle. The

Salmonella induces enteritis. In addition to the intimate pathogenesis of systemic disease has been mainly

interaction with epithelial cells, bacteria also spread

studied in mice and the results extrapolated to other *rapidly to the lamina propria and mesenteric lymph*

animal species. Natural resistance of mice to infection

nodes, as well as being returned to the gut lumen by

with Salmonella is controlled by a genetic locus called extrusion of infected epithelial cells. A significant pro-Nramp 1, which affects the ability of macrophages to

portion of luminal bacteria appear not to invade during

control intracellular bacterial growth in the reticuloen-

the initial stages of infection. The presence of high

dothelial organs during the early stages of infection.

numbers of luminal bacteria may extend the symptoms

Resistance to salmonellosis in cattle may also be under

of enteritis by providing a continual source of bacteria

genetic control and several researchers have com-

to interact with epithelial cells. In addition, many of

mented on the variations in susceptibility to salmonel-

them will be expelled in the copious diarrhoea associ-

losis amongst breeds of cattle. For example, Friesian

ated with disease, and are therefore vital to bacterial

calves are thought to be less susceptible than Channel

spread between animals. Salmonellas that have invaded

Island calves, although the genetic basis of this is not *the lamina propria and beyond may also contribute*

known. A homologue of Nramp 1 has been identified in

to enteritis. For example, S. dublin carrying mutations cattle, but its contribution to susceptibility to salmonel-in TTSS-2, a second TTSS which is not required for

losis is not yet clear.

invasion of bovine intestines but is required for sub-

Several bacterial factors involved in systemic spread

sequent intracellular persistence, are highly attenuated

and/or persistence have been identified. A variety of

Salmonella mutants that are unable to persist within

Systemic spread and persistence may have several

murine macrophages in vitro have reduced virulence in pathological consequences. Release of endotoxin in sys-mice and several bacterial genetic loci influencing

temic organs may result in haemorrhages, leucopenia,

persistence, including those encoding TTSS-2 and the

leucocytosis, hypotension, hypoglycaemia and shock.

two component transcription regulators PhoP/PhoQ

Mutation of endotoxin to make it less inflamma-

have been identified. Mutation of one such gene, slyA, tory reduces the mortality in mice infected with S.

is highly attenuating in mice but only slightly attenuat-

typhimurium without affecting the net rate of bacterial ing in calves, which highlights the differences in patho-growth in the liver and spleen. This suggests that fatal

genesis between these infection models. In contrast,

systemic infection, at least in mice, is due to the inflam-

the spv (Salmonella plasmid virulence) genetic locus is matory response of the host to endotoxin. Bacterial

required for systemic virulence in both mice and cattle.

spread to systemic sites may prolong enteritis by allow-

This locus is located on a high molecular weight

ing continual reinfection of the intestines via the biliary

plasmid, called the virulence plasmid, which is present

system and may also lead to systemic complications

in many Salmonella serotypes. The existence of large

such as pneumonia or abortion. Abortion may occur

molecular weight plasmids in many of the more impor-

before, during, after or even in the absence of enteric

tant serotypes of Salmonella, including S. typhimurium, symptoms. The placenta becomes infected and the

S. dublin, S. choleraesuis and S. enteritidis (but interest-subsequent rapid bacterial multiplication results in a

ingly not in S. typhi which causes the severe disease pyrexic response, severe damage to the placenta and

typhoid fever in humans), has been described for *possible infection and death of the fetus in utero or the more than 20 years. The plasmid harboured is charac-birth of infected calves. Systemic spread may also lead*

teristic of the serotype and they were originally

to the development of the carrier state, characterized

called 'serotype-specific plasmids'. Naturally-occurring

by the continual faecal excretion of salmonellas.

plasmid-free strains and strains from which the plasmid

has been removed are avirulent in the mouse model

Signs of disease

of salmonellosis. In calves infected experimentally,

plasmid-containing strains cause enteritis and a

Adults

generalized systemic infection while plasmid-free

strains induce enteritis in the absence of the general-

The disease in adult cattle is usually sporadic, although

ized infection. It thus appears that plasmid genes are

S. dublin has become endemic in some areas of the

involved in the ability of salmonellas to proliferate

country and acute and subacute forms are recognized.

within the host and that in cattle both plasmid and

In the characteristically severe form of the disease *chromosomal genes are essential for the full expression*

produced by S. dublin in adult cattle the onset is

of the disease. The virulence plasmid may not be

usually sudden. Fever, dullness, anorexia and abruptly

carried by all isolates of a given serotype, particularly

depressed milk yield at first associated with firm faeces,

S. typhimurium, and this may explain, in part, the

which may contain blood, are rapidly followed by

variation in the degree of severity of salmonellosis

severe diarrhoea. The faeces often become watery and

observed in the field where some outbreaks involve

contain large numbers of salmonellas (up to 108/g). The

enteritis only whilst in others this develops into

fever usually persists for several days, then animals

systemic infection.

rapidly become cold and recumbent and death, which

The mechanism by which the spv genes contribute to

may be preceded by abortion, occurs in approximately

systemic virulence is not known, although one study

75 per cent of untreated animals between four and

suggests the locus promotes bacterial replication in *seven days from the onset of clinical signs. In some*

vivo. The virulence plasmid does not contribute to

animals the disease is more protracted and cattle may

persistence within macrophages in vitro and although

become emaciated and dehydrated and show signs of

carriage of the virulence plasmid increases the lysis

abdominal pain. A milder disease, characterized by

of macrophages during Salmonella infection in vitro, diarrhoea and abortion, or abortion in the absence of

this is not attributable to the spv locus. The lysis

other clinical signs, from which animals usually recover,

of macrophages during Salmonella infections in vivo also occurs. A similar disease is produced by other

has received little study and the relative contributions

serotypes including S. typhimurium, although in these of macrophage persistence and lysis to pathogenesis

cases abortion is a less frequent event. Survivors of S.

need to be assessed. The TTSS-2-dependent secreted

dublin infections often remain as carriers, possibly for effector proteins are thought to promote bacterial net

life, while infection with other serotypes seldom results

growth in vivo by two distinct mechanisms: firstly by in the carrier state although excretion of types such as promoting bacterial replication rates; and secondly by

S. saintpaul for up to two years after infection has been preventing killing of bacteria by macrophages.

reported.

Calves

usually excrete large numbers of organisms in their

faeces and determination of viable counts, rather than

In calves, disease usually occurs between two and six

enrichment cultures, should be used (see below). For

weeks after birth. Characteristically, calves become dull

this reason faecal samples rather than swabs should be

and anorexic and develop a fever. Diarrhoea follows,

taken and these should obviously be obtained before

which in young calves involves the excretion of faeces

administration of antibiotics. It may also be possible to

with the colour and consistency of putty. This may be

isolate the organism from oral secretions and by blood

bloodstained and may contain fibrin and mucus. Even-

culture, although these are less reliable than faeces cul-

tually, the faeces become dark brown and watery with *tures and must be taken with care to avoid contamina-*

an offensive odour. More rarely the faeces are heavily

tion. Animals that have died of salmonellosis usually

bloodstained, become stringy due to the presence of

have large numbers of salmonellas distributed through-

undigested milk and pseudomembrane formation and

out their tissues and samples of spleen, liver, hepatic,

may contain shreds of necrotic intestinal mucosae. In

mediastinal and bronchial lymph nodes may yield

older calves the faeces are usually watery, dark brown

counts in excess of 106 organisms/g. Similar concentra-

and offensive. The calves become very weak and dehy-

tions may also be present in the wall and contents of

drated and death usually occurs after five to seven days

the ileum, caecum, colon and associated lymph nodes.

of illness in untreated individuals.

Samples should be taken from the gut and internal

The disease is very variable; in some calves, especially

organs in order to distinguish animals that have died of

those two to three days old, bacteraemia and septi-

enteritis without septicaemia. Samples of fetal fluids, *caemia occur and the animals collapse and die without*

vaginal mucus and cotyledons should be taken from

diarrhoea. In other animals the disease may be so mild

animals that have aborted. Counts will again give a

as to pass unnoticed or may be associated with diar-

more reliable result since the cotyledons from animals

rhoea in the absence of systemic disease. Diarrhoea

that have aborted due to S. dublin infection will usually may be prolonged in some calves, which may eventu-contain between 108 and 1010 organisms/g.

ally die as a result of dehydration, electrolyte loss and

Identification of carriers by bacteriological examina-

acid–base imbalance. In both calves and adults systemic

tion is more difficult and an attempt must be made to

infection may lead to complications such as pneumonia,

distinguish ‘active carriers’ (persistent excretors) from

meningitis and osteitis; polyarthritis and gangrene may

‘passive’ carriers and ‘latent carriers’ (intermittent

occur when the disease has been prolonged. Mortality

excretors). Faeces samples are more reliable than

from acute salmonellosis may be as high as 70 per

swabs and should distinguish persistent excretors whose *cent and all calves in a herd may become infected.*

faeces usually contain in excess of 105 salmonellas/g.

Recovered calves do not normally appear to become

Animals should not be assumed to be excretors on the

carriers of either S. dublin, S. typhimurium or the exotic basis of one isolation, nor should they be considered to

serotypes and consequently infected calves do not grow

be free of infection unless at least three negative faecal

into infected adults. However, the disease is often slow

samples have been obtained. Even in this latter case

to resolve and salmonellas have been isolated from

'latent carriers' and animals that will eventually clear

calves up to six months after their initial infection. The

the infection, and yet are still harbouring salmonellas,

disease produced by different serotypes in calves is

will be missed. There may be an advantage in taking

usually similar, although the peak incidence of disease

samples from adults at calving although care must still

and mortality with S. dublin is at four weeks of age

be observed to distinguish 'passive carriers'. Tradition-

compared with three weeks for S. typhimurium. Calves *ally, samples of gall-bladder or bile have been taken*

from dams infected with S. dublin may be infected from to identify carriers at slaughter. Unfortunately, these

birth and these are particularly likely to succumb to

may not always contain salmonellas unless animals are

septicaemia rather than enteritis.

infested concurrently with F. hepatica and a variety of tissues including alimentary contents and superficial

lymph nodes need to be examined. It may be possible

Diagnosis of salmonellosis

to isolate salmonellas from the walls of the omasum,

abomasum and rumen or from lymph nodes such as the

It will be apparent from the description above that diag-

bronchial node, prescapular node and retropharyngeal

nosis of salmonellosis presents several difficulties. The

node when all other tissues are negative. Similarly, sal-

clinical signs and findings at post-mortem examination

monellas have only very rarely been isolated from the

are not unique to salmonellosis and although a tenta-

tonsil although this has been the preferred site for some

tive diagnosis may be made this should be confirmed in

investigators. Identification of infected herds may be *diseased animals or at necropsy by isolation of the*

achieved by faecal samples but this may present similar

organism. Diseased animals showing signs of enteritis

difficulties to identifying individual infected animals,

particularly in the case of S. dublin. A simple, less insertion sequence), DNA fingerprinting (RFLP:

expensive and probably more reliable method is to take

restriction fragment length polymorphism) and AFLP

samples of slurry where this is available.

(amplified fragment length polymorphism where DNA

A variety of enrichment techniques and isolation

fragments are amplified by PCR). Although used for

media are available for the cultivation of salmonellas.

research purposes, a phagetyping scheme for S. dublin

They rely on promoting the selective growth of salmo-

is not available in the UK (recent studies identified

nellas, whilst inhibiting the growth of contaminants, and

26 groups of S. dublin by phagetyping but more than

identification on the basis of colony morphology and

50 per cent belonged to one group) and this serotype

biochemical reactions. The choice of media depends
is subdivided into biotypes. Unfortunately, although
upon the environment from which the organism must
seven distinct, stable biotypes have been identified, the
be isolated and often depends upon the subjective
majority (approximately 75 per cent) of strains isolated
choice of bacteriologists who specialize in Salmonella
in the UK belong to the same biotype and the scheme
isolation. In general, a range of liquid enrichment
is of little use in epidemiological investigations.
media and the use of at least two types of solid isola-
A number of serological techniques are also used in
tion media are necessary to guarantee the isolation of
an attempt to identify Salmonella- infected animals.
the majority of serotypes. Enrichment media depend
Unfortunately, no single test has proved useful in dis-
upon allowing salmonellas to grow, albeit sometimes in
tinguishing all infected animals, some of which do not
an inhibited manner, whilst suppressing other bacteria
mount an antibody response, and all suffer from an
through the action of chemicals, dyes, antibiotics and

inability to distinguish infected animals from others

enhanced incubation temperature. In common use are

which, although previously infected, no longer harbour

media containing sodium selenite or tetrathionate and

the organism. Various techniques such as ELISA

dyes such as brilliant green or malachite green to which

have been developed but they are usually no more suc-

salmonellas are relatively resistant.

cessful than more traditional methods and are not

After enrichment in liquid culture, colonies of

in routine use.

Salmonella are isolated on solid selective agars such as MacConkey, Brilliant Green, Deoxycholate citrate,

EF-18, Rambach, Hektoen, Bismuth sulphite and

Control measures and vaccination

Salmonella–Shigella. These rely on the resistance of

salmonellas to a variety of antibiotics, bile salts and

Attempts to control salmonellosis in cattle have

dyes, which inhibit other bacteria, and lack of fermen-

involved the use of strict hygiene measures, antibiotics

tation of sugars such as lactose and sucrose to differen-

and vaccination, either singly or in combination. Most

tiate colonies of Salmonella from other bacteria which of the control measures are obvious from the discussion

grow on the media despite the presence of inhibitors.

presented above and the role of antibiotics and vacci-

More recent techniques include the use of immuno-

nation is described below. To prevent the introduction

magnetic separation (IMS) and PCR (polymerase chain

of salmonellosis to herds it is necessary to provide

reaction) or fluorescence PCR, but the use of these is

animals with uncontaminated feed and water, to control

usually confined to research laboratories. Once iso-

ingress of rodents and birds and limit human contact.

lated, the identification of salmonellas to genus level is

When adult stock have to be 'bought in' these should

carried out on the basis of biochemical reactions for

be quarantined and examined bacteriologically. Exac-

which a variety of rapid kits are available. Further

erbating factors such as ketosis and liver fluke infesta-

identification is carried out by slide and tube aggluti-

tion should be controlled and particular care should be *nation tests, which define the serotypes according to*

taken in maintaining the health and hygiene of animals

the Kauffmann–White scheme. Since a large number of

at calving. This should include the use of individual

differential sera are required this is usually the province

calving boxes and thorough cleaning between animals.

of dedicated laboratories.

Calves should be encouraged to absorb sufficient

Important serotypes such as S. typhimurium and S.

colostrum. To prevent acquisition of infection in calf-

enteritidis may be further subdivided by phagetyping

rearing units only good quality calves from herds of

(there are more than 200 phagetypes of S. typhimurium

known health history should be purchased and strict

but one or two phagetypes predominate in the UK at

hygiene should be observed during feeding and clean-

any one time, although 20 to 30 are usually present),

ing. Units should be run on an all-in, all-out basis and

plasmid analysis or a variety of molecular techniques

calf houses should be thoroughly cleaned (preferably

including ribotyping (rRNA gene restriction patterns), *by steam-cleaning, disinfection or fumigation) between*

PFGE (pulse-field gel electrophoresis), IS200 typing (a

batches. In the event of a disease outbreak, affected

method of comparing restriction patterns of DNA after

animals should be quarantined and restrictions should

hybridization to a probe to a unique (IS200) Salmonella

be placed on the movement of susceptible stock.

Human contact with infected animals should be

allowed to graze pasture dressed with slurry for at

restricted and strict hygiene should be observed when

least six months after spreading.

moving between groups. During the course of an exten-

(4)

The principal danger to cattle occurs when fresh

sive outbreak of salmonellosis due to S. saintpaul in two unstored slurry, particularly pig slurry or poultry

large dairy herds many methods to control infections

manure, must be applied to pasture. This danger

and reduce mortality were attempted. These included

can be reduced by using low application rates and *the use of an emergency vaccine, which had no effect*

by leaving pasture as long as possible before

on mortality but reduced the duration of faecal excre-

grazing.

tion, and treatment with oxytetracycline and ampicillin,

(5)

Consideration should be given to mechanical

which reduced mortality and the number of persistent

separation of slurry. This produces a solid frac-

excretors. Other measures included restriction of move-

tion that readily composts and a liquid fraction

ment of stock and personnel, the use of impermeable

in which salmonellas die off rapidly.

clothing and disinfectant sprays, removal of predispos-

(6)

Slurry should not be spread by equipment which

ing factors such as dietary imbalance, reduction of

involves the production of spray.

stocking densities, segregation of susceptible animals,

These recommendations were designed to reduce the

prompt antibiotic treatment of sick animals and *risk of infections from animal wastes but they may be*

removal of ‘persistent excretors’. These measures were

applied, with minor modifications, to the disposal of

designed to reduce the level of environmental contami-

human sewage sludge on agricultural land. However,

nation. This is primarily due to contamination with the

water authorities disposing of sewage sludge produce

faeces of diarrhoeic animals and ‘persistent excretors’

their own codes of practice that should be followed.

from which calves may be infected either at birth,

particularly when communal calving facilities are

used, or when housed in the same buildings as adults.

Vaccination *(see p. 1006)*

Once infected, calves may excrete such large numbers

of organisms that less than 0.1 g of faeces may contain

Prevention of salmonellosis by vaccination has been

a lethal dose for other calves. Thus any measure

attempted since the late nineteenth century. There has

that reduces environmental contamination may help

been considerable scientific debate on the relative

to break the cycle of infection. Methods that appeared *importance of humoral and cell-mediated immunity,*

successful in this particular outbreak were prompt

but it is now generally agreed that solid immunity prob-

antibiotic treatment of sick calves, removal of adult

ably depends on both humoral and cellular responses.

carriers, reduction in stocking densities and segregation

Although the humoral response is not totally protective

of susceptible animals.

it plays an important role in the suppression of infec-

Salmonellosis may be spread from farm to farm and

tion in its early stages. However, a cellular response is

amongst cattle on infected premises by the disposal or

probably required for complete elimination of the

use of animal wastes on pastures as a fertilizer. The

organism. In consequence, both live and killed vaccines

number of organisms contained in such materials is

have been used for the prevention of salmonellosis in

usually low and the risk can be reduced to an accept-

cattle and attempts have been made to protect calves

able level if sensible restrictions are observed. The

actively and passively by transfer of maternal antibody *following code of practice designed to reduce the*

in colostrum. In the UK only an inactivated vaccine is

number of salmonellas should be followed:

available. The inactivated vaccine, which is licensed for

use in both adults and calves, is a formalin-killed prepa-

(1)

When possible, slurry should be spread on arable

ration of S. dublin and S. typhimurium. This vaccine has land or land used for conservation. Salmonellas do

been the subject of recent field and experimental tests

not survive for long enough on grass to be a

and has been shown to be effective when used to induce

danger in hay, nor do they survive efficient silage

antibodies in adults, which could be transferred to

making.

calves in colostrum.

(2)

Composted waste may safely be spread on pasture

The majority of recent attempts at developing new

to be grazed by animals but slurry should be

vaccines have utilized live, attenuated Salmonella stored for at least one month prior to spreading.

strains. These have either been naturally occurring

(3)

Pasture treated with stored slurry should not be

avirulent strains, laboratory-derived strains, sponta-

grazed for at least one month after spreading. If

neous undefined mutants or, more recently, geneti-

the slurry cannot be stored, this interval between

cally-manipulated strains. Amongst the first of these,

spreading and grazing should be extended. In

originally produced in the USA, were strains in which

addition, since young animals may be more

mutations were introduced into genes encoding

susceptible to salmonellosis they should not be

enzymes in aromatic amino acid biosynthesis pathways

known as Aro deletants or Aro strains. Such strains

are responsible for the delivery of effector proteins into

are unable to synthesize chorismate from which p-

host cells, which influence Salmonella intestinal inva-aminobenzoic acid, a precursor of folate, and dihydrox-

sion, induction of inflammation, fluid secretion, bacterial

ybenzoate, a precursor of the iron-binding protein

replication and avoidance of host defence mechanisms

enterochelin, are produced. In the absence of p-

(vide infra). Targeted mutagenesis in Salmonella that aminobenzoic acid and dihydroxybenzoate, which are

results in the disruption of genes influencing Salmonella-

not found in mammalian tissues, they will not grow. Aro

induced inflammatory responses and net bacterial

strains of S. dublin and S. typhimurium have been pro-growth, but not invasion, can optimise the phenotype of

duced and tested experimentally in calves. They induce

vaccine strains such that they remain invasive, and thus

good protection when administered orally or parenter-

immunogenic, but not virulent.

ally, are claimed to cross-protect against challenge with

Since calves may become infected within the first

heterologous serotypes and are claimed to be safe. They

few days after birth and the peak of mortality occurs

do not establish in the host, do not cause side-effects and

between three and four weeks of age, passive protec-

are genetically stable. Their only disadvantages are that *tion by vaccination of adult animals would appear to be not all constructs are equally protective and that they the ideal way of protecting calves. Unfortunately, may not be able to protect calves less than three weeks attempts at passive protection have met with conflict- of age. More recently, constructs deficient in more than ing results. However, an experimental vaccination one enzyme or constructs with auxotrophic and other regimen based on dam vaccination and prolonged mutations have also been produced. These strains, which colostrum feeding has been described. Cows were because they have two or more independent mutations vaccinated with formalin-inactivated S. typhimurium are thought to be safer than strains with a single muta- approximately seven weeks and two weeks preparturi- tion, have also been shown to be effective vaccines for tion. Calves were given the opportunity to suck from calves and may even be able to protect animals within their dam for 48 hours following parturition and were the first month of life. As yet none of these strains are then fed cold, stored colostrum from their own dam for* *available commercially for use in the UK.*

a further eight days. These calves were resistant to a

It is also probable that such strains are not able to

normally lethal challenge of S. typhimurium or S. dublin protect against infection with a variety of serotypes. No

given five days after birth and excreted salmonellas in

study to date has shown good cross-protection between

their faeces for only a short period after infection.

different serotypes for any significant period of time

Mortality was also reduced in calves that sucked from

after vaccination. In one recent study wild-type S.

a vaccinated dam and were then fed on normal colo-

typhimurium and S. dublin strains were used to infect strum and in calves born to unvaccinated cows and

ligated loops of calves previously immunized with

later fed on 'immune' colostrum. In cases of outbreaks

either serotype. Although protection against bacterial

with exotic serotypes the use of emergency vaccines

invasion and induction of enteropathogenic responses

for control has been successful.

was demonstrated it was clearly serotype-specific,

Vaccines may have an important role to play in the *despite the two serotypes being closely related and*

prophylaxis of bovine salmonellosis, but until improved

sharing common virulence mechanisms. It is difficult

vaccines become available they will not be a substitute

to imagine how effective cross-protection between

for good husbandry and hygiene.

serotypes may be obtained in future. It may be possible

to include more than one serotype in a live vaccine.

Recent evidence suggests, however, that distinct vaccine

Antibiotic therapy

strains can interfere with each other when used in com-

bination. Such interference could compromise efficacy.

It is not intended to discuss treatment of animals

Another problem with live vaccines that depend for

infected with salmonellosis in detail here since this is

attenuation on metabolic defects is that they are still

based on the use of antibiotics and fluid replacement

equipped with a full battery of virulence mechanisms

therapy as described earlier (p. 195) . Although antibi-and may in some circumstances still be able to cause

otics are not used in the treatment of gastroenteritis in *disease such as diarrhoea either in vaccinated animals,*

humans their use is justified for bovine salmonellosis,

animals in contact or, in the case of food animals, in the

which can become a systemic disease with a high mor-

human population who later consume their meat. A

tality in the absence of treatment.

common problem with live vaccines has been mild diar-

The concern with the use of antibiotics is that they

rhoea and excretion of the vaccine strain in the faeces of

have the potential of predisposing to colonization with

vaccinated animals. Recent research on the mechanisms

salmonellas, increasing levels and duration of excretion

by which salmonellas induce enteritis may alleviate this

by carriers and of selecting for antibiotic-resistant

problem. Salmonella type III protein secretion systems strains (see p. 210). The effect of antibiotics on an

animal and its resident micro-organisms will depend

Summary

upon the dose level, duration of administration and

antimicrobial spectrum of the antibiotic. The effects of

• Salmonellosis is a disease which ranges in man

antibiotics to which salmonellas are sensitive at thera-

and animals from severe enteric fever, through

peutic doses must be distinguished from the effects of

severe enteritis (with complications) to mild food

the same antibiotic at subtherapeutic concentrations

poisoning.

and the effects at either concentration of antibiotics to

• The disease has a worldwide distribution.

which salmonellas are insensitive. Similarly, since the

• Salmonellosis is caused by bacteria of the genus

antibiotic may have an effect upon the salmonellas or

Salmonella, of which over 2400 types (serotypes)

the normal flora or both, the age of the animal host is

have been identified.

important since age is often the principal factor in

• The disease is characterized by host specificity.

determining the composition of the normal flora. An

Some types cause disease only, or primarily in one

antibiotic to which salmonellas are sensitive, used at the

animal species, whilst others are ubiquitous and *correct therapeutic dose, may be predicted to reduce*

cause disease in many species.

excretion. The same antibiotic at a subtherapeutic dose

• *The disease in animals in the UK is most severe in*

may lead to increased multiplication of salmonellas due

cattle and particularly calves, and can result in high

to a suppressive effect on the activity of growth-sup-

morbidity and mortality. The principal serotypes

pressing normal flora. Similarly, the use of an antibiotic

involved are S. dublin and S. typhimurium. The to which salmonellas are resistant, but the normal flora

former is endemic in dairy herds, particularly in the

sensitive, may be expected to result in increased multi-

west of the UK, and may be maintained in herds

plication and excretion.

by 'carriers'. The disease is also frequently mild or

Antibiotic therapy in uncomplicated Salmonella

characterized by carriage of salmonellas in the

gastroenteritis in humans has not been recommended

absence of disease.

for more than 40 years. Therapy apparently does not

• The disease is controlled in cattle by vaccination

shorten or otherwise alter the clinical course of infec-

and the application of strict hygiene.

tion and has frequently been shown to prolong

• Some serotypes, and particularly S. typhimurium,

postconvalescent excretion. However, antibiotics have

have developed resistance to a number of antibiotics

been used extensively to treat salmonellosis in cattle

and multiple antibiotic resistance may be trans-

without undue complications. It should be clear from

ferred between strains.

the remarks above that the antibiotic sensitivity of the

organism should be determined and the information

used to choose the preferred antibiotic. The use of

antibiotics for prophylaxis is more controversial and

most authorities have reported that medication with

Further reading

antibiotics has no part to play in the prevention of sal-

monellosis. The use of antibiotics in the treatment of an

Wallis, T.S. & Galyov, E.E. (2000) Molecular basis of

outbreak of S. saintpaul infection has been described Salmonella-induced *enteritis. Molecular Microbiology,*

above. In the same outbreak antibiotics were success-

***36**, 997–1005.*

fully used prophylactically and have also been used to

Wray, C. & Wray, A. (2000) Salmonella in Domestic Animals.

effect a bacteriological cure in adult carriers and calves.

CAB International, Wallingford, Oxon.

Chapter 16

Digestive Disorders of Calves

R.W. Blowey

Introduction

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within minutes of ingestion. The clot contracts, express-

Abomasal milk clot failure and milk scour

231

ing the whey proteins (albumin and globulin), minerals

Problems with milk substitutes

232

and lactose in liquid whey, which begins its passage into

Oesophageal groove dysfunction

233

the duodenum 5–10 minutes later. After two to three

Ruminal bloat

234

days the number of parietal cells in the abomasal

Signs

235

epithelium increases and they begin to secrete

Treatment

235

hydrochloric acid. Abomasal pH falls. This converts

Rumen impaction and ‘pot-bellied’ calves

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Abomasal ulceration

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pepsinogen secreted by chief cells into the active form

Signs

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of pepsin. Both pepsin and renin are capable of clotting

Treatment

237

milk and both can digest the milk protein casein, but

Abomasal dilatation

237

pepsin is most effective at pH 5.2 and, additionally, can

Chronic peri-weaning diarrhoea

237

digest a wider range of proteins. The pepsin digestion

Colic

238

system is not fully developed until approximately seven

Necrotic enteritis

238

to ten days old and until that stage calves should,

ideally, receive either whole milk or a substitute con-

Introduction

sisting of whole milk. Similarly, the very young calf has

an immature intestinal digestive system. Pancreatic

The young calf is particularly susceptible to digestive

proteases can cope with whey proteins, pancreatic

disorders, with the major presenting clinical sign of

lipases with fat and intestinal lactase degrades the milk

scouring (diarrhoea) being a significant cause of eco-

sugar lactose into glucose and galactose. The ability to
nomic loss due to ill-thrift and death. Immediately after
digest starch does not develop until the calf is at least
birth the calf is exposed to a wide range of infectious
seven days old and full activity of maltase, sucrase and
agents, to which it must develop an immunity. Many
amylase systems, allowing the calf to digest non-milk
calves are hand-reared and consequently within a few
carbohydrate, is not complete until three weeks old.
days their diet may change from whole milk to milk
Figure 16.1 is a flow diagram of digestion in the young
substitute. Later they must learn to eat solid food, to be
calf. Complete digestion of the abomasal milk clot (or
weaned at six to eight weeks old. Such rapid changes of
‘curd’) by lipases and proteases may take 6–8 hours and
feed and feeding systems, in combination with a chang-
hence calves fed twice daily are without nutrients for
ing immune status, render the calf susceptible to a wide
only a short period. Calves left with their dams may
variety of infectious diseases and nutritional disorders.
suckle seven to ten times each day and any remaining

Infectious conditions are described elsewhere in this

curd forms a nucleus for the next milk clot.

book (see Chapters 14, 15). This chapter discusses the

If abomasal milk clot formation is poor, then whole

common nutritional disorders.

milk spills over into the duodenum, where casein

cannot be digested. In addition to altering the osmotic

balance, this provides an excellent medium for bacter-

Abomasal milk clot failure and

ial fermentation in the lower intestine and scouring

milk scour

results. Similarly, if excessive quantities of milk are

provided (greater than 1.5 l for the young calf), or if a

Abomasal volume in the newborn calf is 1.0–1.5 litres.

hungry calf is allowed to gorge itself, then abomasal

It has a neutral pH, thus allowing the first feed of

digestive processes become overloaded and whole milk

colostrum to pass through unclotted,

so that

spills into the duodenum. This can also be a problem

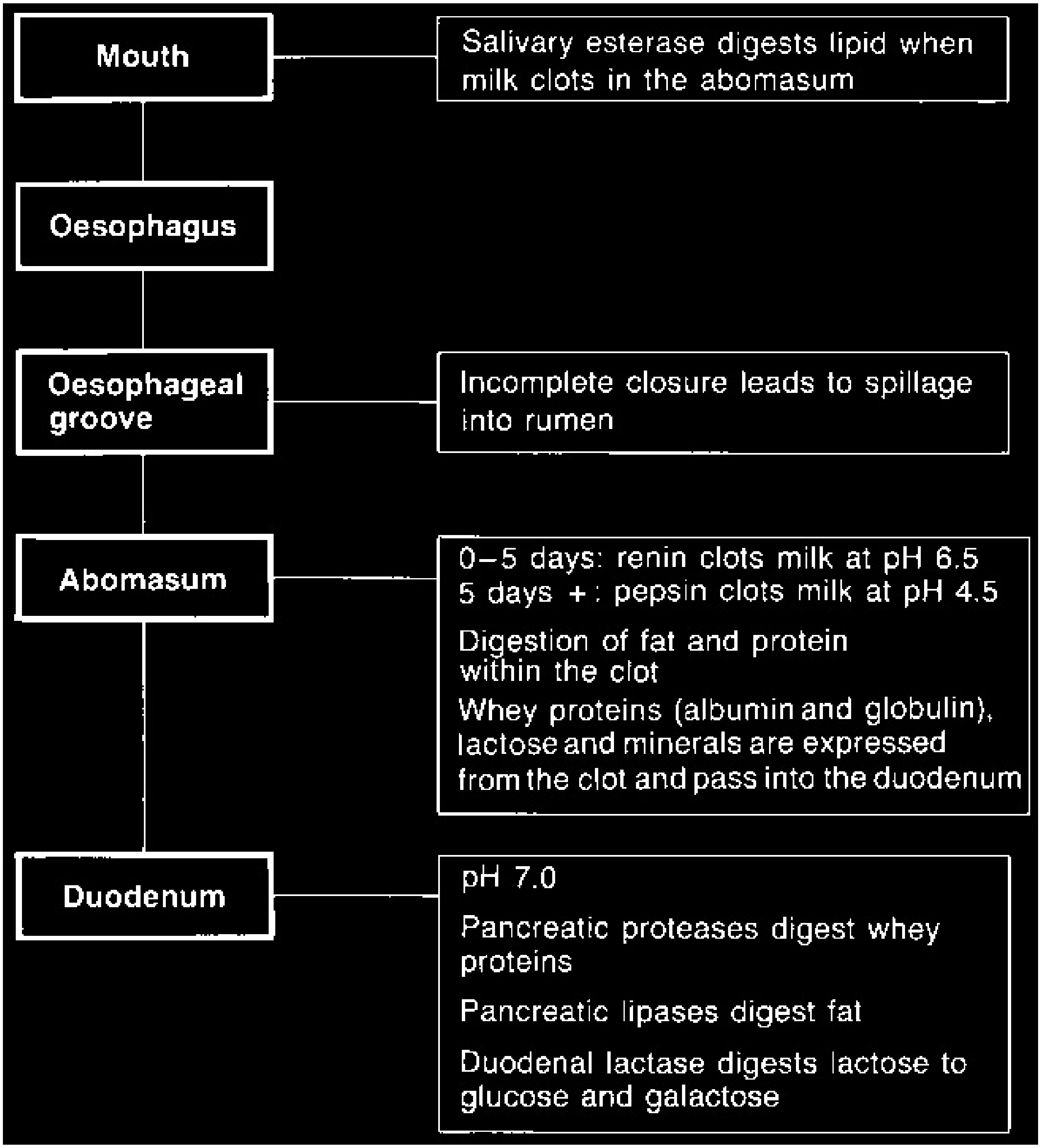
immunoglobulin molecules can be absorbed whole *with suckler calves, especially if the dam is a ‘milky’*

through the intestinal epithelium. Initially, renin coag-

Friesian or Holstein crossbred animal. Although the

ulates milk (optimally at pH 6.5), with clot formation

calf may suckle every few hours, overloading and


Mouth
Salivary esterase digests lipid when milk clots in the abomasum
Oesophagus
Oesophageal groove
Incomplete closure leads to spillage into rumen
Abomasum
0–5 days: renin clots milk at pH 6.5
5 days +: pepsin clots milk at pH 4.5
Digestion of fat and protein within the clot
Whey proteins (albumin and globulin), lactose and minerals are expressed from the clot and pass into the duodenum
Duodenum
pH 7.0
Pancreatic proteases digest whey proteins
Pancreatic lipases digest fat
Duodenal lactase digests lactose to glucose and galactose

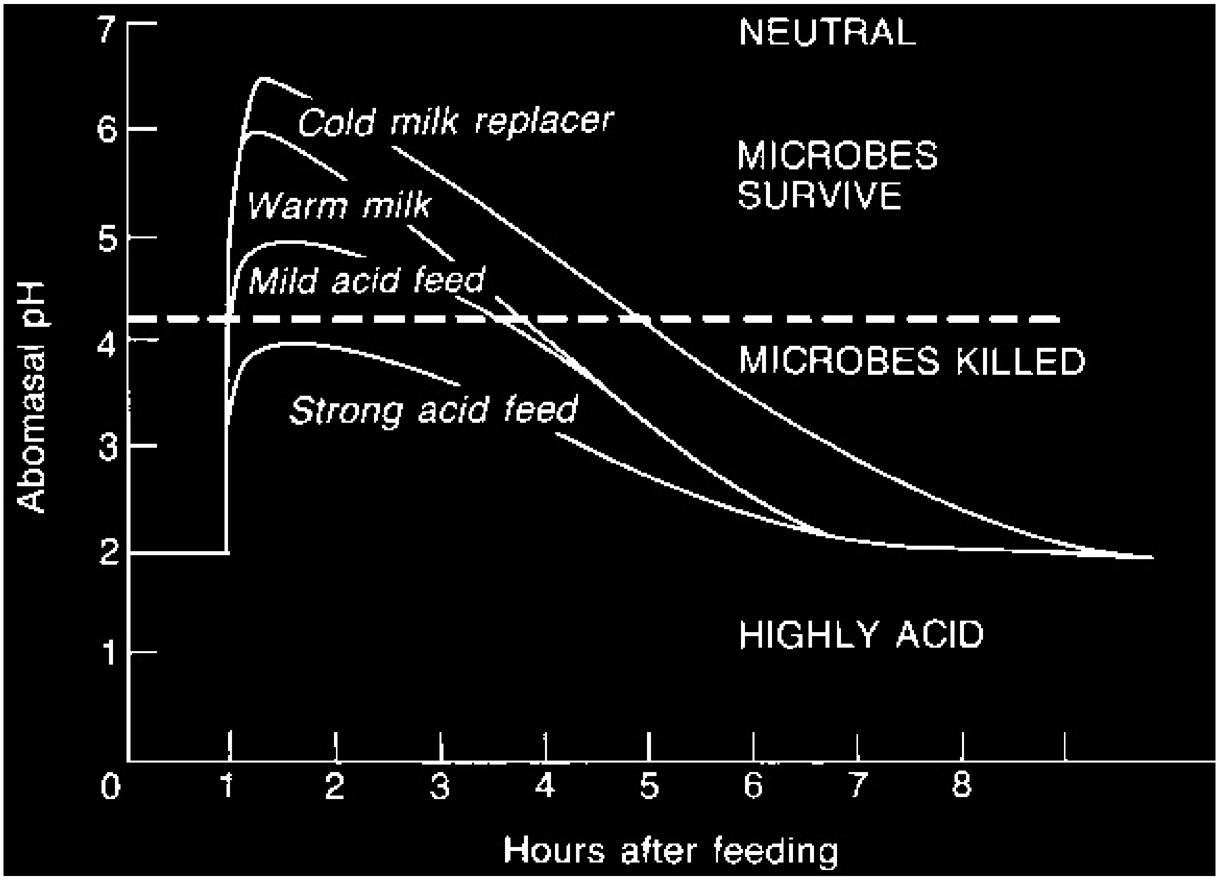


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Fig. 16.2

The effect of type of milk and milk substitute on

abomasal pH (Webster, 1984).

for the first few days of life has an abomasal pH of 6.5,

is particularly susceptible to infection therefore.

However, this is counteracted by surface-active anti-

bodies contained in whole milk and colostrum. In the

older calf, the acidity of the empty abomasum, i.e. after

Fig. 16.1

Flow diagram of digestion in the young calf.

complete digestion of the curd 6–8 hours after the pre-

vious feed, may fall to as low as pH 2.0. Following a feed

of milk, pH rapidly rises towards neutrality (e.g. pH

dietary scouring can still occur. This is particularly

6.5), the extent and persistence of this rise depending

common if cows are put with the calves only twice daily.

on the volume and nature of the liquid milk ingested.

On bucket-rearing systems a variety of management

With warm whole milk, abomasal pH falls to below

factors can lead to poor abomasal milk clot formation.

4.2 within three hours of a meal and bacterial killing

These include:

once again becomes effective. Figure 16.2 indicates

the periods required for other feeds.

• Nervous or stressed calves, for example feeding

Clearly, calves that develop a poor abomasal milk

immediately after arrival from market, dehorning

clot, or that have other abomasal disorders (e.g. abo-

or some other stressful procedure.

masal dilation, p. 237), resulting in increased pH values,

- *Irregular feeding times.*

will be more susceptible to infection. In addition,

- *Milk substitute fed at the wrong temperature or*

improperly digested fats passed in the faeces produce

incorrect strength (see p. 233).

steatorrhoea, with subsequent hair loss over the legs

- *Inflammation of the abomasum (see p. 237).*

and perineal region (Plate 16.1). Affected calves will be

Many enzyme systems are induced, that is, enzyme

unthrifty and in poor condition, due to poor absorption

activity develops following exposure to substrate.

of nutrients.

Calves should therefore be reared on a single type of

Treatment with oral electrolytes for two to three days

milk substitute and, preferably, from a single batch pur-

and dietary correction is normally effective.

chased to cover the whole rearing period. A sudden

change in the ingredients of the milk substitute could

lead to incomplete digestion of protein, fat or carbohy-

Problems with milk substitutes

drates, which later undergo putrefactive fermentation *in the lower intestine, resulting in malabsorption, a fetid*

A full review of liquid feeds and feeding systems is

diarrhoea and weight loss. Such calves are more sus-

beyond the scope of this book. Those interested should

ceptible to colonization by pathogenic Escherichia coli

consult more authoritative texts such as Webster (1984).

and salmonellae.

Because of the immaturity of the pepsin–HCl system,

Irregular feeding and its influence on abomasal pH

calves should receive colostrum and whole milk for the

can also have an effect on the susceptibility of a calf to

first three to four days of life. Most conventional milk

infection. Most ingested enteric infections are killed at

substitutes are based on skim milk powder (SMP), to

an abomasal pH below 4.5. The very young calf, which

which is added lipids and fats from a variety of sources,

all highly emulsified to ensure even suspension

fore, be fed 'half strength' for scouring calves, as this

throughout the milk when it is reconstituted. These

may retard clot formation. Although some proprietary

SMP substitutes should clot in the abomasum. Addition electrolyte preparations state that they can be used with of weak organic acids (e.g. citric or fumaric) reduces whole milk and improve clotting time, there is some evi- the pH to 5.7 and thus improves keeping quality. Fully dence that the clot thus formed is less stable. In general, acidified milk powders, with a pH of approximately 4.2, therefore, it is best to avoid diluting milk substitutes have an even better keeping quality. As casein would and if electrolytes are to be given, they should be fed clot at this low pH it cannot be used and strong acid separately. Similarly, calves should not be allowed to powders primarily consist of whey proteins (albumin drink large volumes of water immediately after milk, as and globulin) with added fat. Without casein they do this will have the effect of diluting the milk.

not clot in the abomasum, but this does not seem to Probably the biggest problem with milk substitutes produce any increase in digestive problems. Such 'zero' comes from careless mixing. Stirring with the hand is replacers (so-called because they contain no skim milk *simply not adequate: a whisk, whether manual or*

powder) are commonly used in ad libitum calf feeding

mechanical, is essential. Carelessly mixed powders

systems.

leave lumps and a sediment of protein in the bottom of

If skim milk powder is overheated during manufac-

the bucket and poorly dispersed fat rises to the top.

ture, casein is denatured, abomasal milk clot formation

Trials have shown that up to 60 per cent of the oils in

is poor, undigested casein passes into the small intestine

a replacer may be wasted in this way, producing

and scouring may result from putrefactive bacterial

poor growth, stunted calves and possibly scouring due

fermentation. Most proprietary milk substitutes are

to inadequate abomasal clot formation.

carefully monitored and the majority of problems

associated with their feeding are managemental in

origin. The first golden rule must be to read the manu-

Oesophageal groove dysfunction

facturer's instructions. To achieve even dispersal of the product, and especially of the fat, many manufacturers

From as early as two weeks of age the young calf begins

recommend that milk is mixed at a higher temperature

picking at hay, grass or other solid foods. Bacteria

(45–50°C) and then cooled to just above blood heat

ingested with this food, initially E. coli and lactobacilli, (42°C) before feeding. A thermometer is needed to do

initiate ruminal fermentation. With increasing age, the

this. The temperature cannot be judged manually. On a

rumen becomes progressively more anaerobic and an

hot day milk will feel cool and consequently may be fed

adult ruminal flora eliminates the early organisms. The

too hot. On a cold day the temperature may be over-

inability of E. coli and salmonellae to survive for sig-estimated and the milk substitute consequently fed too

nificant periods in the rumen is one reason for encour-

cold. Milk substitute mixed below the optimum tem-

aging early ruminal development. However, at this age

perature produces an inferior product. Added protein

rumen fermentation alone would be unable to provide

and minerals sediment to the bottom of the bucket and

adequate nutrients for the rapidly growing calf and

are wasted. In addition, poorly dispersed fats remain as *milk needs to continue ‘monogastric’ digestion in the*

a layer on the surface of the milk, forming a ring around

abomasum. Milk entering the rumen is both wasteful

the calf’s muzzle after feeding, which produces second-

and dangerous and hence it should bypass the rumen

ary alopecia (Plate 16.2). If a long row of calves is fed

and reticulum to enter the abomasum direct. This is

from a single container, the milk for the last calf may

achieved via the oesophageal groove. In the anterior

be appreciably cooler. Again fat will rise to the surface

wall of the dorsal sac of the rumen there is a muscular

and alopecia may develop on the muzzle. A fall of only

channel that runs from the distal end of the oesopha-

6°C in the temperature of the milk fed will double the gus into the rumino-
omasal orifice, as shown in Fig.

time taken to form the abomasal clot. Undigested milk

16.3. A reflex action from suckling results in muscular

may then leak from the abomasum, thus reducing its

closure of this groove, to form an enclosed pipe, and

nutritive value and possibly inducing diarrhoea. Con-

milk is then transferred directly into the abomasum. As *versely, however, if milk is fed too hot calves simply will*

the calf gets older, the thought of being fed and the

not drink it, but no adverse effects have been observed.

sight, sounds and stimuli associated with the arrival of

It is interesting to compare this with our own liking for

its milk will be sufficient to evoke closure. It is most

hot drinks.

important that closure occurs prior to feeding and

Milk fed at the wrong strength can cause problems.

hence the establishment of a standardized feeding

Powder is normally added at 125 g/l for twice-daily

regimen is vital. The calf needs to know that it is about

feeding and 150 g/l on once-daily systems. Abomasal

to be fed, that a pleasurable event is forthcoming.

milk clot will be optimal at these concentrations. If too

Ideally the calves should be able to both see and hear

dilute, clot formation is poor. Milk should not, there-

the feed being prepared, as this will induce a state of

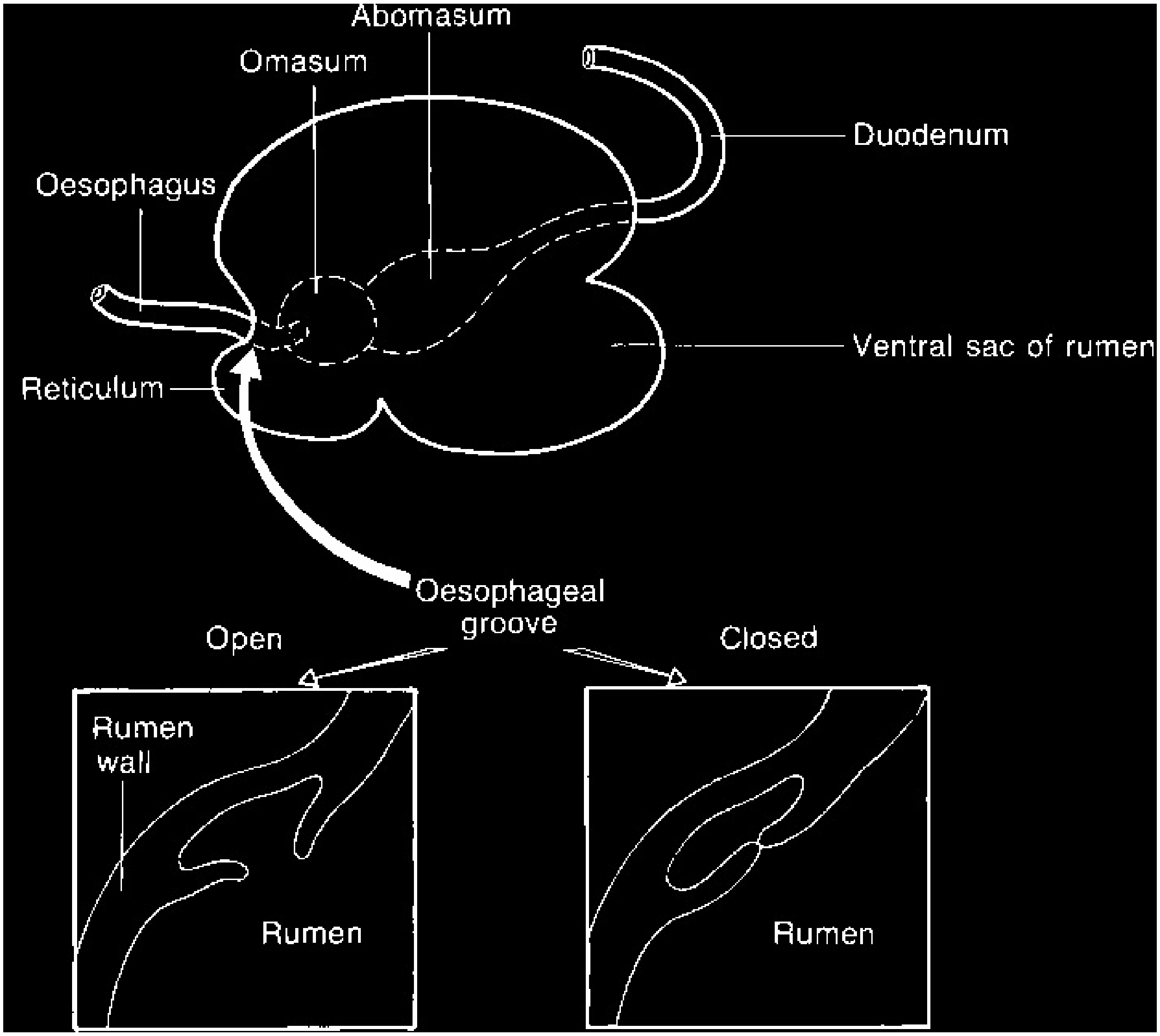

Fig. 16.3

The oesophageal groove.

expectation and stimulate oesophageal groove closure.

lates. Unfortunately, it is all too common to see calves

Feeding times should be consistent each day. Milk

on their knees trying to drink from a bucket some *should be provided at the correct and consistent*

way below pen level. Teats for milk substitute should

temperature, in the same amount at each feed and

be positioned such that the calf has sufficient space to

of a similar taste and consistency. Calves with wagging

stand back to suckle and at a height that allows its

tails and calves which butt the bucket (or udder, or teat)

nose to be tilted upwards and the oesophagus at least

are enjoying their food and the oesophageal groove is

horizontal.

well closed.

Milk spilt into the rumen undergoes rapid fermenta-

Calves on a teat need to work reasonably hard to get

tion. This may produce an acute and sometimes fatal

their milk – a pile of saliva beside the teat is a good sign.

bloat and colic, within 15–30 minutes of feeding. In

Conversely, if milk flow is too rapid, for example a badly

more chronic cases, ruminal development is retarded

damaged teat with an open orifice, the calf will almost

and abnormal products of digestion pass into the

choke with the rate of flow and milk could spill into the *intestine, producing scour. Chronic pain restricts food*

rumen. A sawn-off milking machine liner fitted onto a

intake and therefore growth and development. The

bottle and used by some farmers as a teat produces a

Charolais calf in Plate 16.3 has a typically distended

much too rapid flow rate. Stressed calves, for example

left flank caused by ruminal bloat. The superficial

those that have just arrived from market, may not

haemorrhage resulted from trocarization with a needle.

achieve groove closure and should therefore be given

A pasty scour is evident on the tail.

electrolyte solutions for their first feed. Similarly, calves

Treatment of oesophageal groove closure is, in effect,

should not be moved, handled, dehorned, etc. immedi-

treatment of chronic bloat and is discussed in the next

ately before feeding. Slow drinkers present a problem.

section.

While the milk is warm, oesophageal groove closure

may be adequate. However, if the bucket is left in front

of the calf it may drink later, with possible milk spillage

***Ruminal bloat** (see also p. 832)*

into the rumen. Some calves fail to learn to drink adequately and must be finger or teat suckled until
The development of normal rumen function is a
weaning, although this is preferable to reluctant drink-
complex process and any interference can produce
ing with inadequate groove closure. Bucket height and
bloat. Organisms ingested with feed from approxi-
teat position are important. The bottom of the bucket
mately two weeks onwards eventually establish an
must be at least 30 cm above the floor of the pen, which
anaerobic fermentation. It is the ingestion and subse-
means that it must be raised as straw bedding accumu-
quent fermentation of solid feed that stimulates the

rapid expansion in size of the rumen, although full

Signs

development is not complete until 12 weeks old, when
Typically, bloat is seen 15–30 minutes after a feed of
the rumen comprises approximately 80 per cent of the
milk or concentrate. Mild cases may deflate sponta-
total volume of the four stomachs. During this period,

neously over 3–4 hours, as ruminal contractions recom-

development of the rumen papillae is affected by the

mence. More protracted cases may remain bloated until

type of food offered. Inadequate long fibre and fer-

the next feed, because bloat depresses feed intake and

mentation of a high-concentrate diet leads to low

is therefore, to an extent, a self-perpetuating phenome-

ruminal pH and acidosis. This can restrict development

non. Affected calves are uncomfortable, with bouts of

of papillae to such an extent that inflammation and

colic, often leading to kicking at their abdomen. Many

ulceration of the ruminal wall permits bacterial

develop a chronic scour (see colour plate 16.3), leading

'leakage' and subsequent hepatic abscessation. The

to general poor growth and unthriftiness. Death fre-

addition of 10–15 per cent chopped straw to concen-

quently occurs with acute cases.

trates, especially high-starch products, will improve

rumen fermentation, thereby increasing the overall

digestibility of the ration and promoting increased dry

Treatment

matter intake, since high acidity depresses the activity
of cellulolytic bacteria. Calves that do not have hay on
The syndrome may develop in both preweaned and
offer should therefore be bedded freshly each day, with
postweaned calves and treatment is similar, the method
ample palatable straw. Long fibre encourages rumina-
used depending on the severity of the condition. Acute
tion and subsequent saliva production, which in turn
bloat must be deflated, either using a large bore needle
both neutralizes and dilutes ruminal acidity. Long fibre
through the rumen wall or, preferably, by stomach tube.
essentially acts as a 'scratch factor' and stimulates
Oral antibiotic will depress gas production. Penicillin
rumen motility. Silage or other forages may be used, but
may be the drug of choice, since lactobacilli proliferate
it seems critical that the fibre length is 5.0 cm or above.
in both concentrate overload acidosis and milk fer-
The rate of ruminal contractions and subsequent eruc-
mentation. Withdrawal of food and feeding electrolyte
tation and gas release varies with the physical presen-
solutions for two to three days helps to remove the fer-

tation of the diet, as shown in Table 16.1, and with
menting substrate. Calves should then be returned to a
dietary constituents. High-forage diets produce greater
liquid milk diet for two to three weeks and eventually
ruminal activity than high concentrate. It has been sug-
reintroduced to solid food. Even then, a proportion of
gested that concentrate intakes in heifer calves being
cases recur and in many instances this protracted treat-
reared for dairy replacements should be restricted, as
ment is, for a variety of reasons, impractical. In such
this will encourage greater consumption of forage and
cases the construction of a permanent ruminal fistula in
the development of a larger rumen, capable of sustain-
the triangle between the most caudal point of the last
ing greater intakes later in life.
rib and the lumbar transverse processes is indicated.
Irregularities at any stage of rumen development can
Under local anaesthesia, the rumen wall is sutured to
lead to bloat, but the two most common causes are
the skin and a fistula is created. Although rumen con-
oesophageal groove failure, with subsequent fermenta-

tents may spill onto the flank, this does not appear to

tion of milk in the rumen, and acidosis caused by high-

upset the calf and in many animals the improvement

level feeding of improperly formulated concentrates. In

in growth and general condition following surgery is

both cases the bloat is caused by ruminal atony.

dramatic. A proportion of fistulae seal spontaneously

after six to twelve months. Others require surgical

correction, although this is not normally performed

for beef animals.

On farms where bloat is a common problem, feeding

Table 16.1

Effect of the physical form of diet on ruminating

behaviour of calves 6–9 weeks old (from Webster 1984, adapted

and management systems should be examined, espe-

from Hodgson, 1971).

cially in relation to the encouragement of early ruminal

development. Highly nutritious concentrates should be

Grass Long

or

offered from two to three weeks old onwards, prefer-

pellets

chopped grass

ably in small amounts each day, to ensure freshness and

palatability. Water should be freely available, especially

Eating (min/24 h)

132

276

on once-daily milk feeding. Inadequate access to water

Ruminating (min/24 h)

138

459

restricts concentrate intake and occasionally a long

Eating (min/kg DM)

85

320

drink by a thirsty calf with a dry rumen leads to rapid

Ruminating (min/kg DM)

70

535

fermentation of concentrates and subsequent bloat. In

Dry matter intake (g/24 h)

1553

862

this respect the placing of buckets is important. Water

should always be freely available, but the calf must be

as the left flank, but overall body condition, in terms of

‘programmed’ to regard it as a drink, namely without

fat and muscle cover, will be poor. Ruminal contrac-

stimulating the oesophageal groove closure reflex.

tions may be slow and the rumen feels ‘doughy’ on pal-

However, milk is a food and as soon as the calf has fin-

pation. In an extreme case, where poorly grown calves

ished, replace the milk bucket with another containing

left without food for many hours were allowed unlim-

concentrate. (Many farmers leave the milk bucket in

ited access to palatable straw, the author has seen

situ – to avoid the transfer of infection – and simply add severe illness and even death due to ruminal impaction.

the concentrate bucket.) The calf immediately puts its

However, this is rare. Rumen impaction is almost the

head in and starts to eat, thus encouraging concentrate *reverse of bloat, in that it is associated with overcon-*

intake and, at the same time, discouraging excessive

sumption of dry, fibrous and relatively indigestible

water drinking. Even so, occasional calves will still

foods, sometimes compounded by inadequate access to

drink to excess, looking bloated and uncomfortable

water. It may be a group problem of poor dietary man-

when they do so. In such cases, water is best withheld

agement, or the result of inadequate trough space, when

until 2–3 hours after the feed of milk, accepting the risk

the smaller members of the group get pushed out and

of bloat following rapid fermentation of dry ingested

have to exist on forage alone.

concentrates.

Abomasal ulceration

Rumen impaction and

'pot-bellied' calves

Abomasal ulceration is common in artificially reared

calves, the majority of cases being asymptomatic and

Postweaning feeding is a critical stage of the calf's

seen only at post mortem (for example in veal calves).

development. The rumen is not fully mature, being

Surprisingly, perhaps, the incidence is higher in those

more acid (i.e. lower pH) than the adult and unable

veal calves that have had access to forage. Many clini-

to synthesize sufficient microbial protein, relative to

cal cases are seen at two to three weeks old, when they

energy, to meet the calf's high requirements for growth.

first start eating solid food, or in animals that have

Preweaning, milk has passed directly into the aboma-

developed pica, often as a result of chronic illness.

sum and this source of undegradable protein must be

These points suggest that ulcers may result from large,

replaced by high-quality undegradable foods, e.g.

inadequately digested particles of hay or straw, passing

fishmeal or linseed meal, after weaning. The higher

from the rumen to the abomasum. There is undoubt-

the growth rate required, the higher will be the require-

edly an increase in ulceration in calves with trichobe-

ment for additional undegradable protein. As feed con-

zoars (hair balls), but whether the hair balls lead to

version is much more efficient at a younger age (Table *ulceration, or whether chronic ulceration stimulates the*

16.2), it is still cost-effective to feed expensive, nutri-

calf to lick and eat hair (in the same way as chronic

tious diets to freshly weaned calves.

ruminitis) is uncertain. Ulceration occurs in association

If the diet largely consists of poor-quality forages,

with abomasal dilation (see p. 237) and may also result

the calf's growth will be stunted, and the rumen will

from ruminal acidosis and starch overload, allowing

be distended with slowly fermenting foods. If con-

undigested starch to spill over into the abomasum.

centrate intakes are inadequate, hungry calves may

Fungal hyphae are visible microscopically in a propor-

consume large amounts of forage. Fermentation rates

tion of ulcers and may be involved in the pathogenesis.

will decrease and rumen distension is exacerbated.

Affected calves have a 'pot-bellied' appearance, i.e. the

Signs

lower abdomen is distended, often on the right as well

The majority of ulcers in calves are subclinical although

some may haemorrhage, producing melaena and *anaemia, which is occasionally fatal. Others produce a localized peritonitis of the abomasal serosa, whilst perforating ulcers lead to acute peritonitis and death. The three-week-old Friesian calf in Plate 16.4 was recumbent, in considerable pain, with a subnormal temperature (37.5°C) and sunken eyes. Regurgitated rumen contents are visible at the mouth. Death followed within two hours, despite abomasal drainage, lavage and parenteral metoclopramide. On post mortem*

Table 16.2

The effect of age on feed conversion (Blowey, 1999).

Body weight (kg)	***Feed conversion ratio***
50	*2 : 1*
100	*3 : 1*
300	*5.5 : 1*
500	

8.5 : 1

(Plate 16.5) two large ulcers, one perforated with a

white diphtheritic lining, were present, typically on the

after feeding. Affected animals are seen in severe dis-

greater curvature of the abomasum.

tress, kicking at the distended abdomen or rolling on

the floor. Some cases are fatal, others respond to relax-

ant therapy, for example pethidine or mepramizole. On

Treatment

post mortem the milk has often failed to clot, but no

The treatment of abomasal ulcers is largely sympto-

other lesions are seen and the cause remains unknown.

matic. Valuable calves with extensive haemorrhage may

It has been suggested that it is more common with

be given a blood transfusion, but bleeding ulcers are

infrequent and irregular feeding times.

less common in calves than in adult cattle. Kaolin has

been used, but probably antacids such as magnesium

oxide or magnesium silicate give a better response.

Chronic peri-weaning diarrhoea

Metoclopramide at 0.5–1.0 mg/kg body weight has been used to alleviate abomasal atony (Biggs et al. , 1989). A well-recognized syndrome of a chronic persistent Drainage and lavage may be indicated in concurrent grey/brown scour occurs in calves 4–10 weeks old, i.e. abomasal dilation and ulceration. Antibiotics are before or after weaning (Blowey, 1988, 1994, 2000; indicated when peritonitis is suspected. Bidewell et al., 1999) and when consuming concen-trates. Morbidity is usually high but mortality is low and the few detailed post mortems reported have not shown

Abomasal dilatation

consistent findings. There may be fibrous impaction of the rumen and a distended colon. Many cases of mild Also known as abomasal bloat, this condition of 'looseness' often pass unreported, but if the condition unknown aetiology produces a shock syndrome in progresses, appetite falls and marked weight loss calves, typically at two to three weeks old, when they occurs. The diarrhoea may be unusually persistent, with first start eating solid food. Many cases are fatal.

many cases continuing for 4–6 weeks, leading to marked

Affected calves are very dull, with sunken eyes and sub-

weight loss and stunting. The condition can be a major

normal temperature, and are often reluctant or unable

problem for feed companies because it often becomes

to stand. Enteritis may occur, but it is not a consistent

apparent following (but not necessarily associated with)

feature. The enlarged abomasum, distended by excess

a delivery of food.

fluid and occasionally with gas to produce tympany, can

A range of treatments have been used, but none is par-

be ballotted on the lower right flank. The accumulated

ticularly effective and most calves seem to eventually

fluid has a much higher pH (range 5–7) than a normal

self-cure. Faecal examinations of affected calves reveal

calf with an empty abomasum (pH 2–3), thus allowing

a range of organisms including Giardia, cryptosporidia, the bacterial count to increase to 105–109 ml, with coli-coccidiosis, Campylobacter species and rotavirus. Motile forms predominating. A normal calf has an abomasal

protozoa are commonly seen in fresh faecal smears and

pH range 2–4 and a bacterial count of 50 000/ml, with

although calves can excrete giardial cysts asymptomati-

mainly staphylococci and Bacillus species and very

cally, Giardia duodenalis has been reported to cause

low numbers of E. coli. This has led to the proposal that chronic diarrhoea in calves in the USA (O'Handley et

abomasal dilation is an enterotoxaemia, similar to

al., 1999). Although faecal coccidial oocyst levels are

'watery mouth' in young lambs (Price, 1989).

often low, the author has examined an outbreak where

Abomasal drainage may be achieved by deep inser-

intestinal histopathology was typical of coccidiosis and

tion of a stomach tube. With the calf in lateral recum-

there was an apparent improvement in the remaining

bency on a straw bale and its head hanging down, the

calves following the use of in-feed decoquinate at 1.67

excess fluid is discharged under gravity. The abomasum

kg/t if ad libitum or 2.22 kg/t if feed was restricted to 375

can then be flushed two to three times with electrolyte

g/50 kg body weight of calf. It has been suggested that

solutions and, if the calves are treated symptomatically

the syndrome is similar to colitis in pigs, where a primary

for shock and acidosis and fed electrolytes for 24–48 *dietary imbalance leads to proliferation of intestinal*

hours, recovery rates are acceptable. Metoclopramide

parasites. The rate at which the syndrome passes

at 0.5–1.0 mg/kg body weight has been reported useful

through several groups of calves would suggest that an

to overcome abomasal atony (Biggs et al. , 1989), but the infectious cause is also involved (Plate 16.6).

current author has met with very limited success.

Management factors have been implicated, particu-

In those cases that reach post mortem, a degree of

larly those relating to digestive upsets. The syndrome is

abomasal ulceration, sometimes with fungal hyphae, is

seen more commonly (but not exclusively) with calf

often present.

pellets rather than coarse mix, presumably because

Acute abomasal bloat may also occur in milk

calves eat coarse mix more slowly, chew it more thor-

substitute-fed calves within 20 to 30 minutes or less

oughly and saliva production is therefore increased.

Feeding rancid food, digestive upsets associated with *days. There may be additional respiratory signs, with poor abomasal groove closure and use of 'milking a muco-purulent occulo-nasal discharge originating cow' concentrates and maize gluten, both of which are from ulceration of the mouth and pharynx and in some unsuitable for calves with an improperly developed cases crusting lesions of the nostrils are seen. On post rumen, have all been suggested as causes. Hygiene mortem the characteristic findings are erosive ulcers seems to be important and a thorough cleaning of the throughout the gastro-intestinal tract, with some being affected area helps. The syndrome is more common in sufficiently deep to produce areas of localized peritoni- group housed/fed calves rather than in animals penned tis. The ileum, caecum and colon are the organs most singly and keeping calves individually penned until one commonly affected. Kidneys may be pale and swollen, to two weeks postweaning will help (Blowey, 2000). with infarcts, and there may be lesions of inhalation Treatment is largely symptomatic and includes pneumonia as a consequence of the pharyngeal* *antimicrobials, anticoccidials and vitamins. Macrolides,*

ulceration (Penny, 1999).

for example tilimicosin, have been used and sul-

Typical haematological findings reflect the pathology

phonamides and other anticoccidial agents. Badly af-

and include anaemia, leucopenia, neutropenia and

fected calves should be returned to a whole milk diet,

raised urea values. Treatment is symptomatic and

without access to solid food, and possibly fed three to

includes antibiotics, NSAIDs and fluid therapy. The

four times daily. One severe outbreak dealt with by the

aetiology is unknown. Although the pathology is

author appeared to improve through the use of in-feed

strongly suggestive of BVD (p. 853), the virus is rarely

decoquinate. Lasalocid could also be used. There is an

isolated from affected calves.

urgent need for more epidemiological information on

predisposing factors.

References

***Colic** (see also p. 845)*

Bidewell, C.A., David, G.P., Gonning, R.F., Harwood, D.G., *Higgiov, R.J., Jones, J.R. & Laren, R.D. (1999) Persistent Colic is commonly seen in young calves. It occurs in asso-periweaning calf diarrhoea. UK Vet, **4**, 35–8.*

ciation with many of the syndromes described earlier in

Biggs, A.M., Dainton, J.T. & Tucker, M.E. (1989) Metoclo-

this chapter, namely oesophageal groove dysfunction,

pramide for preventing watery mouth. Veterinary Record, acidosis, ruminal bloat, ruminal impaction, abomasal

***124**, 312.*

ulceration and abomasal dilatation. True intestinal spas-

Blowey, R.W. (1988) A Veterinary Book for Dairy Farmers, modic colic occurs and may precede enteritis and subse-2nd edn. Farming Press, Ipswich, p. 54.

quent diarrhoea. Colic may also be a sign of a more

Blowey, R.W. (1994) Calf feeding practices in relation to

serious abdominal disorder, for example torsion of the

*health. Cattle Practice, **2**, 375–82.*

Blowey, R.W. (1999) A Veterinary Book for Dairy Farmers, root of the mesentery, intussusception, acute peritonitis,

3rd edn. Old Pond Publishing, Ipswich, pp. 21–66.

cystitis with urethral obstruction or atresia ani/coli. The

Blowey, R.W. (2000) Chronic peri-wearing diarrhoea – the

latter condition is seen within 24–48 hours of birth.

*clinical syndrome. Cattle Practice, **8**, 89–90.*

The treatment of colic therefore depends on the

Blowey, R.W. & Weaver, A.D. (1991). A Colour Atlas of

diagnosis and is discussed in the relevant section.

Diseases of Cattle. Wolfe Publications, London.

O'Handley, R.M., Cockwill, C., McAllister, T.A., Jelinski, M., Morck, D.W. & Olsen, M.E. (1999) Duration of naturally

Necrotic enteritis (see also p. 213)

acquired giardiosis and cryptosporidiosis in dairy calves and

their association with diarrhoea. Journal of the American

This syndrome, first reported in the UK in 1991, affects

Veterinary Medical Association, **214**, 391–6.

spring-born suckler calves at 2–4 months old, when they

Orskov, R. (1987) The Feeding of Ruminants. Chalcombe Publications, Marlow, Bucks, pp. 1–90.

are at pasture. Morbidity is low but mortality is high

Penny, C.D. (1999) Necrotising enteritis in beef suckler calves.

(Penny, 1999). Clinical signs are a sudden onset of

UK Vet, **4**, 24–8.

profuse haemorrhagic diarrhoea, which later becomes

Price, T.P. (1989) A treatment of calf enterotoxaemia. In

scant and mucoid with tenesmus. Coccidiosis is there-

Proceedings of British Cattle Veterinary Association

fore an important differential. Pyrexia is common and

1988–1989, pp. 185–93.

the animal becomes progressively more depressed,

Webster, J. (1984) Calf Husbandry Health and Welfare.

anaemic and dehydrated, with death following in 7–10

Granada Technical Books, pp. 1–202.

Chapter 17

Calf Respiratory Disease

A.H. Andrews

Introduction

239

The second problem is in a management system

Enzootic and cuffing pneumonias

239

involving weaned suckled calves, usually six months to

Epidemiology

239

two years old and mainly reared outside. This disease

Aetiology

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occurs following transport and housing and results in a

The environment

240

condition best described as transit fever or shipping

Management

242

fever (see Chapter 20). All the syndromes are best

The calf

242

defined by the circumstances in which they occur

because their aetiology is complex and mainly multi-

factorial in nature. This involves the susceptibility of the

Introduction

animal, the environment in which it is kept, the man-

agement of the animal as well as the various disease

Bovine respiratory disease (BRD) in calves in the

agents to which it is subjected. In many BRD problems

developed world occurs under two main management

the causal agents will be similar in each of the syn-

systems. The first involves young, housed calves, usually dromes and it is only the management conditions that

dairy bred and either reared for beef or as dairy *will be different.*

replacements. These are weaned from their dams

within a few days of birth and then fed milk substitute

or milk until weaned, usually between five and eight

weeks of age. Under such conditions these calves can

Enzootic and cuffing pneumonias

succumb to one of two different respiratory syndromes.

Often one will lead into the other. The first is a problem

The aetiology of pneumonia in young calves is

of slow, insidious onset known as chronic or cuffing

extremely complex in both the acute and the chronic

pneumonia, whereas the second is more sudden and

form. It is fair to suggest that the disease is multifacto-

acute in occurrence and is given a variety of names, the

rial. It is usually seen in calves reared indoors, particu-

most common being calf pneumonia, acute pneumonia

larly when they are reared for beef production and so

or enzootic pneumonia.

have moved farms at an early age. Most cases occur

Fewer problems occur with calves suckling their

between two and five months and usually following *mothers in the beef herd until weaning. However, on*

weaning from a milk-substitute diet. The causes of the

occasion similar types of acute and chronic pneumonia

problem are partly infectious agents, the environment,

occur while the animals are housed, Unusually, out-

management and the animals themselves.

breaks occur in suckler calves whilst with their dams at

grass. These outbreaks are often precipitated by a stress

such as a management change or marked alteration

Epidemiology

in the weather. However some of these are less obvious

Chronic

in their precipitating factors. Investigation of these

problems often shows M. haemolytica to be present.

It is very difficult to determine the incidence of chronic

However, Haemophilus somnus, infectious bovine

or cuffing pneumonia as most affected calves are not

rhinotracheitis (IBR), bovine respiratory syncytial virus

treated and they do not die. In addition, by the time

(RSV) and parainfluenza III virus (PI3) have all been

animals reach slaughter weight or are culled the resid-

detected in various outbreaks. It must also be remem-

ual damage is minimal. However, in a survey of dairy-

bered that calves can pick up lungworm infection and

bred animals reared on a farm it was found that 11 per

this, when in low concentrations, will still cause lung

cent had significant pneumonic lesions and it was esti-

damage. This on its own can create clinical signs or

mated that this resulted in a 7.2 per cent reduction in

activate organisms present within the respiratory tract.

liveweight gain (Thomas et al., 1978).

Acute

involved. Thus the three main mycoplasmal agents are

M. bovis, M. dispar and Ureaplasma spp., although M.

Very few studies have been undertaken into the inci-

canis is increasing. In the case of viruses, those most dence of this condition. However, Thomas (1978)

commonly implicated are bovine respiratory syncytial

obtained health records for 12 beef farms in 11 British

virus (BRSV), parainfluenza III (PI

counties. The records covered 11 050 animals between

3) virus, infectious

bovine rhinotracheitis (IBR) and bovine viral diarrhoea

1970 and 1977. Mortality of bought-in calves is variable

(BVDV) virus.

according to the rearing system used. However, a figure

The bacterial pathogens involved form a very long

of 5.5 per cent is usual and it can be suggested that

list and one or more tends to be isolated from most cases

about half these deaths are due to enzootic pneumonia.

of disease. It is often postulated that these may be sec-

This was seen in the Thomas study, which showed a

ondary invaders after primary damage by mycoplasma

death rate of 2.7 per cent from pneumonia out of a total

or viruses. The most commonly isolated organisms are

mortality of 5.9 per cent. The overall number of animals

Mannheimia haemolytica, Pasteurella multocida and treated for pneumonia was 32.6 per cent although the

Haemophilus spp., especially Haemophilus somnus. In levels on individual farms varied from 3.1 to 52 per cent.

addition, cases that involve toxaemia often include

Recent routine studies of individual outbreaks pro-

Arcanobacterium (formerly Actinomyces, Corynebac-
duced an overall incidence of signs of 68.4 per cent
terium) pyogenes and Fusobacterium necrophorum. M.
(range 41.7–90.5 per cent) (Andrews, 2000). It should
haemolytica serotype A1 is the most common serotype
also be remembered that some calves require more
isolated, although serotype A6 is becoming increasingly
than one treatment for pneumonia. Again, there are
common. The organism has also been involved in pleu-
few records for this but a level of retreatment of 10 per
ropneumonia problems. The involvement of bacteria in
cent of all susceptible animals is probably not unrealis-
this complex condition of enzootic pneumonia is also
tic. The recorded level was 8.9 per cent being treated
enforced by the fact that in most naturally occurring
on more than one occasion over a five-year period
outbreaks of disease there is some clinical response fol-
(Thomas, 1978) in a group of 2040 animals of which 22
lowing the use of antibiotics.

per cent became ill initially. Another problem is that
besides mortality, calves may become chronically

affected and fail to thrive. Culling probably doubles the

The environment

mortality due to disease and a level of 3.6 per cent was

Various factors in the environment tend to be consid-

found in the study by Thomas. The reduction in

ered to be important. There is a popular belief that the

liveweight gain in animals treated for pneumonia but

disease is often associated with low environmental tem-

which were not culled or died, compared with those

peratures and a high humidity (see p. 974). Often a res-

untreated, was found to be 2.6 per cent (Thomas et al., piratory problem is associated with a sudden drop in

1978). A study of eight outbreaks on dairy herds in

temperature 24 to 72 hours previously. It is thought that

1997–99 showed an average cost per ill animal of £43

the cold may allow infection to flare up partly by affect-

and a cost per animal within the group of £30. Veteri-

ing the respiratory defence mechanisms and it also

nary and medicine costs amounted to only 40 per cent

allows disease spread by encouraging calves to huddle

of the total costs of the outbreak (Andrews, 2000).

together. It appears that the alveolar macrophages, cil-

iated and mucus-secreting cells are susceptible to the

Aetiology

environment and cold stress inhibits clearance from the

A large number of different infectious agents have been

lungs. In the cold, animals reduce heat loss by slowing

isolated and suggested to be involved in the aetiology

down their respiratory rate and by a partial reduction

of both chronic and acute calf pneumonia. Often the

in the pulmonary ventilation rate (Webster, 1981b).

enzootic form is called 'viral pneumonia'. However, it

This causes a reduced pulmonary oxygen tension and it

is generally considered this term is a misnomer as it pre-

has been shown that hypoxia reduces the clearance rate

supposes the aetiology and in most cases, even when

of some organisms in mice (Green & Kass, 1965), and

viral agents are present, they only form part of the

there is a reduction in mucociliary rate and alveolar

disease complex. It is usually considered that the most

phagocytic activity (Thomson & Gilka, 1974). The prob-

important agents involved in the chronic or cuffing *able role of hypoxia in respiratory infection is indicated*

form are mycoplasmal. They include Mycoplasma

by the fact that most lung consolidation occurs in the

dispar and Ureaplasma spp. When it comes to the acute ventral parts of the apical and cardiac lobes and these

form there is a very long list of pathogens. Many have

tend to be the areas of lowest oxygen tension and the

been seen in the disease but may not necessarily have

slowest rate of clearance of pathogens (Veit et al., 1978).

produced the problem experimentally (see Table 17.1).

At times, outbreaks of disease occur with a high tem-

However, certain agents do seem to be more commonly

perature and a low humidity. Thus rearing at a temper-

Table 17.1

Infectious causes of enzootic pneumonia. The cause is often multifactorial, probably often mycoplasmal infection followed by viral and bacterial causes.

Viruses

Mycoplasmas

Bacteria

Respiratory syncytial virus (BRSV)a

Mycoplasma bovirhinis

Mannheimia (Pasteurella) haemolytica a

Parainfluenza virus II

M. dispar a

P. multocida a

Parainfluenza virus III (PI3)a

M. mycoides subsp. mycoides

Arcanobacterium (Actinomyces, Corynebacterium)

Reovirus types 1,2,3 (Reo)

(little importance in Europe)

pyogenes a

Bovine viral diarrhoea virus (BVDV)a

M. alkalescens

Streptococcus pneumoniae

Adenovirus types 1,2,3,4

M. arginini

Staphylococcus aureus

Enterovirus

M. bovis a

Strep. bovis

Rhinovirus type 1 (RV)

M. canis

Staph. epidermidis

Infectious bovine rhinotracheitis

M. bovigenitalium

Strep. mitis

(IBR)a

Acholeplasma laidlawii

Strep. faecalis

Respiratory bovine coronavirus

A. modicum

Aerococcus viridans

A. axanthum

Acinetobacter spp.

Ureaplasma spp.a

Micrococcus luteus

Ureaplasma diversum

Staphylococcus spp.

Leach's group 7 mycoplasmas

Neisseria spp.

Chlamydiales spp.

Actinobacillus lignieresii

Klebsiella spp.

Corynebacterium bovis

C. xerosis

Streptococcus spp.

Aerococcus spp.

Haemophilus spp.

Haemophilus somnus a

Aeromonas spp.

Bacillus spp.

Alcaligenes faecalis

Micrococcus roseus

Micrococcus spp.

Escherichia coli

Fusobacterium necrophorum a

a Thought to be the most important causes.

ature of 21°C (70°F) and 47 per cent relative humidity

October and December and the second from February

(RH) predisposed Friesian and Jersey calves to respi-

to May (Thomas, 1978). A study of a veal-calf unit over

ratory disease compared with those kept at a tempera-

a 14-month period showed extensive outbreaks of

ture of 14°C (60°F) and 36 per cent RH (Roy et al., *disease in October, April and early June (Miller et al., 1971). It does seem that a high relative humidity may*

1980).

be beneficial at a high environmental temperature as it

The relationship between season and respiratory

increases the sedimentation rate of airborne particles

disease is probably partly due to management influ-

and thereby reduces the bacterial count of the envi-

ences, particularly the housing of animals in close prox-

ronment. These factors have formed the basis for the

imity, thereby assisting in the build-up and transfer of

establishment of the sweat box system for pigs

infection. However, the correlation between weather

(Gordon, 1963) and this is why water drips are often

and disease is harder to prove, and in a disease outbreak

used in buildings for veal production.

involving veal calves no relationship was found (Miller

Although it is generally recognized that respiratory

et al., 1980). A sudden drop in environmental tem-

disease commonly occurs at certain times of the year,

perature is often followed one to three days later by an

and under certain weather conditions, it is only recently
outbreak of respiratory disease in housed, dairy-bred
that attempts have been made to determine why. In
calves or housed single-suckler calves (Wiseman, 1978).
housed dairy-bred calves on one farm two peak levels
Pneumonia in Irish calves housed in naturally venti-
of enzootic pneumonia occurred; the first was between
lated buildings also tended to be precipitated by change

in weather, such as frost, rain and wind or damp, humid
authors (Wiseman, 1978) that it is the collection of a
conditions (Bryson et al., 1978).
large number of young calves of a similar age and
Body temperature regulation in cattle is well devel-
putting them into the same air space that is the main
oped, so they can tolerate both heat and cold (Webster,
reason for the problem of pneumonia in intensively
1981a). However, draughts in buildings can result in
reared calf systems. It is not always accepted that the
chilling, which increases the metabolic rate and perhaps
number of calves in a single air space is more important

reduces resistance to infection (Webster, 1981b), but
than the air space or floor area per calf. However, over-
high relative humidity on its own does not chill cattle
crowding is a major factor in allowing disease develop-
(Webster, 1979). Webster (1981b) therefore postulated
ment and spread. Other factors involved in increasing
that the main effect of weather was compounded by the
disease levels are the inadequate cleaning and disinfec-
building itself. Thus a badly constructed building with
tion of the building between batches, as well as not
poor ventilation would reduce ventilation rate, and the
allowing the accommodation sufficient rest between
water-carrying capacity of the air would be detrimen-
calf intakes. In some cases younger animals are mixed
tally affected by bad ventilation and possibly poor
with an older group, thereby allowing transmission of
drainage. Such conditions could lead to the relative
micro-organisms from the old, apparently clinically
humidity remaining at more than 90 per cent for several
normal animals. Economic considerations may also
days, and this in turn would increase the survival and

influence the picture if there is a reluctance to employ

spread of pathogenic organisms. Some support for this

preventive measures such as vaccination, etc. Several

view has been obtained by work showing an increased

management procedures such as castration, disbudding

survival of small airborne bacteria at high relative

and weaning all appear to have an effect on the level of

humidities (Jones & Webster, 1981). There is thus an

disease. The importance of microbial agents is indirectly

increase in the number of infective particles that are not

indicated by the importance of adequate uptake of

removed in the nasal passages and these are deposited

colostrum (Phillips, 1975; Thomas, 1979).

further down the respiratory tract, possibly causing

disease.

The calf

There appear to be some breed differences in suscepti-

Management

bility to respiratory disease and Friesian and Jersey

The time of weaning appears to be important in that

calves are more likely to be infected than Ayrshire or *more lung lesions are found in calves weaned at five*

Hereford ¥ Friesians (Roy, 1980). It has been postulated

weeks than those on an ad libitum milk substitute diet that this may be due to an increased skin thickness in

until 14 weeks old (Roy et al., 1971). The reason for this some breeds, which provides better insulation.

is not clear but it might be due to the lower levels of

energy intake, or lower availability of a micronutrient

Signs

(Roy et al., 1971); or perhaps inhaled dust or fungal

spores, which are more prevalent when dry feed is

Chronic: The condition is one of gradual onset. There

eaten, exacerbate the problem (Lacey, 1968); or due to

is generally no illness and so the calf is bright, eats well,

weaning being less stressful or the calf more resistant

but it may have a slight mucoid or mucopurulent oculo-

to respiratory disease at an older age.

nasal discharge. The temperature is normal or slightly

There is a relationship between colostral antibody

raised at 38.5–39.5°C (101–103°F); the respiratory rate

levels and respiratory disease (Thomas & Swann, 1973).

may be at any level from normal to 100 per minute with

This apparent resistance to disease might be due to the

a normal pulse. There is a dry, explosive cough that is

ingestion of increased levels of specific antibody or due

usually produced singly. On chest auscultation there are

to an indirect effect resulting from a reduced amount

noises of whistling, wheezing or squeaking and these

of enteric disease, or possibly the gradual reduction in

are more commonly heard at expiration, although often

passive immunity allowing a more orderly exposure of

they occur at both inspiration and expiration. The

the calf to respiratory pathogens. When colostral anti-

sounds are most common in the anterior and ventral

bodies are low there is a relatively fast loss of antibody,

parts of the chest.

which may then allow the invasion of many pathogens

(Williams et al., 1975).

Acute: Although one calf may be seen to be ill to begin The purchase of a large number of calves from dif-with, several animals will usually become sick within the

ferent sources for dairy and beef production and

next 24–48 hours. There is normally a reduction in feed

keeping them in the same housing allows the easy *intake of the group and widespread coughing will be*

spread of potential respiratory pathogens to other

apparent. The affected animals appear dull and the

animals in close proximity. It is considered by many

head tends to be carried lower than normal. There is

inappetance, pyrexia (40–40°C, 104–107°F) and a dull,

to bronchiolar necrosis; there are basophilic and

sweaty coat. Other signs including a mucoid or mucop-

eosinophilic intranuclear inclusion bodies in epithelial

urulent oculo-nasal discharge, tachypnoea (respirations

and other cells. Intranuclear inclusion bodies, particu-

are usually over 40 per minute), dyspnoea and hyperp-

larly in the epithelial cells of the trachea and bronchi,

noea are normally present. In all but very severely ill

are seen in IBR.

calves there tends to be an increase in the amount of

Type 2. There is often marked consolidation of the

coughing; the cough itself may be of a harsh, dry,

cranial lobes with red or red/grey hepatization with

hacking type, but in others it will be moist. Pinching the *widespread tissue necrosis and in many cases sup-*

upper trachea often elicits a cough. On auscultation of

puration and this may involve up to 70–80 per cent of

the thorax there are usually loud, harsh sounds or

the lung. This type of lesion is often characteristic of

whistling, wheezing or squeaking. These sounds may be

bacterial infection.

Extensive consolidation and

present at inspiration or expiration, but more com-

suppuration are particularly seen in A. pyogenes and monly they are heard at the latter and in some cases

F. necrophorum infections.

there are fluid sounds such as bubbling or gurgling,

which will be audible in the cranio-ventral parts of the

Type 3. This is characteristic of calves that suddenly

lungs. In some bacterial infections, where there is

develop respiratory distress. The syndrome is often

marked lung consolidation, few sounds are present.

called atypical interstitial pneumonia. At post-mortem

examination there is interstitial emphysema, pulmonary

Necropsy

oedema and congestion, with alveolar epithelial hyper-
plasia and hyaline membrane formation.
Chronic: Lesions tend to be confined to the ventral
Besides the lungs, there is usually gross enlargement
parts of the lung lobes and involve, in decreasing sever-
and congestion of the mediastinal and bronchial lymph
ity, the apical, cardiac and cranial parts of the caudal
nodes. In some cases there is fibrinous pleurisy and the
lobes. The area involved may be 5–40 per cent of the
heart may be enlarged with epicardial and endocardial
lung tissue and it tends to be red or purple in colour
haemorrhages. Sero-sanguinous fluid may be present in
and to be indurated. Histologically, there are accu-
the thorax and pericardial sac (Thomas, 1979).
mulations of lymphocytes in the peribronchiolar tissue
Lesions of pleuropneumonia result in a thickened
and it is this that produces a cuff; macroscopically it is
pleura with the lung showing thickened interlobular
seen as a mottling of the lesion's cut surface. When
septa with variable amounts of lung censolidation
accumulation is great, then the lymphocytes can cause

showing dark red to grey hepatization.

a narrowing of the bronchiolar lumen and cause the sur-

rounding alveoli to be compressed. Resolution of the

lesions occurs over several months provided that they

Diagnosis

are uncomplicated. The bronchial and mediastinal

Chronic: Several animals are affected and are

lymph nodes are usually enlarged and there is often a

usually indoors. The problem is gradual in onset and

fibrinous pneumonia.

although the animals show respiratory signs they are

bright and eat well. The respiratory signs include single,

Acute: Within the clinical entity of acute pneumonia

dry coughing.

there are three types of pathological entity that can be

recognized involving the lungs (Pirie, 1979).

Acute: Again this affects a group of calves. Respiratory Type 1. There is localized consolidation particularly

signs are present and the animals are usually obviously

of the cranial lobes and the tissue is dark red, friable

ill. Nasopharyngeal swabs or broncho-alveolar lavage *and there is no gross evidence of necrosis. Interstitial can be undertaken to examine for bacterial, viral or emphysema may be present. Histologically, there is an mycoplasmal presence. The last two groups require absence of peribronchiolar cuffing, but there is necrosis placement in a transport medium. Fluorescent antibody of the bronchiolar epithelium. The changes are often tests are available for most of the more important viral suggestive of a viral infection, but in many cases the causes. Even when a potential pathogen is recovered it presence of a virus cannot be proven because of the does not always mean that it is the same agent as is absence of inclusion bodies or positive immunofluores-causing trouble in the lungs. Paired serum samples can cence. PI3 infection can be suspected when there is be taken two weeks apart. This may indicate the cause alveolar and bronchiolar epithelium proliferation and but is only of value if control measures can then be eosinophilic intracytoplasmic inclusion bodies are implemented for the future. Post-mortem material can present. RSV infection can result in alveolar epithelium* *be cheeked for the presence of organisms and for*

hyperplasia and large multinucleate syncytial cells.

histology to indicate the type of pathogen which might

Bronchial collapse occurs with adenovirus infection due

be involved.

Differential diagnosis

tion, so that it is often a good policy to persuade the

farmer to treat all the cattle in the group, ideally using

Chronic: This needs to be differentiated form acute

a different antibiotic. As with most disease, the earlier

pneumonia but in the latter case the animal is ill. In-

treatment is started, the less the mortality and the fewer

halation pneumonia is likely only to involve a single

the animals that have to be culled because of chronic

animal, which again is ill, and there is usually a related

disease. The drugs commonly used are given in Table

history. Tuberculosis may cause problems but usually

17.2. The therapeutic agent administered should have a

there is a herd history and the dam may be showing

broad spectrum of activity and ideally it should be bac-

signs. Muscular dystrophy (see p. 258) can produce res-
tericidal. The choice will most probably have to be
piratory signs but usually such animals have a fast pulse
based on previous successful usage on that farm or else-
rate and raised serum creatine kinase, and aspartate
where. It is best not to use long-acting preparations
and aminotransferase levels. Congenital heart defects
because if there is no response to treatment it will make
(see pp. 173–4) will usually only involve one animal and
the initiation of subsequent therapy very difficult. If an
there is a heart murmur, possibly with signs of cyanosis.
animal dies then culture of swabs from the lung,
Salmonellosis can result in signs but the calf is
bronchial and mediastinal lymph nodes and the subse-
noticeably ill with diarrhoea (see p. 226).
quent antibiotic sensitivity of the isolates may be of use.
The ideal is to culture swabs from material in carcasses
Acute. Chronic pneumonia is a major differential di-
that have not been treated. The culture of nasal or pha-
agnosis but the animals are not really ill in such cases.
ryngeal swabs from live infected calves is of less value

Uncomplicated IBR infection (see p. 289) could cause

as it cannot be certain that the organism cultured will

difficulties but there are mainly upper respiratory signs

be the same as the one causing disease in the lungs.

and a noticeable conjunctivitis. Salmonellosis (Chapter

However, it does indicate possible pathogens.

15) will usually present with enteric signs. Although

Therapy should be continued for three to five days,

mucosal disease (see p. 853) can give rise to respiratory

depending on the drug used and the response to treat-

signs, there is usually also diarrhoea and, in some

ment. In acute cases the choice of antimicrobial agent

cases, mouth ulceration. Inhalation pneumonia mainly

is normally dictated by those that can be given intra-

involves a single animal and there is an appropriate

venously. Intratracheal administration of antibiotics has

history. Tuberculosis will be detected by a history of

been advocated by some practitioners and in such cases

disease in the herd. Congenital heart defects (see pp.

those in aqueous solution are preferable to those in

173–4) involve a single animal and there is usually a *organic solvent. No antibiotic is at present licensed in*

heart murmur. Calf diphtheria (see p. 251) results in

Britain for this route of administration. Those com-

stertor and is again a single animal problem. Malignant

pounds most commonly used have included erythro-

catarrhal fever (see p. 935) affects single animals and

mycin, trimethoprim and sulphadoxine.

there is lymph node enlargement, corneal opacity and

often nervous signs present. Acidosis (p. 829) can mimic

(2)

Corticosteroids. Some of the compounds avail-

pneumonia.

able are shown in Table 17.3. The drugs commonly in

use today include betamethasone, dexamethasone,

Treatment

prednisolone, flumethasone and triamcinolone. These

Chronic: Therapy is usually not necessary unless the calf compounds provide symptomatic relief only and do not

is showing severe coughing. Several antibiotics are of

cure the condition. Many people consider them to be

use, including tylosin at 4–10 mg/kg (2–5 mg/lb) body *overused (Pirie, 1979), but often an animal will show weight, oxytetracycline at 10 mg/kg (5 mg/lb) body little or no improvement on antibiotic therapy alone, weight, spiramycin at a dose of 20 mg/kg (10 mg/lb) only to recover rapidly once corticosteroids are added body weight of spectinomycin at 20–30 mg/kg (10– to the treatment regimen. Their action is to suppress all 15 mg/lb) body weight. The macrolide antibiotics stages of inflammation regardless of whether the cause (tilosin, erythromycin, spiramycin) are all concentrated is physical, chemical or immunological in origin. Thus in the lungs and have good efficacy against mycoplasmal in the acute stage, corticosteroids reduce vasodilation, infections. The fluorquinolones have activity against oedema formation and leucocyte infiltration (Eyre, mycoplasma but probably cannot be recommended for 1978). The drugs also have a 'euphoric' effect on the this purpose due to human health implications.*

dull animal and this may allow the calf to eat and otherwise speed its recovery (Pirie, 1979).

Acute:

The main problem with corticosteroids is the unse-

(1) Antimicrobials. If more than 30 per cent of the

lective suppression of inflammation that therefore

animals are affected at one time and need treatment it

includes those parts of the inflammatory and immune

is probable that many others are incubating the condi-

response, such as macrophage infiltration, which are

Table 17.2

Some of the antimicrobial compounds used in calf pneumonia therapy.

Antimicrobial

Bactericidal (C) or

Route of

Dosage

compounds

bacteriostatic (S)

administration

(mg/kg)

(mg/lb)

Amoxycillin

C

i.v., s.c., i.m., oral

7 (15 LA)

3.5 (7 LA)

Amoxycillin and

C

i.m., s.c.

8.75 (am)

4.38 (am)

clavulanic acid

1.75 (cl)

0.88 (cl)

Ampicillin

C

i.v., s.c., i.m., oral

2–7

1–3.75 (7.5 LA)

Baquiloprim and

C

oral

4–8 (baquil)

2–4 (baquil)

sulphamidine

36–72 (sulpha)

18–36 (sulpha)

Ceftiofur

C

i.m.

1

0.5

Chloramphenicol (some countries)

S

i.v., s.c., i.m., oral

4–10

2–5

Danofloxacin

C

i.m.

1.25

0.6

Enrofloxacin

C

s.c.

2.5 or 7.5

1.25 or 3.75

Erythromycin

S

i.m.

2.5–5

1.25–2.5

Florfenicol

S

s.c., i.m.

40 (s.c.), 20 (i.m.)

20 (s.c.), 10 (i.m.)

Marbofloxacin

C

i.v., s.c., i.m.

2

1

Oxytetracycline

S

i.v., s.c., i.m., oral

10 (20 LA)

5 (10 LA)

Penicillin plus

10–15 (pen)

5–7.5 (pen)

streptomycin

C

s.c., i.m.

10–20 (strep)

5–10 (strep)

Spectinomycin

C

i.m.

12.5–30

6.25–15

Spiramycin

S

i.m., oral

20

10

Sulphadimidine

S

i.v., s.c., oral

initial

200

100

maintenance

100

50

Sulphamethoxypyridazine

S

s.c., i.m.

22

11

Sulphapyrazole

S

i.v., s.c., i.m.

30–100

15–50

Tilmicosin

S

s.c.

10

5

Trimethoprim and sulphadiazine

C

i.m., oral

15–22.5 (active)

7.5–12 (active)

Trimethoprim and

sulphadoxine

C

i.m.

15 (active)

7.5 (active)

Tylosin

S

i.m., oral

4–10

2–5

LA, long-acting; am, amoxycillin; cl, clavulanic acid; baquil, baquiloprim; sulpha, sulphadimidine; pen, penicillin; strep, streptomycin; active, active ingredients.

Table 17.3

Corticosteroids used in respiratory disease in *immune response can also increase the ability of the*

calves.

same organisms to reinfect the animal following re-

covery. It is therefore essential that antibiotic therapy

Drug

Dose per animal (mg)

is administered concurrently with corticosteroid therapy

and in most circumstances it is probable that a bacteri-

Betamethasone

2–10

cidal drug is indicated rather than a bacteriostatic drug.

Cortisone

up to 500

Adequate therapeutic doses of the antibiotic should be

Dexamethasone

2–5

given and maintained for sufficient time. Another

Flumethasone

0.5

problem with the prolonged use of corticosteroids is

Hydrocortisone

up to 300

that there is a risk of inducing permanent adrenal insuf-

Prednisolone

up to 20

Triamcinolone

up to 5

ficiency, but this has produced little worry in cattle.

(3)

Non-steroidal anti-inflammatory drugs

(NSAIDs) (see Chapter 62). These drugs are salicylate-

concerned with the control and removal of infectious

like compounds and although many are not registered

organisms. In such an environment an organism can

for use in cattle, they do help reduce inflammatory

multiply and spread within the animal. This may be the

reactions by blocking the synthesis of prostaglandins

agent that caused the pneumonia or an opportunist

and inhibiting kinin formation (see p. 1050). They

organism that enters the body. The reduction in the

also antagonize the actions of some of the chemical

Table 17.4

Some non-steroidal anti-inflammatory drugs.

Route of administration

Dosea

Acetyl salicylic acid

Oral

1.0–4.0 g/animal

Carprofen

Injection (i.v., s.c.)

1.4 mg/kg (0.7 mg/lb)

Flunixin meglumine

Injection (i.v.)

2.2 mg/kg (1.0 mg/lb)

Ketoprofen

Injection (i.v., i.m.)

3 mg/kg (1.5 mg/lb)

Meclofenamic acid

Oral

2.2 mg/kg (1.1 mg/lb)

Meloxicam

Injection (i.v., s.c.)

500 mg/kg (250 mg/lb)

Naproxen

Oral

10 mg/kg (5 mg/lb)

Phenylbutazone

Oral/injection

4.4 mg/kg (2.2 mg/lb)

Sodium meclophenamate

a Doses are only guidelines. Note that many of the drugs are not registered for use in cattle in some countries.

mediators in the lungs such as 5-hydroxytryptamine

others are available and are given. Their actions are re-

(5-HT) and histamine, which are mainly released

latively similar to those of adrenaline. There is stimula-

from mast cells in response to antibody–antigen

tion of the central nervous system where caffeine is the

reactions (Pirie, 1979). Besides an anti-inflammatory

most powerful, myocardial stimulation where amino-

action, NSAIDs have two properties that corticos-

phylline and diprophylline are strongest, bronchodila-

teroids do not possess, namely they are anti-pyretic *tion and diuresis. Their main uses in respiratory disease*

and analgesic. Until the availability of flunixin these

are bronchodilation and, to a secondary extent, fluid

compounds were little used in Britain although they

removal. The mild action of these drugs compared with

are frequently prescribed in Holland where corticos-

substances such as adrenaline means that they are all

teroids are not allowed to be used for respiratory

relatively safe.

diseases in calves. Some of the main drugs available are

(7)

Expectorants. One drug used at present as a

shown in Table 17.4. The drugs most commonly used in

spasmolytic is bromhexine hydrochloride, which can be

Britain are carprofen, flunixin meglumine, ketoprofen

given orally or by intramuscular injection at a dose of

and meloxicam.

about 0.5 mg/kg body weight for five to seven days. Its

(4)

Antihistamines (see Chapter 62). These drugs

action is mainly to reduce the viscosity of mucus and *have been used in the past but most clinicians have found*

thereby help in its expulsion, resulting in improved res-

them to be of little use in calf pneumonia. This is proba-

piratory function. Other expectorants have often been

bly because the main chemical mediator of cattle is not

used in chronic cases of coughing. These include a

histamine but 5-HT. The histamine that is released

mixture of strychnine hydroxide, arsenic trioxide and

occurs very quickly following the antibody–antigen

ferric ammonium citrate given at a dose of about 5 ml

reaction so that antihistamines can only be of use in the

orally twice daily, or diphenhydramine hydrochloride,

early stages of the inflammatory response (Pirie, 1979).

ammonium chloride, sodium citrate and menthol at

5–10 ml orally two or three times daily. There is limited

(5)

Sympathomimetics.

These drugs are all

benefit form the antihistaminic action of diphenhy-

adrenaline-like and their actions to a varying degree are

dramine hydrochloride in cases of calf pneumonia.

similar to it.

(8)

Antisera. Several antisera are available in some

Although both adrenaline and isoprenaline are of

countries that have been produced either in cattle or

some use in relieving respiratory signs, they are little

horses against P. multocida, the septicaemic and pneu-used because of their stimulatory effects on the heart.

monic strains of M. haemolytica and, in some cases,

This is because adrenaline acts on many types of recep-

diplococci. Little experimental work is available to

tors that are designated a and b, those of the heart and

demonstrate their efficacy or lack of it and so their use

lung being b1 and b2 receptors, respectively. Recent

is speculative (Thomas, 1979). As has already been indi-

work has produced compounds that will act on only one

cated there are numerous organisms involved in the

type of receptor and not on the others. For various

aetiology of calf pneumonia and it would be only right

reasons including some of their other potential proper-

to expect benefit in some cases where the organisms in *ties their use has been curtailed in many countries.*

the anti-sera are a major factor in the disease process.

(6)

Xanthine derivatives. Those commonly in use

(9)

Supportive therapy. During the disease phase

are etamiphylline camsylate and diprophylline, but

many animals become partially or completely anorexic

and it has been suggested that multivitamin injections,

year, the time when disease starts should be noted and

particularly of the vitamin B group, may be of use in

checked to see if it can be associated with any changes

overcoming any temporary deficiencies that might

in management, etc. Calves bought as batches should

occur as the result of the low storage of vitamins

be kept together and not mixed with other batches. An

(Thomas, 1979). As vitamin A is of use in epithelial

all-in all-out policy for rearing calves is best advocated.

repair it may be advantageous to inject this compound

Ideally, calves should be reared before and after *to ensure speedy respiratory mucosal regeneration.*

weaning in the same building for at least a month and

preferably longer.

(10)

Nursing. As with many other diseases,

There are various vaccines available and, as might be

although nursing is important, it is often neglected.

expected with a disease of such complex aetiology, the

Affected animals should be removed from the in-

results experienced by different farmers and veterinary

contact group partly to reduce spread of infection and

surgeons are extremely variable (see p. 1007). In some

also to allow access to feed and water away from com-

cases this may be due to the type of vaccine used. It is

petition. Feed supplied should be highly palatable and

thought that the age incidence of enzootic pneumonia

non-dusty to encourage uptake. The environment of the

may well coincide with the decline in colostral immu-

convalescent calf should include plenty of bedding, and

nity. Thus peak onset of pneumonia in housed calves is

draughts must be avoided. The provision of oxygen by *often at two to four months old when concentrations of*

means of a mask and reducing valve has been used in

serum IgG

animals at indoor agricultural and fatstock shows.

1, IgG2 and IgA are at their lowest (Corbeil

et al., 1984). It must also be remembered that several of (11)

Vaccination. It is possible to obtain rapid con-

the pathogens involved in the disease complex are

firmation as to the aetiology of outbreaks of calf pneu-

immunosuppressive. These organisms include M.

monia. If the cause is viral it is possible to use live

dispar, ureaplasmas and M. bovis as well as BRSV. In vaccines and to vaccinate in the face of an outbreak.

consequence, vaccination of calves where the organisms

This can be very effective provided it is undertaken in

are already present in the animals is likely to reduce the

the early stages of disease among the group. It appears

immune response.

to produce non-specific interferon followed by good

Dead vaccines are used to provide immunity against

specific immunity to the virus vaccinated against. To be

P. multocida and septicaemic and pneumonic strains of effective a live vaccine needs to be used and it must be

M. haemolytica. Following successful experiments administered intranasally.

(Gilmour et al., 1979) several M. haemolytica vaccines for serotypes 1 and 6 are now available in Britain.

Killed polyvalent vaccines are used in some countries,

Prevention (see pp. 1007–11)

and contain artigens such as RSV, PI3, IBR and BVDV.

As the disease is multifactorial, preventive measures

They are usually administered parenterally and usually

include attention to management as well as possible

require two injections to produce immunity. Recent

vaccination. Thus ensuring there are no more than 30

developments have included combined live and dead

calves in any one air space as well as making sure that

viral components of the four main antigens which are

different age groups are not mixed is helpful. If disease

injected intramuscularly. When live vaccines are used,

tends to follow particular patterns it is best to alter the

the integrity of the vaccine must ensure absence of

time of undertaking stressful procedures such as

other potential contaminants, both viral and other *weaning, castration and disbudding. Often ensuring cas-*

pathogens. Subsequently, modified live intranasal vac-

tration and disbudding are undertaken more than two

cines have been available. A study of the live IBR

weeks before weaning can be helpful. Increasing the

vaccine in the absence of disease showed virus could be

duration of feeding milk substitute can also be useful,

isolated from most animals (10/11) and there was sero-

as well as ensuring weaning is not undertaken at a time

conversion in 7/11 (Lucas et al., 1982). Although good when this is likely to result in pneumonia. Gradual

immunity was conferred to animals by modified live

weaning is often helpful, particularly when cattle are

vaccination, it was shown that some cattle became car-

fed in groups on a milk dispensing machine that will

riers after exposure to field strains of IBR (Nettleton &

provide feed throughout the 24 hours.

Sharp, 1980).

When calves are home-reared, it should be ensured

A dead vaccine has been produced against M. bovis,

that they receive adequate amounts of colostrum. All *but it has had only limited success experimentally.*

calves should be given adequate good quality feed. If

There are several live vaccines used in Europe includ-

calves are bought-in they should be examined at entry

ing ones against respiratory syncytial virus and parain-

and any which show purulent ocular or nasal discharge

fluenza III virus. A vaccine for PI3 has been licensed and

rejected. Calves should not receive dusty or overmilled

it is possible others will eventually be available in

feed. As disease occurs on the same farms year after

Britain and elsewhere.

From experience, the vaccines themselves do appear

Lacey, J.C. (1968) The microflora of fodders associated with

to have variable results on individual farms. This is pro-

bovine respiratory disease. Journal of General Microbiol-

bably due to the type of vaccine used, i.e. live or dead,

*ogy, **51**, 173–7.*

other underlying pathogens, the level of infective dose

Lucas, M.H., Roberts, D.H., Sands, J.J. & Westcott, D.V.E.

and whether or not the particular pathogens present in

(1982) The use of infectious bovine rhinotracheitis vaccine

in a commercial veal unit: antibody response and spread of

the vaccine are responsible for disease on that farm.

virus. British Veterinary Journal, **138**, 23–8.

Before embarking on a vaccination programme it is

Miller, W.M., Harkness, J.W., Richards, M.S. & Pritchard, D.G.

important to ensure that the pathogens on the farm are

(1980) Epidemiological studies of calf respiratory disease in

correctly identified so that the programme can be intro-

a large commercial veal unit. Research in Veterinary Science, duced correctly. Such regimens will usually work well

28, 267–74.

on farms housing just home produced cattle. However,

Nettleton, P.F. & Sharp, J.M. (1980) Infectious bovine rhino-there is a particular problem for farmers who continu-

tracheitis virus excretion after vaccination. Veterinary

ally buy in batches of calves as the pathogens intro-

Record, **107**, 379.

duced with each group are likely to be different. Thus

Phillips, J.I.H. (1975) Bovine respiratory disease. In Veterinary it is very difficult to create a suitable vaccination policy

Annual, 15th issue (ed. by C.S.G. Grunsell & F.W.G. Hill), pp. 13–15. Wright, Bristol.

to prevent pneumonia, unless several vaccines are used

Pirie, H.M. (1979) Respiratory Diseases of Animals, pp. 68–70.

to cover most of the major pathogens. Such a policy is

Notes for a Postgraduate Course, Glasgow Veterinary

obviously costly and at times very wasteful as it will

School.

result in immunization for diseases that are not present.

Roy, J.H.B. (1980) The Calf, 4th edn. Butterworth, London.

This has led to the suggestion that in such units it is best

Roy, J.H.B., Stobo, J.F., Gaston, H.J.G., Anderton, P., Shotton, to make a diagnosis as to the likely cause of enzootic

J.M. & Ostler, D.C. (1971) The effect of environmental tem-pneumonia in the first animal(s) to be affected. If the

perature on the performance and health of the preruminant

agent is primarily viral then the calves can be vacci-

*and ruminant calf. British Journal of Nutrition, **26**, 363–81.*

nated in the face of an outbreak.

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situation in the UK. In Respiratory Diseases of Cattle.

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Martin), pp. 57–65. Martinus Nijhoff, The Hague.

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clearance of bacterial aerosols emphasizing aspects of

in serum and nasal secretions of calves at the onset of

particular relevance to veterinary medicine. Canadian

*pneumonia. American Journal of Veterinary Research, **45**, Veterinary Journal, **15**, 99–107.*

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Webster, A.J.F. (1981a) Optimal housing criteria for rumi-

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titative studies on bovine immunogobulins. Veterinary

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*Record, **96**, 81–4.*

*British Journal of Experimental Pathology, **46**, 360–6.*

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Jones, C.R. & Webster, A.J.F. (1981) Weather-induced changes disease. In Respiratory Diseases of Cattle. Current Topics in in airborne bacteria within a calf house. Veterinary Record, Veterinary Medicine, Volume 3 (ed. by W.B. Martin), pp.

***109**, 493–4.*

149–57. Martinus Nijhoff, The Hague.

Chapter 18

Other Calf Problems

A.H. Andrews

Stillbirth/perinatal weak calf syndrome

249

have enlarged thyroids (greater than 14 g is suspect),

Joint ill or navel ill

249

parturition is slow and often there are retained placen-

Oral and laryngeal necrobacillosis

250

tae. Poor fertility may be seen with suboestrus and

Oral form

250

delayed ovulation, lowered milk yield, lowered libido in

Laryngeal form

251

bulls, ill thrift in cattle and lowered herd immunity.

Meningitis

251

Otitis

252

Bovine papular stomatitis (BPS)

252

Joint ill or navel ill

Calcium, phosphorus and vitamin D deficiency

253

(see p. 455)

Copper deficiency

254

Hypomagnesaemic tetany of calves

255

Joint or navel ill is a common problem in the calf. At

Vitamin A deficiency

256

birth there is a sudden change from the fetal circulation

Iodine deficiency

257

to that of the newborn calf. The blood vessels in the

Iron deficiency

258

umbilical cord rapidly lose most of the blood within

Selenium/vitamin E deficiency

258

them but still remain patent, thereby allowing the in-

Zinc deficiency

260

troduction of infection. Infection can be caused by a

Furazolidone poisoning

260

single organism or a mixture. A wide variety can be

Iodism

261

involved including Streptococcus spp., Escherichia coli, Cerebrocortical necrosis (CCN, polioencephalomalacia)

261

Erysipelothrix insidiosa, Pasteurella multocida, Arcano-Urolithiasis

263

bacterium (Actinomyces, Corynebacterium) pyogenes

and Fusobacterium necrophorum. The problem nor-

mally arises from calving taking place in conditions with

Stillbirth/perinatal weak

poor hygiene. Often the calf will not have had sufficient

calf syndrome

intake of colostrum and usually the navel will not have

been treated. Many infections also enter via the tonsils.

This is an important cause of losses in the young calf

Infection entering the umbilicus may result in a local

and has considerable economic consequences to the

reaction at the point of entry into the body, between the

farmer. Very few studies have been undertaken to

muscle layers or in the peritoneum. In other cases entry

determine the factors involved. However work done in

is via the urachus and can lead to local infection. Other-

Northern Ireland (McCoy et al., 1997) showed that

wise the bacteria may pass via the umbilical vein to

nearly half (46 per cent) of the animals examined had

the liver and then in the blood to the body. When infec-

non-inflated lungs and so were true stillbirths and

tion is present in the blood it may cause a septicaemia

another 22.7 per cent had severe trauma (mainly rib or

or eventually result in chronic illness due to localization

spinal fractures) from calving. Otherwise the largest

in organs such as the heart, brain, eye and most often

number of weak calves (36.7 per cent) had thyroid

the joints, leading to joint ill.

abnormalities and within the study 20 per cent had low

thyroid iodine levels. Other problems were of an infec-

Signs

tious nature including leptospirosis (13.4 per cent),

pneumonia (9.1 per cent) and bacterial isolation (9 per

The signs vary and can be restricted to local inflamma-

cent); virus isolation was low.

tion of the navel or the abdominal wall muscles. In such

Iodine deficiency is more common than recognized in

cases the navel is swollen, soft and usually painful. The
suckler herds and dairy and suckler heifers who receive
umbilical blood vessels are swollen at their base. Local-
limited feed supplementation. The problem normally
ized peritonitis may be difficult to detect. Where there
arises from increased calf mortality as abortion, still-
is septicaemia, the calf rapidly becomes ill with depres-
births, weak calves and neonatal mortality. The calves
sion, pyrexia (40.5°C, 105°F) and accelerated respira-

tory and pulse rates. The mucous membranes become
the animals are dehydrated, parenteral or oral elec-
reddened and there are often petechial haemorrhages.
trolyte solutions will be required. In the more localized
There may be a varying degree of dehydration, followed
forms involving the navel or urachus, the infected ma-
later by acidosis, recumbency and death.
terial should be removed. There are problems in the
In cases of bacteraemia that localize, the signs are
treatment of localized chronic infection such as joint

often missed for several weeks or even months. In some ill. In some cases the use of potentiated sulphonamides animals there is inappetance, dullness and an intermit- or lincomycin by injection has given good results. Surgi- tent slightly raised temperature (39–40°C, 103–104°F). cal opening of the joints with removal of pus and Other signs depend on the organs affected. When there affected tissue and joint flushing can be useful. Slow is local infection of the urachus the animal will become release gentamicin polymethylmethacrylate (PMMA) unthrifty and slightly slow to move. There may be a beads have been used in cases of septic arthritis with slightly raised tail with micturition. In animals with evidence of concurrent osteomyelitis. The beads are localization in the heart valves, endocarditis results inserted after debridement of osteomyelitic bone via an with a heart murmur. If the eye is involved there is arthrotomy incision or with arthroscopic examination. panophthalmitis with hypopyon. In the case of menin- Success rates in early cases have been good (Butson, gitis there is likely to be nystagmus, hyperaesthesia

1994).

and tonic–clonic convulsions. The most common form

Control is dependent on whether the calves are on

is joint ill and one or more joints may be involved. In

their farm of origin or have been bought-in. If the

many cases there is bilateral involvement with pain and

former, then all navels should be dipped immediately

swelling, commonly of the carpal joints. Aspiration of

after birth in an appropriate disinfectant. Tincture of

the affected joints usually reveals thick pus. The animal

iodine or iodine teat washes are useful for this purpose.

tends to become lame and to have an altered stance.

Generally they allow the navel to be sterilized and help

to cause desiccation. Antibiotic aerosols are used but it

is often difficult to ensure the whole navel is completely

Necropsy

covered. In purchased animals the navels should be

Post-mortem examination may reveal the presence of

examined, and calves with enlarged navels rejected. The

infection in the umbilical vessels, which are swollen and

joints of the animals should also be inspected. The *contain blood. There may be localized peritonitis. In the*

navels should be dipped in an appropriate disinfectant

septicaemic form petechial and ecchymotic haemor-

solution on arrival at the farm.

rhages are evident on the subserosa and submucosa of

various organs. In the more chronic form various organs

Oral and laryngeal necrobacillosis

will show inflammation and abscessation.

This is also known as calf diphtheria and there are two

Diagnosis

forms: oral which is most common, and laryngeal. The

Diagnosis is aided by the presence of a swollen navel

condition is caused by Fusobacterium necrophorum.

as well as by the signs. There may be a neutrophilia and

blood culture may be helpful. The main difficulty is in

***Oral form** (see also p. 822)*

differentiating the condition from other forms of enteri-

This is quite common and is usually sporadic in occur-

tis, septicaemia and locomotor problems such as mus-

rence although there may be outbreaks where hygiene

cular dystrophy (see p. 258). If surgery is contemplated *is poor. In such cases it is probably spread by dirty milk*

it is best to X-ray the joint lesions first.

pails, machine teats or feeding containers. Individual

cases sometimes occur where fibrous and coarse food is

Treatment and control

offered. Although mainly seen in housed calves, it can

also occur at pasture. Affected calves are usually up to

Treatment of the septicaemia will usually involve

three months old and often have intercurrent disease,

the use of antimicrobials, which in the main should be

nutritional deficiency or their teeth are erupting. The

given intravenously. Appropriate antibiotics include

incubation period is about four days.

amoxycillin, ampicillin, oxytetracycline, sulphonamides

or potentiated sulphonamides. Chloramphenicol can be

Signs

of use in some countries and florfenicol has been used

successfully although not licensed for the purpose. In

The major sign is a swelling of the cheek, particularly

less severe cases other treatments such as penicillin and

in the region of the first cheek teeth. The calf is often *streptomycin may be given by the parenteral routes.*

bright and active with a normal temperature. Opening

The duration of therapy should be at least five days. If

the mouth reveals a necrotic swelling in the cheek, in

which may be impacted food material, and there may

In the oral form, parenteral or oral therapy is usually

be a foul smell. The animal may salivate a little. In a few

successful. Suitable antibacterial agents include oxy-

cases there is also involvement of the tongue, which

tetracycline, potentiated sulphonamides, streptomycin,

may become swollen and protrude from the mouth. Ne-

sulphonamides orally or parenterally or penicillin par-

glected cases may extend to the nasal cavity, pharynx,

enterally. Therapy for three to five days is usually suffi-

lungs, abomasum and coronets of the legs.

cient in the oral form. When the animal is inappetant

it should be encouraged to eat. In the laryngeal form,

Necropsy

therapy needs to be continued for longer (e.g. 2–3

weeks) and should be parenteral. If breathing is very

On post-mortem oral lesions are usually well circum-

laboured then it may be necessary to undertake a tra-

scribed with an area of oedema and a necrotic centre.

cheotomy and insert a tracheal tube. In some cases

If the necrotic area is lost, an ulcer is seen.

success is only achieved by surgical removal of the

necrotic area and then using an intratracheal tube until

Diagnosis

the laryngeal oedema has reduced.

The main differential diagnoses are foreign bodies in

the mouth, papular stomatitis, mouth and jaw injuries

Control

and BVD/mucosal disease. All are quite easy to elimi-

If more than a single case occurs, hygiene should be

nate by thorough oral examination.

improved. The calves should be fed with their own

buckets and quality feed should be used. The milk and

Laryngeal form

water buckets should be cleaned and disinfected after

This form is less common and is sporadic in occurrence.

each feed and the feed bucket disinfected at least twice

It has been seen in animals up to and over a year old.

a week. Occasionally, it is necessary to give oral antibi-

otics as a prophylactic measure. Suitable agents include

chlortetracycline and oxytetracycline.

Signs

These cattle tend to be dull with inappetance or

anorexia. Often there is pyrexia (40.5°C, 105°F) and

Meningitis *(see p. 901)*

there may be stertor. Usually respirations are dyspnoeic

to a varying degree. There may be a cough that is moist

This is an inflammation of the meninges. The condition

and painful. Palpation of the larynx is resented and can

is uncommon and most often occurs following a pre-

elicit the cough. The mouth may be foul smelling. Many

existing disease such as septicaemia. The organisms

of these animals do not respond well to treatment and

that can be involved are usually bacteria and include

the diphtheritic area may become detached resulting in

Listeria monocytogenes, Escherichia coli, Pasteurella sudden asphyxiation or lung infection.

multocida and Haemophilus somnus. A secondary meningitis can follow infection with Mycobacterium

Necropsy

bovis. Although most cases are haematogenous in

origin, a few result from spread of local infection or can

The lesion in the larynx is normally well embedded into

follow disbudding, skull injuries, otitis media or frontal

the laryngeal cartilage. When lung lesions occur there

sinusitis. In most instances meningitis is the result of

are necrotic areas present surrounded by a catarrhal

central infection causing local swelling and inflamma-

pneumonia.

tion around the nerve trunks. Spinal meningitis will

often lead to hyperaesthesia of the body, muscular

Diagnosis

tremors in the limbs and neck and an arched back.

The main differential diagnoses are laryngeal oedema,

laryngitis, necrotic enteritis and vocal cord paralysis.

Signs

These may be hard to eliminate unless an endoscopic

examination is undertaken or an exploratory laryngo-

The condition usually starts with a sudden onset of

tomy is performed.

pyrexia and in many cases toxaemia. There is hyper-

aesthesia to any cutaneous sensation and muscular

tremors of the neck and head with opisthotonus and pad-

Treatment

dling movements of the limbs. There may be ocular

In either case the animal should be isolated from the

lesions with hypopyon and ophthalmitis. The animal may

others. It should have its own feed and water buckets.

appear blind and the pupillary reflex may be sluggish.

Ophthalmoscopic examination may show the retinal

Signs

irises to be engorged with oedema of the optic disc.

In otitis externa the animal is well and has a normal

temperature but the ear tends to be droopy with a foul-

Necropsy

smelling purulent discharge. In middle ear infection,

unless bilateral, the head is rotated and there is a degree

On post-mortem examination the meninges are

of incoordination. The animal is often dull and there is

thickened and opaque, especially ventrally, and there *inappetance. Radiography may show rarefaction of the*

is engorgement of the meningeal vessels with haemor-

tympanic bulla.

rhaging. The cerebrospinal fluid (CSF) is often cloudy.

Diagnosis

Diagnosis

This is difficult in the live animal but the nervous

This condition is differentiated from brain or spinal

signs are an indication and there is a leucocytosis.

abscesses or injury by the rotation of the head.

Confirmation can only be obtained by examination of

the CSF, showing it to be cloudy with a high white cell

Treatment and control

count and possibly bacteria present. The differential

diagnosis includes coccidiosis (see p. 282), septicaemia

Treatment of the external form is relatively simple and

(see p. 204), vitamin A deficiency (see p. 256), hypo-

involves the local application of antibiotics, in practice

magnesaemia (see p. 255) and poisoning with various

often from intramammary tubes. Suitable antibiotics

substances (see Chapter 54)

include cloxacillin, chlortetracycline and penicillin and

streptomycin. Otitis media is much less satisfactory

to treat and involves puncturing the tympanic mucosa,

Treatment and control

irrigation with antiseptic solutions and local and par-

Treatment involves the use of a broad-spectrum anti-

enteral antibiotics. Prevention is difficult as the cause is

microbial that will penetrate the blood–brain barrier.

often unclear but it should involve adequate treatment

The potentiated sulphonamides or chloramphenicol

of all cases of calf pneumonia.

in countries where available are probably most useful.

Florfenicol has also been used although it is not

licensed for this use. These preparations are able to

Bovine papular stomatitis (BPS)

diffuse into the CSF. Results of therapy are generally

disappointing. Prevention is difficult but should involve

This is caused by a virus of the genus parapoxvirus.

the rapid treatment of all septicaemias, otitis or local

The condition is very common throughout the world.

injuries. Disbudding should always be undertaken with

Lesions can occur in any age of animal and both sexes.

care.

However, most lesions are seen in young cattle. The virus causes pseudocowpox in cows (see p. 364). The organism has a high morbidity and is found in the saliva

Otitis *(see also p. 903)*

and nasal secretions. Spread is by contact. The disease is usually of little importance except in the differential

Otitis media and externa both occur. The condition has diagnosis of other oral lesions, although occasionally it recently been more frequently diagnosed in calf-rearing can be of financial significance. The condition found is units in America and Britain. The cause is unknown but variable but can be seen in calves of seven days old or most outbreaks have been preceded by enzootic pneu- more. It can be transferred to others, particularly fol- monia and it is thus possible that an ascending infection lowing a bite, cut or scratch. Most lesions are local but occurs along the Eustachian tube. In some outbreaks may take many weeks to heal. Occasionally, systemic up to 30 per cent of calves have been involved. In in-

signs occur (see p. 822).

dividual cases of otitis media there may be extension

from an otitis externa or from navel infection via

Signs

the haematogenous route. The organisms involved vary

but vitamin A deficiencies have been reported in some

The lesions vary in severity. The mild form is the most

outbreaks. The external ear form is such that there are

common with the animal remaining healthy, eating well

often streptococci and staphylococci present. When

with no evidence of pyrexia, diarrhoea or respiratory

there is middle ear infection these two species may

distress. The lesions tend to be ring-like and pathogno-

be present, or M. haemolytica, Haemophilus spp. or monic. The periphery of the lesion is a thin red zone,

Neisseria catarrhalis.

within which is a white, slightly raised area of hyper-

plasia, with a yellow or brown centre due to tissue

to primary and secondary deficiency, but conditions

necrosis. Lesions heal from the middle outwards. Most *relating to their lack are very rare in calves. The dis-*

involve the rhinarium and mouth and are often found

eases of the skeleton that do occur are usually associ-

near erupting teeth. Occasionally, a second type of

ated with faulty mineral supply rather than vitamin D

lesion is a brownish-purple colour and usually the size

problems.

of the ring lesions. It heals from the middle outwards

Calcium is well absorbed in the calf's small intestine.

producing a horseshoe shape lasting from four days to

Therefore, primary deficiency is extremely unlikely, as

about two weeks. However, areas of lesions may last

is secondary deficiency, which could possibly occur if

several months overall.

very high levels of cereals were fed without additives or

The severe form is less common and often associated

high phosphorus levels were used. The daily calcium

with other intercurrent disease, e.g. parasitism. Lesions

requirement of calves is 10–30 g (1/3–1 oz) depending on

are slightly raised, diffuse and roughened, and are

size and growth rate.

yellow or grey in colour. They are seen in any part of

Phosphorus is very efficiently absorbed from milk,

the mouth and can involve marked sloughing of the

but less so from dry feeds. Primary deficiencies may

mucosae. As the more diffuse lesions heal, an underly-

resemble rickets. Secondary problems resulting from

ing circular form often remains. In some cases saliva is

low vitamin D levels, high calcium or high vitamin A are

held in the mouth making the lips wet.

rare. Phosphorus deficiency is widespread due to the

types of soil present in an area. Leaching by rain or con-

stant removal by cropping can lead to phosphorus-

Necropsy

deficient soil. Excessive calcium, iron or aluminium

Death from BPS is rare. Most lesions are in the mouth

can also result in the problem. The optimum calcium :

or rhinarium but may occasionally be seen in the

phosphorus ratio is 2 : 1.

oesophagus, rumen, reticulum and abomasum. Typi-

Vitamin D is usually provided by good quality hay

cally, there are no vesicles and on histology there is a *and exposure to sunlight. Present feeding systems in-*

ballooning degeneration of the stratum spinosum cells,

clude supplementation of milk substitutes and so do

which may contain eosinophilic intracytoplasmic inclu-

not normally predispose to the problem, although

sion bodies.

lush green feeds contain much carotene and other

substances that have anti-vitamin D properties.

The optimal daily intake is 7–12 iu/kg body weight

Diagnosis

(3.5–6 iu/lb).

Diagnosis is dependent on examining the lesions, the

animal remaining healthy, viral isolation, histopathol-

Signs

ogy and use of an electron microscope. Immunity can

The signs are usually only seen in the best-growing

be measured by the serum neutralization test but levels

calves. There is some degree of lameness, particularly of

are usually low. The main conditions to be differenti-

the forelimbs, which are bent forwards or laterally. The

ated are foot-and-mouth disease, mucosal disease, *limb joints and costochondral junctions are swollen. In*

malignant catarrhal fever, rinderpest, vesicular stomati-

some calves the back will be arched and in severe cases

tis, BIV, BLAD and mycotic stomatitis.

the tail is elevated. There may be a marked tendency to

lie down.

Treatment

Treatment is not justified but in severe cases concurrent

Necropsy

infections can be treated. Antibiotic therapy is recom-

On death the animal is in poor condition. The ribs are

mended to resolve secondary infections. Prevention is

easily cut and the limb bones are soft with thin, compact

not practical at present but the condition is less severe

bone and they are easily fractured. The joints tend to

in healthy herds so good nutrition and freedom from

be enlarged with thickened epiphyseal cartilage.

parasites are important.

Diagnosis

Calcium, phosphorus and vitamin D

Diagnosis is usually on clinical signs. The alkaline phos-

deficiency *(see p. 462, 791)*

phatase level will be raised. The levels of serum calcium

and phosphorus will depend on the cause of the con-

These conditions are all closely related and it is best to

dition but phosphorus will be low if it is due either

consider them together. All three compounds can lead

to vitamin D or phosphorus deficiency. Radiographic

examination shows the bones to lack density and the

increased by the presence of sulphur, which may be in

ends have a diffuse appearance. The epiphyses tend to

the form of protein. High levels of iron, zinc, lead,

be widened and irregular. The ash content of the bone

cadmium and calcium carbonate also reduce copper

is reduced from 60 per cent to 45 per cent and the

absorption.

ash : organic matter ratio will be reduced from the

Copper is concerned with the formation of cyto-

normal 3 : 2. The main problems to be differentiated are

chrome oxidase, which regulates oxidation processes

copper deficiency (but the plasma and/or liver copper *and electron transfer in tissues. It is also part of the*

concentrations will be low), arthritis and epiphysitis.

enzyme lysyl oxidase, which is used for elastin or colla-

gen synthesis and deficiency results in skeletal defects

Treatment and prevention

and blood vessel fragility. Copper is also present in

caeruloplasmin, which releases iron from stores into

Treatment varies according to the cause. In minor Ca :

plasma for erythropoiesis and deficiency results in

P imbalances sufficient vitamin D is all that is necessary.

anaemia.

Where the skeletal deformities are pronounced, treat-

ment will have only limited effect. Otherwise in calcium

deficiency check there is no excess phosphorus present.

Signs

Calcium should be provided but not to excess as this

The signs of primary deficiency are that the calves have may cause other deficiencies. If phosphorus is deficient,

a reduced growth rate; sometimes there is a scour but

dicalcium phosphorus or disodium phosphate should

not usually as pronounced as in secondary deficiency.

be used. The ratio of calcium : phosphorus of 2 : 1 should

There may be a stilted gait with some ataxia develop-

be provided by the diet. A vitamin D injection of

ing after exercise, but recovery occurs after rest. Ribs

3000–5000 iu/kg body weight will provide adequate

and limb bones may develop spontaneous fractures, the

levels for one to three months. Response to treatment

shaft thickness may be reduced and there is osteoporo-

is usually slow. Prevention requires ensuring adequate

sis. Thickened epiphyses, particularly in the fetlock

levels of minerals and vitamin D in the diet. Bone meal

region, may be noted, and stiffness of the joints.

and dicalcium phosphate are ideal sources of both cal-

Secondary deficiency is usually seen in calves sucking cium and phosphorus but they are expensive and

the dam or grazing. There is again a stiff gait and

cannot be used in many countries. Ground limestone is

unthriftiness. Molybdenosis is characterized by severe

a useful cheap method of ensuring adequate calcium in

scours. Some calves become very lame with epiphyses

the diet, but its overuse can result in other mineral *that are painful to palpate and usually the distal ends*

deficiencies.

of the metapodial bones are enlarged. On radiography

there is a thickened irregular epiphyseal plate, and the

***Copper deficiency** (see Chapter 21)*

metaphyses are thickened. In some animals depigmen-

tation of the hair occurs.

This is either primary due to a lack of copper in the diet

or secondary when the dietary level is adequate but

Necropsy

there is a failure in digestion, absorption or metabolism

of the copper. In calves, deficiency can be seen at a few

On post mortem there is usually emaciation with

weeks old although it is much more common when

anaemia seen as thin, watery blood and pale tissues.

three or four months old. This is because copper is

Where copper levels are low there are deposits of

stored in the liver and there is preferential absorption

haemosiderin in the liver, kidney and spleen. The limb

from the dam. Milk contains little copper although

bones may show evidence of rarefaction and fracture.

levels are high in colostrum. In the milk-fed animal

A thickening of the epiphyseal plates, particularly of the

absorption in the small intestine is high (up to 80 per

metapodial bones, may be present. In the small intes-

cent) but this falls as the animal becomes a ruminant

tine there may be villous atrophy. Histologically, the

(2–10 per cent). Milk substitutes tend to be supple-

bones show osteoporosis.

mented with copper and so most cases arise in calves

sucking their dams or at grass. Problems often occur in

Diagnosis

the spring or summer when the mineral content tends

to be lower.

In practice the majority of cases are diagnosed because

Primary deficiency depends on the soil type and is

of the area where the animals have lived, and most

common on sandy soil, particularly where there is much

calves will be sucking a cow or at pasture. The signs give

rain and leaching, and on peat. Secondary deficiencies

an indication of the condition and it usually affects

are probably more numerous than primary. They can *several animals. Examination can involve looking for*

be due to high molybdenum levels and this effect is

anaemia with a reduced erythrocyte count (2–4 ¥ 1012/l;

normal, 5–10 ¥ 1012/l) and low blood haemoglobin (5–

been used to release copper slowly from an intrarumi-

8 g/100 ml; normal, 8–15 g/100 ml). Plasma copper levels

nal bolus. The use of pasture dressing annually with

are low (normal, >15 mmol/l; deficient, <0.9 mmol/l)

5.6 kg/ha (5 lb/acre) copper sulphate is effective. As

as are liver levels (normal, 100–200 ppm dry matter

there is a possibility of poisoning, animals should not

(DM); deficient, <50 ppm DM). Cytochrome oxidase

graze the pasture until after heavy rain or three weeks

(normal, >7.0 mmol/g wet liver) and caeruloplasmin

after application. The copper supplementation of water

levels are low. Copper can also be estimated in the diet,

has been advocated (Farmer et al., 1982). Salt licks con-pasture and soil. Often response to copper therapy

taining 0.5 per cent copper sulphate are safe in use but

gives an indication.

are not permitted in all countries.

Treatment

Hypomagnesaemic tetany of

When therapy is undertaken it is important to confirm

calves *(see p. 787)*

the presence of copper deficiency, as overdosing is toxic.

Oral administration of 1.5 g copper sulphate weekly is

The condition occurs most commonly in calves on high-

very useful, but requires constant handling of the calves.

milk or milk-substitute intakes that are receiving little

Parenteral administration of copper can overcome

other feed. It results from a hypomagnesaemia that may

the problem. Copper sulphate has been used at a dose

be associated with hypocalcaemia. The young calf has a

level of 200 mg/calf. A methionine copper complex can

serum magnesium level similar to the dam and receives

be administered as a deep intramuscular injection at a

extra magnesium in its colostrum. However, milk is

dose of 40 mg/calf, as can diethylamine copper oxy-

deficient in this element and if it constitutes most of the

quinoline sulphonate at a rate of 0.24 mg/kg body

feed then there will be a gradual fall in circulating mag-
weight by subcutaneous injection and copper edetate
nesium levels. This is partly allayed by the absorption
as a subcutaneous injection of 50 mg. Experiments in
of magnesium from bones. The calf is also able to
sheep have shown high doses of copper methionine
absorb magnesium very efficiently from the small and
subcutaneously to be safer than calcium copper edetate
large intestine in early life but this capacity reduces so
and diethylamine copper oxyquinoline (Mahmoud &
that by three months old it becomes poor. The problem
Ford, 1981) but it was considered that this might have
is often seen in veal or suckler calves after two months
been the result of the rapidity of absorption depending
of age. Occasionally, hypomagnesaemia is seen in the
on the route of injection. A comparison of the efficacy
young calf about two weeks old and this is due to poor
of copper preparations in cattle showed copper edetate
absorption, which can occur with diarrhoea, the feeding
to be best with copper diethylamine oxyquinoline
of liquid paraffin or the use of fibrous feed, which

sulphonate 19 per cent worse, aqueous copper methion-

increases salivation and thereby causes the body to lose

ate 36–48 per cent worse, and cupric sulphate produc-

magnesium. A calf requires 1–5 g daily, according to size

ing the second-best result. The injections also cause a

and growth rate.

local reaction, with copper diethylamine oxyquinoline

sulphonate giving least damage, copper edetate pro-

Signs

ducing an intermediate reaction and copper methion-

ate causing most swelling (Suttle, 1981a).

In the early stages there is hyperexcitability to stimuli

with increased ear movements, interspersed with the

ears being held back. There tends to be opisthotonus,

Prevention

ataxia and head shaking. The animal may have trouble

Prevention is to ensure that the level of copper in the

drinking from a bucket on the ground. The temperature

diet of dams and calves is at least 10 mg/kg dry matter

is normal and the pulse rate rapid. Later on there are

of feed. When deficiency has been determined it may *muscular fasciculations with jaw champing, frothing at be necessary routinely to inject or drench the cattle. the mouth and a spastic gait. Convulsions may occur However, no such programme should be undertaken starting with the calf stamping its feet, pricking its ears, unless a sample of the animals has been checked to retracting its eyelids and the head being held up. The ensure blood copper levels are low. The timing of the animal may fall and show tonic–clonic movements of first injection (in severely affected herds) is at about six the legs with uncontrolled passage of urine and faeces, weeks old, but subsequent injections need to be based a fast pulse over 200/minute with heart sounds audible on further blood sampling. Copper sulphate can be away from the chest and respirations ceasing. The used as a drench at a level of 1.5 g weekly. Cupric oxide temperature is often raised to 40.5°C (105°F) due to needles have been used to alleviate hypocupraemia muscular exertion. If the convulsions are severe the in heifers (Suttle, 1981b). A form of soluble glass has pulse is often imperceptible, cyanosis develops and the* *animal dies within about 30 minutes. In some cases*

given to calves in the form of magnesium boluses or in

there are periods of relative normality between bouts

molassed creep feed.

of convulsions.

Vitamin A deficiency

Necropsy

On post-mortem examination there is usually extensive

The condition results from a deficiency of the fat-

haemorrhage and congestion of the organs including

soluble vitamin A or its dietary precursor carotene. Sec-

the aorta, mesentery, pericardium, gall-bladder and in-

ondary deficiency can arise where there is sufficient

tercostal walls.

vitamin A/carotene in the diet but it does not reach a

normal tissue level due to a failure in digestion, absorp-

tion or metabolism. In calves the condition may result

Diagnosis

in skeletal changes, which can affect the brain or spinal

Diagnosis depends on the history of the feeding *cord. The condition can be congenital or postnatal and*

regimen used or presence of diarrhoea as well as the

is often partly due to the nutritional status of the dam.

signs present and serum magnesium levels (normal,

Usually, a diet of green food will provide sufficient of

0.9–1.4 mmol/l,

2.2–3.4 mg/100 ml).

Clinical signs

the precursor carotene and hence vitamin A. Thus

may occur at 0.12–0.33 mmol/l (0.3–0.8 mg/100 ml).

problems do not occur at pasture until there are periods

In animals that die the Ca : Mg ratio in the caudal

of prolonged drought, which can cause deficiency in the

vertebrae or rib bone is increased from a normal of

calves of affected dams or beef calves about six months

70 : 1 often to over 90 : 1. The aspartate aminotransferase

old.

and creatine kinase levels also tend to be raised

The condition is more common in housed animals fed

because of the increased muscular activity. The main

diets likely to be deficient in vitamin A such as straw, *differential diagnoses involve conditions resulting in*

cereals or sugar beet pulp. The dam's nutrition is impor-

clonic convulsions. These include tetanus (but the

tant in that carotene in green food does not pass across

course is usually longer) (see p. 733), arsenic, lead or

the placental barrier until it is converted to vitamin A.

mercury poisoning (but in all these there is colic and

It can then be taken up by the fetus and stored in the

diarrhoea and with lead there is blindness). Strychnine

liver, as also can the vitamin A in water-soluble injec-

poisoning can occur and results in a stiff gait. Hypo-

tions or fish oils. Colostrum is a major source of vitamin

vitaminosis A may well result in night blindness.

A for the calf and the introduction of extra carotene or

Encephalitis (which may be viral or bacterial in origin)

vitamin A to the dam's diet precalving can be useful.

or meningitis may be difficult to determine. Clostridium

The vitamin A requirement for a pregnant cow is about

perfringens (welchii) type D produces apparent blind-80 iu/kg body weight daily and that for a calf is about

ness and a raised blood glucose level (normal, *40 iu/kg.*

2.5 mmol/l, 45 mg/100 ml).

Calves that are fast-growing, stressed or in a high

environmental temperature require more vitamin A.

Many factors that influence the vitamin A and carotene

Treatment and prevention

contents of feeds can lead to secondary deficiencies. Vit-

Treatment should include the use of magnesium sul-

amins C and E help to prevent vitamin A loss, and the

phate (50 ml of 25 per cent solution) subcutaneously

uptake of the vitamin is inversely proportional to the

and possibly calcium borogluconate intravenously.

phosphate present in the diet. The vitamin is not very

Magnesium given intravenously can lead to medullary

stable and so pelleting of the rations, storage at high

depression and cardiac embarrassment. If necessary

temperatures and rancidity all decrease the content of

the animal should be sedated with acepromazine or

the diet. Wood preservatives such as chlorinated naph-

xylazine. When the problem is the result of diarrhoea

thalenes inhibit carotene conversion to vitamin A and *then this should be rectified. The condition in the older*

prolonged oral use of liquid paraffin or other mineral

calf is prolonged and there will be greatly reduced

oils can produce a deficiency. Vitamin A is used to

magnesium levels in bone, etc. Thus these animals will

produce visual purple for the retina, normal epithelium

need to be supplemented with 2–4 g magnesium oxide

and bone, and for normal CSF absorption.

or 4–8 g magnesium carbonate daily.

Prevention involves the provision of roughage,

Signs (see p. 925)

usually as good quality hay, from ten days of age. This

is difficult in suckler calves but can be overcome by

Congenital: Calves are born blind due to impingement

feeding the cows with magnesium oxide (calcined mag-

of bone on the optic nerve. Other signs are due to

nesite) at a level of 60 g daily. Magnesium can also be

increased CSF resulting in syncope with the calves

showing tonic–clonic convulsions, ventral flexion of the

where convulsions are occurring. Subsequently, an ade-

head and neck, retraction of the eyeballs and tetanic

quate level of vitamin A should be present in the diet

closure of the eyelids. The calves are not blind. They

to provide 40 iu/kg body weight. Often in practice daily

may die during convulsions. In some outbreaks the

allowances are doubled. Green feed or early-cut hay,

affected calves develop severe diarrhoea and occasion-

good quality silage or dried grass should be given.

ally otitis media.

However, very high daily levels of vitamin A supple-

mentation in the diet can lead to exostoses on the digits

Postnatal: One of the most common lesions is the pres-

and loss of epiphyseal cartilage. This produces lame-

ence of large amounts of brown, bran-like scales in

ness, ataxia and poor hoof development. Where it is dif-

the coat and this is particularly seen in fast-growing

ficult to supplement the diet, injections of vitamin A can

animals. A reduction in growth rate may occur but is

be used every two months at 5000 iu/kg body weight,

usually also the result of other deficiencies combining

but dietary supplementation should be the primary aim.

with that of vitamin A. Classical xenophthalmia with

thickening and whitening of the cornea is unusual.

When it does occur, it may be accompanied by serous

***Iodine deficiency** (see p. 301, 586)*

ocular discharge. Nervous signs usually start with ataxia

and weakness of the hind limbs and then the forelimbs.

This can be the result of a primary lack of iodine. Sec-

Increase in CSF pressure results in nerve compression

ondary deficiency is recorded following high intakes of

and can lead to fainting with animals showing tonic–

brassicas, high calcium ingestion, heavy bacterial con-

clonic convulsions for up to half a minute. The signs are

tamination of feed or water, a low level intake of linseed

similar to those for congenitally affected animals.

meal or other plants containing cyanogenetic glyco-

Night blindness is more likely to be seen in yearling

sides. Iodine deficiency occurs in most parts of the

cattle.

world where there is a high rainfall and there is little

exposure to oceanic iodine. Soils with a high calcium

content are likely to be deficient. The condition is

Necropsy

mainly seen in the newborn calf of a deficient dam,

Following death it may be possible to see the constric-

usually in suckler herds. Iodine forms part of the

tions of the optic nerve, or the cranial cavity or verte-

hormone thyroxine, and a deficiency will result in the

bral cord may be reduced in size leading to injury to the

pituitary increasing the production of thyrotrophic

spinal nerve roots. Histologically, there is squamous

hormone. This in turn leads to goitre. Calves born alive

metaplasia of the interlobular ducts of the parotid sali-

are prone to die if chilled, etc.

vary gland that is pathognomonic. The epithelium of the

prepuce, reticulum and rumen shows hyperkeratosis.

Signs

The liver may show focal necrotic areas.

Many of the affected calves are aborted or stillborn

and usually there is evidence of thyroid enlargement

Diagnosis

(goitre). If the animal is born alive it will be weak and

Diagnosis depends on post-mortem findings, plus a *disinclined to suck. Occasionally, the gland will be felt*

history of a lack of green feed and the signs. The defi-

to pulsate. Very rarely areas of alopecia are apparent.

ciency can be confirmed by determining plasma vitamin

The cow is often slow in calving.

A levels (normal, 25 mg/100 ml; deficient, <10 mg/100 ml)

and CSF pressure (normal, <100 mm H2O).

Necropsy

The condition needs to be differentiated from hypo-

magnesaemia where the animal is not blind, lead poi-

The thyroid glands are enlarged and heavier than usual

soning where there is abdominal pain, tetanus where

(normal fresh weight 6.5 g; a weight greater than 14 g is

there is no blindness and Clostridium perfringens

suspect). Histologically, there is thyroid hyperplasia.

(welchii) type D where there are high blood glucose

levels. Bacterial and viral encephalitis and meningitis

Diagnosis

(see p. 251) usually result in pyrexia.

Diagnosis depends on the area or a diet containing

goitrogenic plants. There is thyroid enlargement in the

Treatment and prevention

calves and several heifers or cows abort or produce still-

Treatment involves the parenteral administration of

born or weak calves. Plasma protein-bound iodine

aqueous vitamin A at a rate of 400 iu/kg body weight.

levels are low (normal, 24–140 mg/l). The plasma

The animals often respond quickly to treatment even

inorganic iodine can be used (optimum 100–300 mg/l;

marginal 50–100 mg/l; low 20–50 mg/l; very low <20 mg/l).

from the cow's milk there is a need to supplement with

Most (90 per cent) of circulating iodine is bound as thy-

hay, straw and cereals. The only source of iron for veal

roxine and normal values are 36–89 mg/l (80–160 nmol/l).

calves on slats without roughage is the milk substitute

The thyroid weight is increased and the iodine content

and this needs to be supplemented. Levels less than

of the gland is low (normal, 15.6–39.0 mmol/kg DM;

19 mg soluble iron/kg DM of feed are likely to result in

deficient, 9.5 mmol/kg DM). Differential diagnosis is

problems.

mainly to eliminate other causes of abortion (see

Chapter 37).

Signs

The main sign is a reduction in appetite followed by

Treatment and prevention

reduced weight gain. The mucous membranes tend to

Treatment is to ensure that the calf sucks and is kept

become pale, but death is extremely rare.

in a warm, draught-free environment. Thyroid extract

can be used at a dose of 1–2 mg/kg body weight (0.5–

Necropsy

1 mg/lb). Intravenous sodium iodide can be used at a

dose of 5–7 g for the young calf, but it is not without

Necropsy findings are of pale muscles with the blood

risk; potassium iodide can be used orally at about 3 g

thin and watery and clotting slowly. The liver tends to

per calf. Iodism (iodine poisoning) can sometimes

be enlarged and there is moderate anaemia. Diagnosis

develop (see p. 261).

depends on the history of the diet and signs. It can be

Prevention involves allowing the dams adequate *confirmed by haematological examination demonstrat-*

iodine in the diet. A recommended level is 0.8 mg/kg DM

ing a reduced erythrocyte count and low haemoglobin

for pregnant and lactating cows. The level for calves

value. The serum iron level is low (normally 30 mol/l,

should be 0.12 mg/kg DM. Pouring on to the coat 7 ml of

167 mg/100 ml when born, reducing to 12 mmol/l,

5 per cent tincture of iodine weekly can be helpful. One

67 mg/100 ml at three weeks). The main differential

millilitre of tincture of iodine per cow per day in the

diagnoses are those of copper and cobalt deficiency

water or 800 mg potassium iodide per cow every two

but signs additional to the anaemia will be present.

weeks by drench or added to the drinking water can

work. Injections of iodized poppy seed oil can assist. A

Treatment and prevention

bolus of 3400 mg iodine with selenium and cobalt can

release iodine for five to six months. Some fertilizers are

Treatment usually involves the injection of 1 g of iron

high in iodine and seaweed meal can be given in the feed

weekly to each calf as iron dextran or 0.5–1.0 g iron as *and typically contains 50–100 mg/kg DM iodine.*

ferric polygalactofuranose. Vitamin B12 is also often

used at levels of 5–10 mg/kg body weight. Prevention is

by supplying milk substitute containing an iron con-

Iron deficiency

centration of 25–30 mg/kg DM. This will ensure that the

animal has a normal appetite and growth and it will

Iron deficiency is not common in cattle and the primary

help to produce pale meat suitable for veal (Bremner

condition is mainly seen in veal calves without access

et al., 1976). This is because the level is sufficient to give to roughage. The secondary condition usually follows

an acceptable blood haemoglobin without there being

heavy infestation with sucking lice such as Haematopi-

enough to produce much myoglobin. Most milk substi-

nus eurysternus and Linognathus vituli or after haem-tutes for calf rearing contain considerably more iron.

orrhage. The primary condition can occur in veal calves

or others fed predominantly raw milk or unsupple-

mented milk substitute. The calf has only sufficient iron

Selenium/vitamin E deficiency

for about three weeks after birth and milk is a poor

(see p. 302)

source of iron. In the case of veal calves there is an

attempt to maintain iron levels low to keep the meat

Vitamin E and/or selenium can be deficient and result

white. Over half the iron in the body is in the form of

in muscular dystrophy, also known as white muscle or

haemoglobin with small amounts present in myoglobin

fish flesh disease. It can be seen at any age after birth.

and in enzymes used for oxygen utilization. The normal

Selenium deficiency is mainly dependent on the area

blood haemoglobin values for adult cattle are 8.0–

where crops are produced. Soils derived from granite

15.0 g/100 ml. However, the value in a calf at birth is

or pumice are deficient. Alkaline soils encourage sele-

12.9 g/100 ml, dropping to 10.4 g/100 ml on a diet of milk

nium absorption by plants. The condition appears to be

and solid feed (Holman, 1956). The calf's daily iron

becoming increasingly important, probably due to the

requirement is 50 g and as only about 2–4 g are received

increased cost of bought-in feeds causing farmers to use *more home-produced crops for their animals. The*

However, it is fully conscious with normal appetite,

accepted level of selenium in feeds is 0.1 mg/kg DM.

normal temperature and usually normal respiratory

Selenium is mainly used by the body in the production

rate, but the heart rate may be raised. In many cases the

of the enzyme glutathione peroxidase.

gait is abnormal and it moves by rotation of the hocks.

Vitamin E deficiency is much more dependent on the

In some cases the affected muscles are swollen and firm

type of crop grown and its storage, etc. Vitamin E levels

on palpation. It has been shown that there is increased

tend to be high in green pasture, silage, dried grass or

susceptibility to infectious diseases such as calf pneu-

kale. Adequate levels of the vitamin are also present in

monia due to delayed lymphocytic response.

cereal grains, well-cured fresh hay, maize silage and

brewers' grains, but deficiencies can occur on poor

Necropsy

quality hay, straw or root crops unless there is a suitable

supplement provided. Vitamin E tends to deplete with

On necropsy of calves with the sudden death syndrome
storage. Calf diets high in unsaturated fatty acids, as can
there are often no macroscopic lesions. Other cases may
occur where cod liver oil, fishmeal, soya bean meal or
show congestion of the liver and lungs. The heart shows
linseed oil are fed, may become deficient due to their
a slight pallor of the myocardium. Histologically, lesions
oxidation, resulting in rancidity and the destruction of
not otherwise apparent can be detected with a haema-
vitamin E. Storage of grains when wet or with propi-
toxylin basic fuchsin–picric acid method and these are
onic acid can also reduce the vitamin E level. Normal
considered to be peracute myocardial degeneration. In
levels for growing cattle are considered to be 150 mg of
acute muscular dystrophy there are localized streaks in
a-tocopherol, and for the calf, milk substitutes should
the diaphragm and skeletal muscles. In the latter they
contain antioxidants and 300 iu/kg DM a-tocopherol.
tend to be bilaterally symmetrical white or grey areas
The condition affects muscles, particularly cardiac,
in the muscles. In the heart there may be cardiac hyper-

skeletal and diaphragmatic. Deficiency can occur in

trophy and myocardial degeneration with pulmonary

suckler calves sucking mothers with low selenium or

congestion and oedema. Histologically, there is no

vitamin E levels or in artificially reared calves on defi-

inflammation but changes vary and include hyaline

cient diets. The condition results from unsaturated fatty

degeneration and coagulative necrosis. In subacute

acids entering the muscle cells where they accumulate.

muscular dystrophy there is usually no cardiac involve-

They are oxidized to lipid peroxides, which result in

ment but the skeletal muscles show bilateral grey or

degeneration and calcification. It is believed vitamin

white areas.

E helps prevent lipid peroxide formation within the

muscle cells whereas selenium compounds with many

Diagnosis

unsaturated points are known as polyunsaturated fatty

acids and these are particularly common in vegetable

Diagnosis depends on the area and diet provided as

oils, which therefore predispose to peroxide formation.

well as the signs. Decreased glutathione peroxidase

levels occur (normal >23 iu/ml RBC) and the normal

level of selenium in the blood is 0.63 mmol/l. There are

Signs

raised plasma creatine phosphokinase and aspartate

The signs vary in degree and in the sudden death

transaminase levels. The blood vitamin E level normal

syndrome the calf appears perfectly healthy but while

range is 3.0 to 18.0 mmol/l and it will be low in deficiency.

drinking or normally within 30 minutes of feeding the

Otherwise liver and kidney levels of selenium can be

animal will suddenly collapse. Death is usually within a

examined (normal, 3 and 30 mmol/kg DM). Response to

minute of collapse. Mortality is 100 per cent.

treatment can be determined as a means of diagnosis.

Acute muscular dystrophy is again sudden in origin.

The animal becomes dull and lies in lateral recumbency.

Treatment

There is respiratory distress, a heart rate often elevated

to 150–200 beats/minute and irregular. The rectal tem-

Therapy can involve the use of vitamin E and/or sele-

perature is normal, the calf is fully conscious and has
nium depending on the cause of deficiency. The dose of
normal eye reflexes. Most calves die within 6–18 hours
DL2-a-tocopherol acetate is about 6 iu/kg body weight.
and the mortality approaches 100 per cent.
Selenium can be injected as 0.1–0.15 mg/kg sodium
The most common form seen is subacute muscular
selenite. Long-acting selenium injections are obtain-
dystrophy and the morbidity is variable between about
able. The combined injections have become available
10 and 40 per cent of calves. The signs depend on the
and produce acceptable results. Selenium can also be
muscles affected. The animal may stand stiffly; it is
given in the form of reticular bullets or in soluble glass.
reluctant to move and when it does it may have a stiff
The diet should provide sufficient vitamin E and sele-
gait. The calf is often weak and will not stand for long.
nium. Cows with calves at foot or in late pregnancy can

be given a combined vitamin E/selenium injection to
Treatment and prevention

supplement their calves.

Treatment involves oral medication with zinc sulphate

at a level of 2 g weekly, or 1 g weekly by injection is

Prevention

useful. Any calcium oversupplementation should be

corrected and fibrous roughage should be reduced. A

For prevention, growing calves should be given a sup-

diet containing 50 p.p.m. zinc should prevent the con-

plement at the rate 0.1 p.p.m. selenium of the total

dition. Weekly oral medication with 0.5 g zinc sulphate

ration and 150 mg/head of a-tocopherol daily. Cows

can be helpful. Long-term control can be obtained with

should receive a supplement of vitamin E during the

zinc-containing fertilizer.

last two months of pregnancy. Injections of selenium

and vitamin E can be used; selenium bullets or soluble

glass intraruminal boluses are also of value. Pastures

***Furazolidone poisoning** (see p. 941)*

can be top-dressed with fertilizer containing sodium

selenite 75–150 g/ha (1–2 oz/acre) or foliage dusting or

Furazolidone was a common form of prophylactic medi-

spraying can be undertaken at 17.5 g/ha (1/4 oz/acre).

cation in calves, which can result in problems of toxic-

Analysis of pasture should be undertaken to determine

ity. However, its use is now banned in many countries.

that toxic levels of selenium are not produced; this can

There are two syndromes, one of which (the acute)

occur at levels of 0.5 mg/kg. Selenium can be added to

involves overdosing at levels of 20–30 mg/kg body

the drinking water.

weight and the classic condition results from long-term

feeding of low levels, often 2 mg/kg. Both are usually the

Zinc deficiency

result of poor mixing, which allows some animals in a

group to receive more than the others. Mortality in both

cases is high and the chronic form may be seen several

This can be either primary due to a lack of zinc, or sec-

days after furazolidone feeding ceases.

ondary due to impaired uptake. It is usually seen in

calves from six to ten weeks old, particularly in the

period after weaning, and most commonly they are

Signs

housed. Usually, calves do not show signs on diets con-

taining 40 ppm zinc, but it is probable that calcium and

In the acute form there are nervous signs with hyper-

highly fibrous diets reduce zinc availability and perhaps

excitability, including muscle tremors, arched back and

low copper levels reduce uptake. A congenital skin con-

possibly circling, convulsions and death normally within

dition occurs in Friesian calves resulting in an increase

a few days. When the chronic condition occurs there

in requirement (see p. 181).

tend to be necrotic lesions and haemorrhages in

the mouth and lower gut. This results in melaena or

dysentery.

Signs

Signs usually occur about two weeks after the deficient

Necropsy

diet is introduced. The main signs are of poor growth

with possible stunting. There is alopecia and paraker-

After death few lesions are seen in the acute condition

atosis often affecting the limbs, muzzle, vulva, anus and

but when chronic there are haemorrhages and necrosis *tail head. There are fewer lesions on the main part of*

in the alimentary tract. Haemorrhages are present

the body. In some cases any wounds or abrasions will

on the peritoneal and pleural surfaces and there is

take longer to heal. Most animals do not die but skin

decreased myelopoiesis in the bone marrow.

biopsies show increased thickness of all skin compo-

nents and the stratum corneum contains nucleated epi-

Diagnosis

dermal cells.

Diagnosis depends on the signs and feeding the com-

pound and can be confused with bracken poisoning (see

Diagnosis

p. 946) or anthrax (see p. 717).

Diagnosis is partly on the lesions and a biopsy

shows parakeratosis. Normal plasma zinc levels are

Treatment and prevention

9–18 mmol/l (80–120 mg/100 ml). Serum alkaline phos-

phatase, albumin and amylase levels fall whereas serum

Little therapy can be given in either case but in the

globulin levels rise. The calves usually start to respond *acute form furazolidone feeding should be stopped at*

to therapy in about a week.

once. Noise should be kept to a minimum and excite-

ment should be avoided. Sedatives such as acepro-

contain high levels of thiaminase. Amprolium is also a

mazine, xylazine or magnesium sulphate can be helpful.

specific thiamine antagonist and has also been used

In the chronic form little can be done, except perhaps

experimentally. Molasses toxicity results in a similar

to give blood transfusions. Prevention, where allowed,

problem due to a fall in the proprionate levels. Thi-

involves the correct dosage of furazolidone being

amine is naturally synthesized in the rumen. It forms an

offered to calves and it should be thoroughly mixed. If

essential component of several enzymes used in gluco-

given with milk substitute from a bulk container the

lysis in the brain. Deficiency in thiamine results in

milk must be constantly agitated. Furazolidone in the

increased blood pyruvate levels and a decrease in the

micronized form or combined with diethyl sulphoxide lactate : pyruvate ratio as well as a depression of the

or other nitrofurans will reduce the risk. Therapy with

erythrocyte transketolase level. This causes an interfer-

furazolidone in those countries where still allowed,

ence with normal carbohydrate metabolism and the

whether medicinal or prophylactic, should not be

cerebral cortex in particular requires the oxidative

repeated.

metabolism of glucose.

It is possible that thiamine deficiency might have

a direct metabolic effect on the neurones, particularly

Iodism (see pp. 302, 823)

in the calf which is very dependent on the pentose

pathway of metabolism in which the transketolase

The overuse of sodium or potassium iodide in therapy

enzyme limits the rate of activity. Thiamine pyrophos-

for conditions such as actinobacillosis, iodine deficiency

phate is a coenzyme for several carbohydrate metabolic

or ringworm can lead to iodism. The signs depend partly

reactions and it is associated with transketolase in the

on the form of administration. If intravenous the animal *pentose pathway of glucose oxidation. There tend to be*

can show considerable discomfort with dyspnoea,

marked cerebral oedema and cerebral necrosis and the

staggering and tachycardia. When given subcutaneously

signs are mainly the result of an increase in intracranial

there may be swelling following injection for about two

pressure.

days and local discomfort for about two hours after

The morbidity is usually low but occasionally up to

administration. In the oral form the coat becomes stary,

25 per cent. However, mortality can be 25 to 50 per cent

with a scaly skin and often a fine, white dandruff. There

if not treated early, with higher levels in young cattle

is excessive lacrimation and nasal discharge with, in

(six to nine months) than older ones.

some cases, a degree of inappetance. If problems arise

in treatment from the intravenous route then the iodine

Signs

should be given subcutaneously or orally. When signs

occur following oral administration, treatment should

In acute cases there is a sudden onset of nervous signs *be discontinued.*

including blindness, muscle tremors, particularly of the

head and neck, head pressing, jaw champing and frothy

salivation. Animals tend to be hard to handle and in the

Cerebrocortical necrosis

early stages signs may be intermittent. Although the

(CCN, polioencephalomalacia)

animal appears blind, and the menace reflex is absent,

the palpebral and pupillary reflexes are present. The

Aetiology

convulsive signs soon become continuous with the

animal becoming recumbent. The signs are then of

It is a deficiency of thiamine caused by endogenous

opisthotonus, nystagmus, optic disc oedema, often stra-

thiaminase. Thiaminase has been found to be produced

bismus and clonic–tonic convulsions which become

by Clostridium sporongenes and certain Bacillus spp.

worse when the animal is stimulated. The temperature

which can be found in cases of CCN. However, this does

is normal, the ruminal movements are normal but the

not mean they are the only factors (see p. 903).

heart rate is variable. Calves often die in one to two

days although older animals show signs for a longer

period. Recovery following therapy may well take two

Occurrence

to four days or longer.

It is a sporadic condition which can occasionally occur

The signs of the subacute form last for a few hours to

as outbreaks. Most animals affected are fast-growing,

several days and include blindness, head pressing and

well-nourished animals between 6 and 18 months old.

standing. The condition will resolve in some cases.

It can occur following deprivation of food followed by

However, in an outbreak of CCN some of the animals

good grazing or feeding with concentrate.

show anorexia, partial impairment of eyesight and a

Similar syndromes can be produced experimentally

mild depression. Almost all of the subacute animals

by feeding large amounts of bracken or horsetail which

recover within 24 hours of therapy.

Although recovery may occur, some animals may still

(10)

Haematology virtually normal although total

remain blind. The longer the time between onset of

and differential counts may show a mild stress

signs and therapy, the less favourable the prognosis.

reaction.

When cattle remain dull and anorexic after three days'

(11)

Increased cerebrospinal fluid pressure, 200–

treatment they are unlikely to recover and should be

350 mm saline (normal 120–160 mm saline).

slaughtered.

(12)

Histology – bilateral necrosis in cerebral cortex

(bisect brain longitudinally, put one half in

buffered formalin, the other is deep-frozen).

Necropsy

(13)

Green fluorescence of brain when exposed to

Most of the animals do not show any gross changes

long-wave ultraviolet light.

in the body other than the brain. There is usually

Differential diagnoses are shown in Table 18.2.

increased intracranial pressure with a yellowing and

compression of the dorsal cortical gyri. The cerebellum

tends to be compressed into the foramen magnum and

Treatment

recovered animals show decortication of the motor area

Thiamine hydrochloride should be administered intra-

and occipital lobes. Histologically there is bilateral

venously at a dose of 10 mg/kg (5 mg/lb) BW, and the

necrosis of the dorsal occipital and parietal cerebral

dosage should be repeated every three hours or so for

cortex and also, occasionally, the thalamus, basal

five treatments. A response will occur in 24 hours if

ganglia, lateral geniculate bodies and mesencephalic

animals are caught in the early stages, otherwise recov-

nuclei. Cerebellar lesions also occur.

ery is slowly progressive over several days. Multi-

vitamin injections are often used but although they are

Diagnosis

suitable for follow-up therapy, in the initial stages insuf-

ficient thiamine will be administered unless very large

Diagnosis can be made from the following:

doses are given.

(1)

History – age of animals, a change in feeding and

Nursing is important and the cattle should be pre-

the condition of the animal.

sented with wholesome food including at least 50 per

(2)

Signs – blindness, normal palpebral and pupillary

cent good quality roughage. Rumen liquor from cattle

reflexes; normal ruminal movements, normal

on predominantly roughage diets may be helpful. The

temperature but otherwise many nervous signs.

use of dried brewers' grains can help the conditions as

(3)

Blood pyruvate and lactate levels are increased.

they contain high levels of thiamine and others of the

(4)

Urine pyruvate levels increased.

(5)

Erythrocyte transketolase activity reduced

(Table 18.1).

(6)

Pyruvate kinase levels are much increased.

Table 18.2

Differential diagnoses.

(7)

Thiamine levels in erythrocytes, blood and

plasma may be in the normal range.

Disease

Differential diagnoses

(8)

Blood creatine phosphokinase (CPK) levels may

occur.

Listeriosis

Unilateral facial paralysis, pyrexia

(9)

Thiaminase levels increased in rumen liquor and

Lead poisoning

Abdominal pain, diarrhoea, no

in faeces.

pupillary reflex, no ruminal

movements

Coenuriasis

Slow onset, circling

Molasses poisoning

Similar to cerebrocortical necrosis

Table 18.1

Differences in thiamine levels within certain tissues

but history of feeding large

of the body in animals with or without cerebrocortical necrosis.

quantities and also glucose

(After Edwin et al., 1979.) TPP = total plasma protein.

levels fall whereas thiamine

levels remain normal

CCN (±SEM)

Not CCN (±SEM)

Amprolium poisoning

Similar to cerebrocortical necrosis

but history of feeding it

Liver dry (mg/g)

2.5 ± 0.43

11.1 ± 2.11

Bracken or horsetail

Similar to cerebrocortical necrosis

Heart dry (mg/g)

2.5 ± 0.56

13.2 ± 2.12

poisoning

but highly unlikely to cause such

Brain dry (mg/g)

1.8 ± 0.37

7.7 ± 1.52

a manifestation other than

Erythrocyte

172

15

experimentally

transketolase

Haemophilus somnus

Infection, but usually pyrexia and

(% TPP effect)

neutrophilia

B vitamin group. Levels of 0.5–1.0 kg/300 kg BW

passage of small amounts of urine, often blood-tinged,

(1–2 lb/6 cwt) have been suggested.

or the attempts are unproductive. Calculi may be

present on the prepucial orifice hairs. There is usually

evidence of mild to severe colic with kicking at the

Control

belly, paddling movements and tail swishing. In most

The precipitating factors for CCN are still not known,

untreated cases with complete urethral obstruction,

which makes it difficult to recommend preventive

there will be perforation of the urethra or bladder

measures. As the condition is the result of endogenous

rupture. When either takes place there is usually a

thiamine activity, provision of extra thiamine is of

period of relief from abdominal pain. When bladder

limited value. Most natural feeds contain thiamine at a

rupture has occurred the urine enters the abdomen,

level of 2 ppm and this, plus the vitamin synthesized in

which becomes distended and there is a fluid thrill *the rumen, is normally sufficient. Provision of adequate*

present on percussion. In those with urethral perfora-

amounts of roughage should prevent the condition and

tion, urine tends to dribble under the skin, causing

a level of 1.5 kg roughage per 100 kg BW is suggested.

ventral abdominal distension, which will start to

progress anteriorly. In most cases there is some

toxaemia and possibly uraemia and this is seen as

Urolithiasis

inappetance, with increasing dullness of the animal,

which will ultimately become comatosed and die.

Urinary calculi are either organic or inorganic. The

organic type are less common and form casts or urinary

Necropsy

deposits. The inorganic ones tend to be crystalline and

are more common. The condition is usually seen in

At necropsy there is usually some degree of cystitis,

calves that are housed, with milk substitute as their

often with urinary deposits present in the bladder.

main source of feed or in weaned growing animals fed

When the bladder ruptures there is much fluid in the *high levels of concentrates. Some pastures are problem*

abdomen and in those cases of urethral perforation

areas, which can be due to high plant oestrogen,

there will be erosion in the area of the calculus and

oxalate or silica levels. Most calculi in housed animals

urine, possibly with cellulitis, present subcutaneously.

contain calcium or magnesium ammonium phosphate

The position of the calculus can be ascertained by the

although struvite and oxalate deposits occur at times.

passage of a catheter.

At pasture, carbonates of calcium, magnesium and

phosphorus are most common. Vitamin A deficiency

Diagnosis

has been suggested as a precipitating factor both

indoors and when cattle are grazing. The urinary pH has

The diagnosis depends on the history, particularly of the

an influence and phosphate and carbonate calculi form

area and feeding as well as the sex of the animal and

more readily in an alkaline than an acid urine (adult

signs. If there is bladder rupture then the fluid can be

ruminant urine is alkaline with a pH of 7 to 9). Binding *aspirated from the abdominal cavity. It is often difficult*

of the calculi occurs with mucoprotein in the urine and

to determine that urine is present without its odour and

this is seen more frequently when oestrogens from

appearance. Urinary crystals may be present on pre-

plants or growth promoters are present, or the ration is

pucial hairs and these should be analysed. The main

pelleted.

differential diagnoses are ascites, intussusception and

Urolithiasis can occur in all animals fed a predispos-

constipation.

ing diet regardless of sex; however, the condition is

mainly seen in the male because signs are not normally

Treatment

observed unless some form of urethral blockage occurs.

More cases are found in castrated than entire animals.

Treatment of the condition is primarily by surgery. If

Calculi can lodge anywhere in the urethra but occur

the animal is nearing slaughter and there is no bladder

most commonly at the sigmoid flexure of the penis with

rupture or urethral perforation then casualty slaughter *the region of the ischial arch being the second most*

is best. Otherwise, treatment is usually only successful

common site.

in the early stages and all treated animals and others in

the group must be carefully examined for several days

subsequently. It may be possible to perform a urethro-

Signs

tomy and remove the calculi. Provided the stones are

Most of the signs are associated with partial or com-

distal to the ischial arch then the provision of a ure-

plete blockage of the urethra. This is seen as frequent

throtomy in the perineal region may overcome the

attempts to urinate, which may be accompanied by the

problem and, if it proves impossible to remove the

calculi, the opening can be made permanent. Medical

available at pasture and areas likely to produce urolithi-

treatment can include hyoscine butylbromide injected

asis are best grazed by female cattle.

intravenously or intramuscularly at a dose of 20–

40 mg/animal, or 5–10 ml of protein-free pancreatic extract possibly repeated once or twice. Acetylpro-

References

mazine can give useful results acting as a smooth muscle

relaxant. Withdrawal of concentrates may assist the

Bremner, J., Brockway, J.M., Donnelly, H.T. & Webster, A.J.F.

condition and the provision of salt water following

(1976) Anaemia and veal calf production. Veterinary

relief of the blockage is useful.

Record, **99**, 203–5.

Butson, R.J. (1994) Bovine septic arthritis: a review of current and future treatment regimes. Cattle Practice, **2**, 315–21.

Edwin, E.E., Markson, L.M., Shreeve, J., Jackman, R. &

Prevention

Carroll, P.J. (1979) Veterinary Record, **104**, 4–8.

Farmer, P.E., Adams, T.E. & Humphries, W.R. (1982) Copper

Prevention is partly dependent on feed alteration, and

supplementation of drinking water for cattle grazing

precipitation of phosphate can be avoided by having a

molybdenum-rich pastures. Veterinary Record, **111**, 193–5.

correct ratio of calcium to phosphorus, which should be

Holman, H.H. (1956) Changes associated with age in the *at least 1.2 : 1, but levels up to 2.5 : 1 have been sug-*

blood picture of calves and heifers. British Veterinary

gested. The concentration of magnesium in the diet

*Journal, **112**, 91–104.*

should be kept low and this means that the maximum

McCoy, M.A., Smyth, J.A., Ellis, W.A. & Kennedy, D.G. (1997) amount of magnesium oxide that should be added to

*Stillbirth/perinatal weak calf syndrome. Cattle Practice, **5**, the diet is 200 g/t (1/*

31–4.

2 lb/ton) of feed. In the concentrates,

up to 3 per cent salt has been recommended and it is

Mahmoud, D.H. & Ford, B.J.H. (1981) Injection of sheep

thought to have an ionic effect rather than just causing

*with inorganic injections of copper. Veterinary Record, **108**, 114–17.*

diuresis. Such diets should only be used where there is

Suttle, N.F. (1981a) Comparison between parenterally

always free access to water. The addition to feed of

administered copper complexes of their ability to alleviate

urinary acidifiers such as ammonium chloride or phos-

*hypocupraemia in sheep and cattle. Veterinary Record, **109**, phoric acid can be helpful. In animals at pasture the use*

304–7.

of salt in the water can reduce the concentration of

Suttle, N.F. (1981b) Effectiveness of orally administered cupric silicic acid in the urine, thereby preventing silica calculi

oxide needles in alleviating hypocupraemia in sheep and

formation. Adequate water supplies must always be

cattle. Veterinary Record, ***108****, 417–20.*

Growing Cattle

Chapter 19

Endoparasites

S.M. Taylor and A.H. Andrews

Introduction

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ment of parasitic disease, to inquire whether the two

Nematodes

267

preconditions have existed and to involve their separa-

Parasitic gastroenteritis (PGE)

267

tion as part of the therapeutic and prophylactic advice

Parasitic bronchitis (husk, hoose)

272

given.

Stephanurosis (kidney worm)

274

Bunostomosis

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Haemonchosis

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Trematodes

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Nematodes

Fasciolosis

276

Paramphistomosis (stomach fluke disease, intestinal

Parasitic gastroenteritis (PGE)

amphistomiosis)

279

The term itself is currently specifically associated with

Schistosomosis (bilharziosis)

279

Cestodes

280

the presence of large numbers of nematodes in the abo-

Taenia saginata

280

masum and intestines rather than any other endopara-

Echinococcus granulosus and hydatid cysts

281

sites. The nematodes in the abomasum are generally

Protozoa

282

considered to be the primary pathogens, with those in

Coccidiosis

282

the intestines playing a lesser but synergistic role.

Neosporosis

283

In temperate areas the predominant worms in the

Toxoplasmosis

284

abomasum are those of the genus Ostertagia, with O.

Sarcosporidiosis (sarcocystosis)

284

ostertagi the most important and numerous. In the small intestine Cooperia oncophora and Nematodirus helve-tianus are commonest.

Introduction

There are two common forms of ostertagiosis, type I

and type II, and since they are the result of different

Although cattle of all ages may become infected with

manifestations of the bionomics of O. ostertagi they will many species of parasites, clinical disease caused by parbe described separately.

asitism is mainly observed in groups of animals under

18 months of age, especially when two preconditions

TYPE I OSTERTAGIOSIS

coincide:

This form of the disease is characterized by a profuse

(1)

The availability of large numbers of the infective

watery diarrhoea in calves at grass. The faeces, because

stages of the parasite (a variable that is usually

of the grass diet, is usually green. There is rapid loss

dependent on the relationship between the bio-

of weight in severe cases, coupled with a slight hypo-

nomics of the parasite and suitable maturation

albuminaemia due to protein loss and in chronic cases *conditions).*

this can eventually result in submandibular oedema.

(2)

The presence of susceptible cattle grazing on the

It is most common in late summer and autumn in

contaminated area.

northern temperate areas.

When these two conditions are fulfilled, the resultant

simultaneous maturation of large numbers of parasites

Aetiology and epidemiology

in a specific host organ produces severe tissue disrup-

tion and the consequent signs associated with the par-

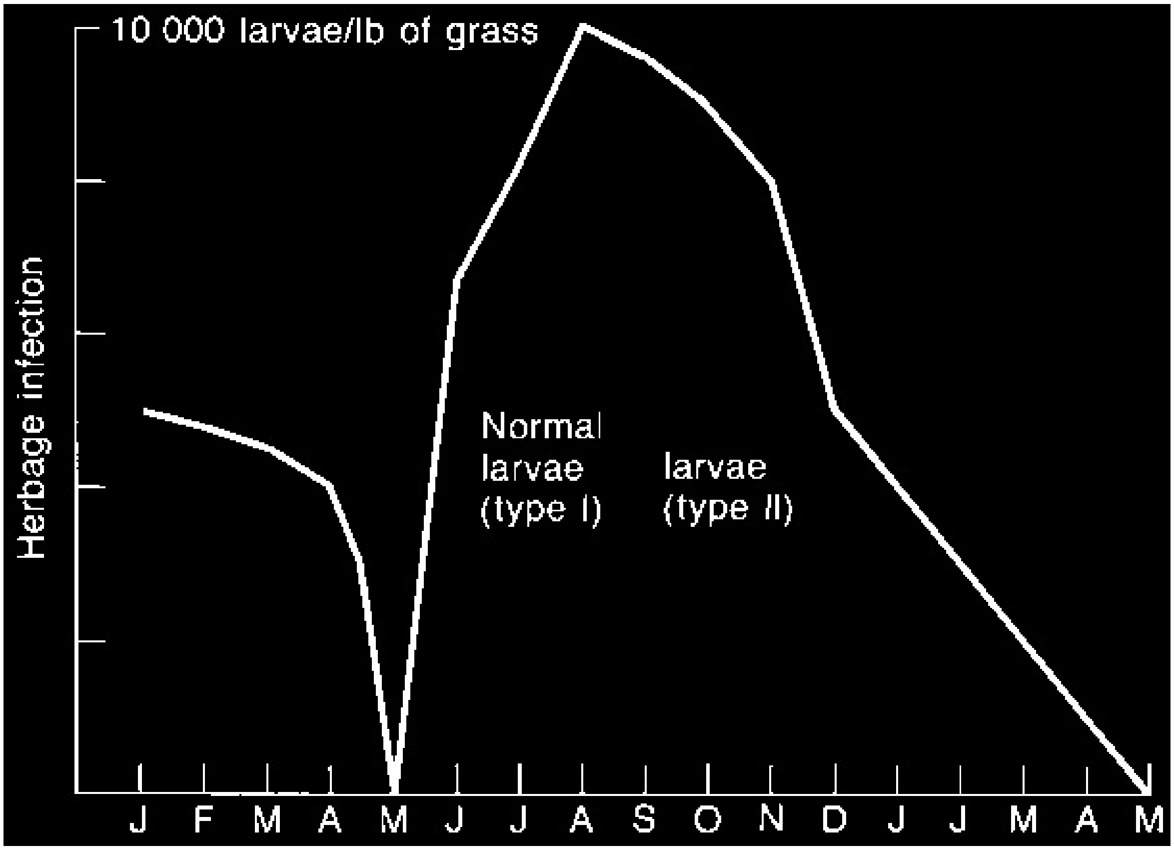
The direct cause is the ingestion over a relatively short

asite involved. The gastrointestinal tract, lungs and liver

period of large numbers of the infective larvae of O.

are the organs most commonly affected. It is prudent,

ostertagi. The presence of such large numbers of larvae therefore, when considering the diagnosis and treatis a result of several epidemiological interactions, a



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Parasitic gastroenteritis normally occurs when calves or non-immune older cattle are grazed on pastures on which a large number of infective larvae are present. Typical cases occur in dairy herds where autumn-borne replacement calves are put out to graze for the first time in April or May. The pastures used are frequently close

inhibiting

to the farmhouse to enable both ease of inspection and rehousing should weather conditions deteriorate. For *these reasons the same fields frequently have the same*

use each year. The calves remain on the fields until mid-

summer, excreting eggs that initiate the midsummer

larval increase. At that point, when grass in such pad-

docks requires resting, the farmer has aftergrass avail-

F

able after conservation for silage or hay. The calves

Fig. 19.1

Normal annual pattern of worm larvae on pasture in

are transferred to the aftergrass with or without

northern temperate countries.

anthelmintic treatment. Shortly afterwards, by which

time the grass in the original fields has recovered

slightly, spring-born calves are put out on to it. If no

prophylactic measures are taken, the inevitable result

working knowledge of which is necessary if the best

of severe type I ostertagiosis ensues a few weeks later

advice on treatment and prophylaxis is to be offered.

in the latter calves, caused by ingestion of massive

The annual pattern of fluctuations of infective larval

numbers of infective larvae by fully susceptible cattle *numbers on calf grazing was described by Michel*

over a relatively short period of time.

(1969), and can be seen in Fig. 19.1, which shows that

the number of infective larvae in northern temperate

Pathogenesis

areas is lowest in May and June but rises to a peak in

late August and September. Summarized, the pattern

Ingested infective larvae of O. ostertagi develop in the arises from the following sequence of events. Calves put

gastric glands in the abomasal mucosa, emerging 18–21

out to graze in April or May, on grazing that has been

days later as adults. Whilst in the mucosa their presence

used for cattle (and especially calves) during the pre-

produces distension of the parasitized acini, which in

ceding year, ingest some of the infective larvae remain-

turn causes several pathological and biochemical

ing on the pasture from the contamination produced in

lesions. Firstly, the hydrochloric acid-producing parietal

the previous summer. These infective larvae develop

cells in the acini are destroyed and replaced by rapidly

into adults in approximately three weeks and egg-laying

dividing undifferentiated cells that do not produce acid.
commences. The rate of hatching of these eggs is influ-
If the infection is severe and lesions extensive a thick-
enced by temperature and availability of moisture, and
ened hyperplastic gastric mucosa results, little acid is
providing the latter is present increases as the tempera-
produced and the pH of the abomasum rises from pH
ture rises, reaching a peak in midsummer. The larvae
2 to pH 7, and the intercellular junctions are disrupted.
thus hatched in May, June and July migrate or are
The change in pH has several major consequences.
washed out of faecal pats on to surrounding herbage to
Above pH 4.5 pepsin ceases to be active in protein
await ingestion by the eventual host. Their numbers are
digestion; at pH 6 and above pepsinogen is not con-
maximal in late July, August or early September, the
verted to pepsin and remains unaltered in excess and is
precise timing depending on the climate in the area
reabsorbed into the bloodstream via the ruptured inter-
involved during the year in question. In normal climatic
cellular connections, raising the blood pepsinogen con-

years in the British Isles the maximum number of infec-
centration. At the same time blood proteins such as
tive larvae is found in southern England in late July, and
albumin can leak outwards into the lumen. As a result
in the west of Scotland and Northern Ireland in mid to
of the rise in pH the abomasal contents become less
late August. Wet summers produce an earlier peak but
bacteriostatic and bacterial overgrowth of the damaged
numbers of infective larvae decrease more quickly than
wall results.
normal due to more rapid depletion of the numbers in
faecal pats and to dilution due to the more abundant
Signs
grass growth under these conditions. Conversely, in dry
summers the build-up is delayed; release of larvae from
When all the above events occur the intestinal metab-
faecal pats does not take place under the autumn rain-
olism is also affected and the classical signs of acute
fall and the larval contamination is maximal thereafter.
diarrhoea, inappetance and weight loss commence.

TYPE II OSTERTAGIOSIS

of infective larvae remaining on pasture can be suffi-

ciently high to cause normal type I disease from 4 to 6

This form of the disease is usually found in yearlings in

weeks after going to grass.

the late winter or spring following their first season of

grazing. Affected cattle can be housed or outwintered.

Nematodirosis in calves

Aetiology and epidemiology

Parasitic gastroenteritis due to large infections of the

nematode Nematodirus battus has recently been

As with type I disease the direct cause is the simulta-

observed. Normally recognized as a parasite of sheep,

neous maturation of large numbers of O. ostertagi. The it has recently been observed to be able to be trans-circumstances surrounding the event require some

mitted by cattle, both on farms where annual alterna-

additional explanation, since the normal time of the

tion of sheep and cattle has taken place and even where

disease is not when infective larvae on the pasture are

cattle only are kept, and has caused severe outbreaks

most abundant.

of diarrhoea in calves.

Infective larvae present on pasture after September

and ingested from that time until the following spring

undergo a change in their normal parasitic develop-

Cooperiosis in calves

ment, which results in a period of delayed development

In the last decade, as a result of the widespread use of

at the early fourth larval stage while within the abo-

suppressive regimes with avermectins and moxidectin

masal wall. The behavioural change has been shown to

that are more effective against Ostertagia than Coope-be more common in some strains of O. ostertagi than

ria species, the prevalence of Cooperia oncophora, the others and to be brought about by either cold or desic-commonest of that genus in northern Europe, has

cation in their preparasitic exposure (Armour et al. , increased in comparison to Ostertagia species. In faeces 1969). In the late autumn, calves that have not had

samples taken during the first two-thirds of the grazing

adequate prophylactic treatment may harbour many

season on farms where intermittently applied aver-

thousands of such larvae but relatively few normally

mectins have been routinely used for prophylaxis,

developing larvae or adult worms. Type II ostertagiosis

Cooperia species eggs can form up to 90 per cent of the results when these inhibited larvae resume their devel-eggs excreted, with Ostertagia species forming the

opment in the late winter or spring, the emerging larvae

majority of the remainder. In such circumstances large

producing the same lesions as those causing type I

Cooperia oncophora worm burdens can accumulate in

disease.

a short time when hatching conditions are favourable.

These can result in outbreaks of acute diarrhoea and

ATYPICAL FORMS OF PARASITIC

loss of condition, and are rather similar to Nematodirus

GASTROENTERITIS

battus infections in lambs in spring, although in calves they usually occur in July or early August. If left

Parasitic gastroenteritis in beef herds

untreated calves normally recover after a few weeks

This is not usually a problem in spring-calving herds,

and become immune to Cooperia oncophora, but the

since most of the infective larvae are consumed by the

loss of condition can be prevented by prompt

adult cows, which normally have enough immunity to *treatment.*

prevent a high percentage of worms establishing and

producing eggs. The calves that might transmit the

Parasitic gastroenteritis in adult cattle

infection are too young to consume much grass in the

early part of the season. As a result the peak of infec-

Although uncommon, since most cattle acquire immu-

tive larval numbers does not develop until September

nity by the age of 18 months, occasional individual cases

or October when most calves are weaned, treated and

can occur. Bulls that are grazed on calf paddocks and

housed. Conversely, in autumn-calving herds in which

cows, which due to debilitating intercurrent diseases

calves are weaned in the following spring and grazed in

such as fascioliosis may have some of their normal

the same manner as dairy replacements, the same epi-

immune reactions depressed, can both suffer from type

demiological picture can result, i.e. type I ostertagiosis

II ostertagiosis.

will occur in the absence of preventative measures.

Diagnosis

Early-season type I ostertagiosis

Affected animals invariably present with diarrhoea,

In areas where climatic conditions allow autumn-born

which may be present to a greater or lesser degree in

calves to be put out in March or early April, the number

all members of the group. Younger animals are fre-

Table 19.1

Differentiation between type I and type II ostertagiosis.

Type I

Type II

Seasonal incidence

Predominantly July–November;

February–May

occasionally April–May

History

Usually in calves at grass for the first time, heavily

Always in calves that grazed on heavily stocked

stocked (8–10/ha). Occasionally in beef yearlings

pasture during the previous autumn, usually in

during the second year's grazing, and in individual *younger members of group. Can also occur in*

cows and bulls transferred from hill herds to more

bulls grazing calf paddocks. Occurs usually when

intensive systems

housed or within 3 weeks of being put to grass

Clinical signs

Profuse green diarrhoea; will only usually recur

Intermittent profuse diarrhoea. Recurs every 2

once approx. 10 days after treatment. Rapid loss

weeks until supply of inhibited fourth stages is

of body weight. Morbidity high, mortality low

exhausted. Morbidity low, mortality high

Laboratory findingsa

Not usually anaemic

Mild anaemia

PCV > 0.3

PCV 0.22–0.26

RBC > 7 ¥ 106/mm3

RBC 5.6 ± 106/mm3

Hb > 10 g/100 ml

Hb 8.4 ± 0.5 g/100 ml

Plasma pepsinogen 2–5 iu

Plasma pepsinogen 2–8 iu

Post mortem

pH abomasal contents

pH abomasal contents

>5.0

>5.0

>50 000 adult

>50 000 adult

O. ostertagi

O. ostertagi plus large numbers of

Severe abomasal reaction

immature fourth stages

Severe abomasal reaction

a PCV, packed cell volume; RBC, red blood cell; Hb, haemoglobin.

quently the most severely affected. There will be a

(3)

Plasma gastrin. The plasma concentration of the

history that indicates grazing on potentially infected

hormone gastrin has been shown to rise at the time of

pasture during the preceding four to eight weeks in the *patency in experimental infections and to peak at levels*

case of type I ostertagiosis or during the previous late

between 500 and 1000 pg/ml. Although still under inves-

summer and autumn for type II ostertagiosis.

tigation it may be used as a substitute for plasma

Specific diagnosis (see Table 19.1) can be assisted by

pepsinogen in the future.

the following tests.

(4)

Post mortem findings. In both type I and type II

(1)

Faecal egg counts. Despite the dilution of faeces

ostertagiasis the abomasum (providing the animal

caused by diarrhoea, the nematode egg counts will be

has remained untreated) will contain large numbers of

in excess of 1000 eggs/g. Counts may be higher in less

adult O. ostertagi. The number can vary from 50 000 to severely affected calves that have not yet become

1 000 000 in extreme cases. In type II disease pepsin

severely diarrhoeic. In older animals and in some indi-

digest of the abomasal mucosa or incubation in luke-

viduals in type II cases the faecal egg counts may be low

warm normal saline will reveal large numbers of inhib-

enough to be misleading, and if suspected the results of

ited fourth stage worms. The pH of the abomasal

other tests should be borne in mind.

contents will be raised to pH 4.5.

(2)

Plasma pepsinogen. In healthy calves the normal

Treatment (see Chapter 60)

level of plasma pepsinogen is less than 1 international

unit (iu) of tyrosine. In affected calves the level will nor-

Type I disease can be treated with almost any of the

mally be greater than 3 iu, and in very severely diseased

anthelmintics currently available such as levamisole,

individuals up to 4.5 iu. It should be pointed out that in

benzimidazoles or avermectins. Type II disease requires

adult cattle the normal pepsinogen level can be 1.5–

the use of some of the modern longer acting benzimi-

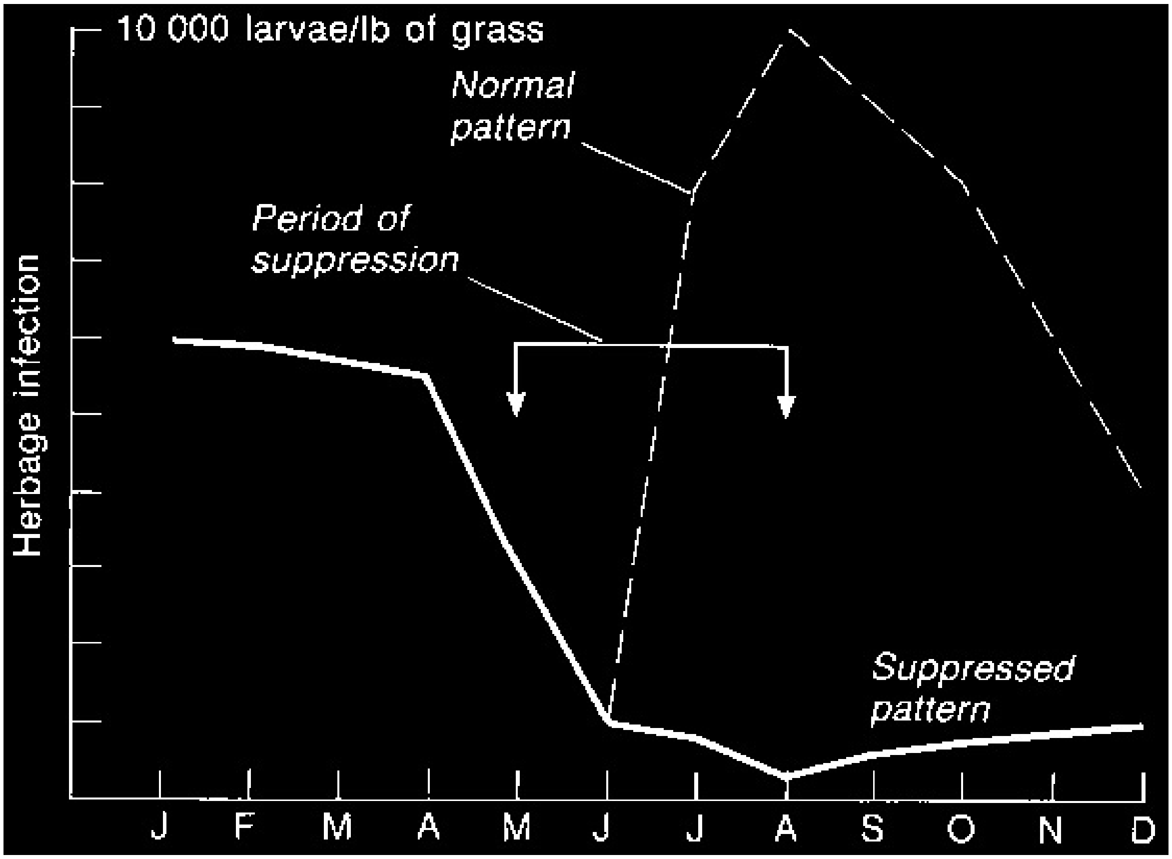
2 iu, almost that found in calves in the prepatent period

dazoles or pro-benzimidazoles or avermectins such as

of type II ostertagiasis. Plasma pepsinogen levels in *ivermectin, doramectin, abamectin, eprinomectin or*

adults therefore should be carefully evaluated.

moxidectin. The avermectins and moxidectin are much



the most effective in removing both adult and inhibited

although not ovicidal have an even longer half-life and

fourth stage parasites as a result of their persistence and

will inhibit further infections for at least two weeks. On

slow excretion. Levamisole is much less effective for

the other hand, levamisole has a rapid excretion rate

*type II disease, as it has a poor efficiency against inhib-
and is also not ovicidal. If reduction of contamination
ited worms due to its rapid excretion (see p. 1021), and
as well as nematode removal is intended, cattle treated
the benzimidazoles can vary in efficacy depending on
with levamisole require to be yarded after treatment at
the time of treatment in relation to the onset of inhibi-
least overnight, if not for 24 hours. After this first treat-
tion of the worms, i.e. in the early and late stages of inhi-
ment in early to mid July, and depending on the avail-
bition the larvae are thought to have a more active
ability of grass and its previous grazing history, the
metabolism, and therefore absorb more anthelmintic; in
calves may require no further treatment until housed in
the middle of the inhibition period they absorb less, and
late autumn, although in practice many are treated four
it is then that the benzimidazoles do not have the per-
to six weeks after the first movement. Although highly
sistence necessary to kill the worms.
effective and the most economical method of prophy-
laxis when carried out carefully, it should be pointed out*

that although excellent for control of gastrointestinal

Prevention

nematodes it is not completely effective in the preven-

As for most parasitic diseases, prevention is more cost-

tion of lungworm infection caused by Dictyocaulus

effective than treatment. Since there are no vaccines yet

viviparus.

available for gastrointestinal nematodes, numerous

schemes that combine grazing management and

Suppressive strategies: These have been introduced

anthelmintic therapy have been developed. The

gradually since the mid 1970s and are also based on

methods fall into three types: (i) evasive; (ii) suppres-

knowledge of the epidemiology of the infections.

sive; and (iii) dilution.

Unlike the evasive systems, which allow natural infec-

tion and pasture contamination to take place in spring

Evasive strategies: The basis of this category (also

and early summer, the basis of these methods is to sup-

called the 'Weybridge' system) was first enunciated by

press egg production during that period (Fig. 19.2). If

Michel (1968) at the laboratory of the same name.

pasture contamination is prevented or reduced, the

Using the knowledge of the epidemiology of parasitic

summer increase of infective larvae is of such propor-

gastroenteritis that had then become available, Michel

tions as to cause a negligible risk of severe parasitism.

pointed out that if susceptible cattle were removed

Suppression is carried out by two different methods: (i)

from infected to uninfected grazing just before the

repeated anthelmintic treatments with standard prepa-

summer increase in infective larval numbers, serious

rations, the interval between which is determined by the

parasitism could be avoided. When combined with

pharmacokinetic properties of the chemical used; cur-

anthelmintic treatment at the time of movement the

rently most of the anthelmintics used are avermectins

system reduces the level of nematode worm egg con-

or moxidectin: or (ii) the use of a device, usually an

tamination on the clean grazing. In essence, therefore,

intraruminal bolus, which has a continuous slow release

the system involves taking no prophylactic action until *of the active anthelmintic for periods from 60 to 140*

early July. At that time, pasture which has not been pre-

days. Such boluses are usually administered by balling-

viously used for cattle grazing that year is available,

after grass has been taken for silage making or some

other form of conservation.

The calves are given anthelmintic treatment before being moved to it. The timing of the treatment can vary with the pharmacokinetics of the anthelmintic used and its effect on nematode eggs if contamination of the aftergrass is to be avoided. For instance, the longer acting benzimidazole anthelmintics (e.g. oxfendazole, albendazole, fenbendazole) are ovicidal within a few hours after treatment and their slow rate of excretion means that cattle are protected from infection with susceptible parasites for approximately 30 hours after treatment. They can therefore be put back safely onto the contaminated grazing for 24 hours after treatment before transfer to the aftergrass. The same technique can be applied with avermectins and moxidectin, which

Fig. 19.2

Rationale for anthelmintic suppression.

gun at or just before susceptible calves are put out to

sufficiently large to cause disease. In general, calves

grass in the spring, although recent experiments have

at grass from midsummer to autumn are those most

shown that they can also be effective when given in

frequently clinically affected, but heavy infections in

midsummer to prevent infection in calves grazing pre-

animals of any age previously uninfected will produce

viously contaminated fields. The length of prophylactic

signs. It is most prevalent in dairy-type calves, but is also

activity varies between different climatic areas and

common in weaned beef calves. The range of signs can

nematode species, e.g. in south-eastern areas of the UK

vary from occasional coughing to severe respiratory dis-

suppression for eight weeks after being put to pasture

tress, and is a reflection of the number of infective

in spring may be sufficient, but in wetter western areas

larvae ingested during a relatively short period.

it may require to be prolonged for a further five weeks *and if lungworm infections are present on the farm for*

Aetiology and epidemiology

up to 15 weeks.

The immediate cause of clinical symptoms is the inges-

Dilution strategies: Originally described in New

tion two to four weeks previously of large numbers of

Zealand as the Ruakura method (McMeekin, 1954) and

infective larvae of D. viviparus by non-immune cattle.

further amended by Leaver (1970), the methods consist

Experimentally, severe infections can be induced by a

of the grazing of paddocks in relays by groups of calves

single administration of larvae at a rate of between 25

followed by groups of older cattle. The basis of the tech-

and 50 larvae/kg body weight. Typically, an affected calf

nique is that the greater consumption of infective larvae

weighing 300 kg will have ingested between 7500 and

by the immune or partially immune adults will delay

15 000 L3 (third stage larvae). This is a much smaller

and reduce the build-up of infective larvae on the pad-

infection than is required to cause parasitic gastroen-

docks. Initially, no anthelmintic treatments were given, *teritis by O. ostertagi, and is an indication of lesser but in modern practice the method is frequently com-margin for error involved in ensuring adequate*

bined with either of the evasive or suppressive

prophylaxis.

techniques.

The epidemiology is more complex and infections are

The advantages and disadvantages of each of the

also much less predictable than are those of gastroin-

three preventive methods are summarized in Table 19.2.

testinal nematodes, principally because at present not

all details of larval survival and transmission are known.

Infections are more prevalent in wetter areas, especially

Parasitic bronchitis (husk, hoose)

those in the west of the British Isles. One of the major

Dictyocaulus viviparus is almost the sole cause of

differences between D. viviparus and gastrointestinal severe pulmonary helminth infections in cattle. Occa-nematodes that has an influence on the unpredictabil-

sionally other parasites are found, but rarely in numbers

ity of infections is that the female worm produces eggs

Table 19.2

Advantages and disadvantages of the prophylactic methods for gastrointestinal parasites.

Method

Advantages

Disadvantages

Evasive

Low labour cost

Does not protect against

Low anthelmintic cost

lungworm

Not likely to lead to anthelmintic

Reduces the flexibility of pasture

resistance in nematodes

usage in the late summer

Suppressive

If carried out for long enough

Higher labour or anthelmintic

will reduce the chances of

costs especially in the case of

lungworm infection

slow-release boluses

More likely to lead to

Allows more flexible use of

anthelmintic resistance in

grazing

target nematodes

Dilution

Lower anthelmintic costs

Requires excellent fencing and

high labour costs and is generally

used only in well organized dairy

farms

Is not effective for prevention of

lungworm infection

containing fully developed larvae, which are passed in

Necropsy

the faeces. These become infective within a much

The pathological progression during maturation pro-

shorter time than the eggs of Ostertagia species and

gresses from alveolitis and bronchiolitis to bronchitis

hence in optimal conditions can produce a rapid

and severe emphysema, sometimes with superim-

increase in their numbers. In addition to rapidity of *position of a secondary bacterial pneumonia. If left*

maturation to infectivity, larvae are also dispersed from

untreated after patency even moderate infections can

faecal pats by some of the following means: (i) ascend-

progress in severity due to aspiration of eggs and

ing the common faecal fungus Pilobolus and being pro-

hatched larvae back into previously unaffected alveoli

pelled into the air on discharge of the sporangium,

and smaller bronchioles, resulting in bronchitis and

to be carried by wind to adjacent areas; (ii) although

pneumonia.

unverified, there is evidence that earthworms or

coprophagous beetles may act as transport hosts; (iii)

also unverified, it has been reported that the European

Diagnosis

hare (Lepus europaeus) can be infected, although

experiments have shown that the smaller blue hare (L.

Affected cattle invariably present with varying degrees

timidus), common in Ireland, is refractory to infection.

of respiratory abnormality, and since similar signs can

In addition to these means of dispersal it has been *occur as a result of infection by a variety of pathogens,*

shown that infective larvae can remain viable in soil as

careful differential diagnosis is advisable. The grazing

well as on pasture over the winter, and that small

history and time of the year in northern temperate

numbers of adult worms and hypobiotic larvae can

areas invariably involve cattle grazing established

survive and overwinter in infected animals despite their

pasture previously used by other cattle plus the appear-

hosts having some immunity to further infection, only

ance of clinical signs between July and October. Since

to mature and propagate larvae during the following

the caudal lobes of the lung are more frequently

spring.

affected, adventitious lung sounds are usually more

apparent from these areas, in contrast to those from

viral pneumonias, which usually affect the cranial and

Pathogenesis

medial lobes. Confirmation of the diagnosis by identifi-

After ingestion, infective larvae penetrate the intestinal

cation of larvae in faeces or sputum samples can only *mucosa, moult to the L4 stage of their life cycle and*

take place after patency, which takes place approxi-

migrate via bloodstream and lymphatic channels to the

mately 25 days after infection, although it should be

lungs. This takes place approximately one week after

noted that in adults that are suffering from a re-

being consumed, and up to this point no clinical effects

infection the infection usually does not reach patency.

are observed in the host. After that period, larvae break

out of blood vessels into alveoli and small bronchioles,

Treatment (see p. 1027)

after which they moult to become young adults, and as

they increase in size they ascend the bronchiolar tree

In order to kill the worms and larvae present in the lung

towards the large bronchioles and bronchi. Larvae are

tissues, anthelmintic treatment is essential. The most

first found in faeces from the 25th day after infection.

effective are the avermectins and moxidectin; lev-

amisole and some of the more recently developed

benzimidazoles or pro-benzimidazoles,

such as

Signs

oxfendazole, fenbendazole, albendazole and netobimin,

Clinical signs appear during the second week after

are also effective, but the incidence of alveolar epithe-

infection and their severity depends on the number of

lialization is more common after their use, since they

developing worms. The signs range from occasional to

have little persistent efficacy and reinfection can occur

repeated coughing, with a noticeably increased respira-

if the same grazing is used before and after treatment.

tion rate in the worst affected. By the third week,

Severely affected animals may also require antibiotic

severely affected cattle do little else except stand in

therapy to control secondary bacterial pneumonia, and

a characteristic head extended position with rapid

if anorexia has been present rehydration with elec-

shallow breathing and frequent coughing.

trolytes may also be helpful. In most outbreaks a range

Although most calves, if not severely affected, will

of severity is observed and it is frequently advisable to

recover after treatment, a small percentage will suffer

house the worst affected cattle, especially if climatic
a relapse of clinical signs in the absence of fresh infec-
conditions would be stressful even to healthy calves. In
tion. The precise aetiology of this is uncertain, but
addition, because treatment of severe cases can exacer-
autopsy reveals an oedematous rubbery lung with alve-
bate signs farmers should be warned of the possibility.
olar epithelialization observed microscopically.

In outbreaks involving adult dairy cows care should be

taken that the anthelmintic used does not prevent sale
time of turn-out to grass, and intraruminal boluses
of milk products for a prolonged period until a with-
designed to release anthelmintic either intermittently or
holding time long enough to allow excretion of the drug
continuously for periods up to 140 days. The level of
has passed. The most appropriate drug currently avail-
immunity stimulated depends on the number of larvae
able is eprinomectin, the use of which requires no
ingested from pasture and, since this can be highly vari-
period of milk withdrawal from sale.

able, some cattle in a group may have inadequate resist-

ance to future infection should they be exposed to it. As

a result, careful monitoring is necessary after ces-

Prevention

sation of anthelmintic treatment and some thought

There are two major methods available, the first relying

required to plan cattle husbandry during the subsequent

on inducing immunity and the second on suppression

year and then as adults.

of infections.

Stephanurosis (kidney worm)

Vaccination (see p. 1011): Immunity can be stimulated

Aetiology and epidemiology

by the use of a live vaccine, which takes the form of two

doses of 1000 infective larvae irradiated by gamma irra-

This is mainly an infestation of pigs but it can infect

diation. Calves should be two months old before vacci-

calves and is due to Stephanurus dentatus. The adult is nation and the doses separated by four weeks and

up to 45 mm in length.

preferably both doses given before going to grass in

The condition is found in the tropical and subtropi-
the spring or before the time of earliest challenge in
cal countries of Africa, East and West Indies, Brazil,
outdoor calves. Although the vaccine induces excellent
Hawaii, Philippines, Australia and southern Europe
protection against clinical disease it does not com-
where pigs are kept, but in calves adult worms do
pletely prevent all worms from natural infections com-
not develop. The larvae cause damage to the liver
pleting their life cycle, so that the parasite can be
parenchyma during migration and produce thrombosis
maintained at a very low level on pasture grazed by vac-
of the abdominal blood vessels, which may be fatal.
cinated cattle. If the farmer neglects to vaccinate, para-
Aberrant larvae can encapsulate anywhere in the host
site numbers can quickly increase sufficiently, if weather
but the majority are found in all parts of the kidney. The
conditions are favourable, to affect non-immune cattle
eggs produced in the pig form hatch to produce first
within their first grazing season.
stage larvae. These develop to third stage infective

larvae if there is warmth and moisture. The larvae are

Suppression: On farms where calves have suffered lung

often ingested by earthworms and these act as a vector

damage due to viral pneumonia, vaccination may be

for infection. The infective larvae are otherwise sus-

inadvisable because of the possibility of exacerbation

ceptible to cold or drying. Transmission is either by

of the existing lesions. Under these circumstances it

ingestion, which may include earthworms, or by skin

has been found that regular anthelmintic treatments

penetration. In the host they pass to the liver where

throughout the grazing season can suppress infection

they remain for a considerable time before going to

sufficiently to minimize the danger of clinical disease

other parts of the body.

and at the same time allow some immunity to be

induced by the natural ingestion of infective larvae from

Signs

pasture which are subsequently killed before comple-

tion of their life cycle (see p. 1027). The method has also

They are mostly of anaemia, ill thrift and ascites. Many *been successfully applied to normal healthy calves, but*

infestations are without signs.

it requires to be carried out and monitored carefully,

since there are potential problems in its use. Firstly, the

Necropsy

length of time during which anthelmintic suppression is

Necrotic lesions with thrombosis in the mesenteric

required may vary between areas with different climatic

blood vessels and hypertrophy of the mesenteric lymph

patterns and farming practices. In general in the British

nodes are likely to be found. In a few cases there may

Isles it is necessary to provide anthelmintic cover until

be haemorrhages and abscesses in the lungs and

mid August. The methods of application require that the

kidneys.

anthelmintic must be extremely effective against all

stages of the parasitic life cycle of the nematode. Those

Diagnosis

anthelmintics used fairly successfully have been aver-

mectins, either as injections or pour-ons administered at

This will depend on the presence of calves grazing areas *intervals after going to grass that are dependent on the*

with infected pigs. An immunodiffusion test can be

particular pharmacokinetics of the drug used and the

used. There is a marked eosinophilia.

Treatment and control

suck blood and cause haemorrhagic anaemia and

hypoalbuminaemia, and small numbers (about 2000) in

Fenbendazole at high doses may be effective. Calves

comparison to other gastrointestinal nematodes, other

should not graze pastures recently used by pigs.

than Haemonchus placei, will cause very severe disease and death.

Bunostomosis

Bunostomosis in cattle is caused by the hookworm

Diagnosis

Bunostomum phlebotomum. It mainly affects cattle up

to one year old and causes a range of signs from unrest

It is difficult to diagnose when prepatent and mild

and mild abdominal pain to diarrhoea and eventually

anaemia is the main sign. When patent it should be dif-

anaemia depending on the stage of the infection and the *ferentiated from other parasites that cause haemor-*

number of worms present. It is more prevalent in sub-

rhagic anaemia, e.g. H. placei and F. hepatica, and those tropical and tropical regions than in temperate; this

deficiencies such as cobalt or copper (Chapter 21) that

distribution has become especially marked during the

adversely affect erythropoiesis.

last decade as the worm, which does not occur in

large numbers, seems especially sensitive to some of the

Treatment and control

modern anthelmintics and may now be absent from

those areas where frequent suppressive anthelmintic

The parasite is sensitive to modern anthelmintics and

treatments have been applied.

can be controlled by their suppressive or strategic use.

Other measures in housed cattle should be the provi-

sion of dry bedding and its replacement when soiled.

Aetiology and epidemiology

Once infected and treated, cattle normally develop a

Bunostomum phlebotomum parasitizes the small intes-

strong immunity to the parasite.

tine of cattle. Adults can reach 3.0 cm in length and are

characterized by a large buccal capsule with lateral

Haemonchosis

cutting teeth and a tooth-like structure in its base, which

is the duct of an oesophageal gland. The worms suck

Haemonchosis is manifested by haemorrhagic anaemia

blood, which can induce anaemia and in large numbers

and diarrhoea, and is caused by the presence in the abo-

cause diarrhoea.

masum of Haemonchus placei (synonym H. similis). As The eggs from adult females pass out with faeces.

with bunostomosis it is mainly pathogenic in immature

Depending on climatic conditions, a parasitic infective

cattle, since infection in the first three years of life

larva, which is susceptible to desiccation, will develop

usually produces a strong immunity to reinfection. It

under optimal conditions of adequate moisture and

also has a similar distribution, being commonest in sub-

warmth within one week. The infective larvae can infect

tropical and tropical countries, but present in most tem-

susceptible cattle in either of two ways.

perate countries and able to cause disease during any

unusually warm periods of weather.

• By penetration of the skin after which it enters the

bloodstream and passes to the lung, emerging

into the alveoli and after further moulting up the

Aetiology and epidemiology

bronchial tree to the pharynx, where it is then swal-

Adults of H. placei suck blood from the surface of the lowed and passes to the intestine to mature.

abomasum. They are fairly large in comparison to other

• By direct ingestion after which it burrows into the

abomasal nematodes and measure 3 cm in length when

intestinal wall during development to emerge as an

fully grown. In the female the ovaries and intestine are

adult.

spirally intertwined to give the worm its ‘barber-pole’

The prepatent period is eight weeks. The worm flour-

appearance and nickname. The male has large barbed

ishes in conditions of adequate moisture and warmth

spicules, and both sexes a small lancet in the buccal

and thus is generally a subtropical problem, but disease *capsule.*

has been recorded in countries as far north as Scotland,

Female H. placei are very prolific egg producers and

where it has been seen in cattle maintained indoors on

can lay up to 10 000 eggs daily. The eggs are passed in

damp straw bedding.

faeces and undergo a typical trichostrongyline devel-

opment to infective larvae. The time taken to reach this

stage varies considerably between temperate and sub-

Signs

tropical climatic areas. In the former, it may take

Heavy percutaneous larval infections cause restless-

several weeks in contrast to four days under suita-

ness, stamping and itching. Once in the intestine adults

ble conditions. The conditions for development of

Haemonchus spp. have been studied in some detail, and Treatment and control

it has been concluded that they require a temperature

Anthelmintic treatment is the primary consideration

in excess of 18°C and rainfall of 5.3 cm/month for

and H. placei is susceptible to levamisole, avermectins, maximum translation, *but can develop provided the*

moxidectin and modern benzimidazoles as well as the

mean minimum temperature is not less than 10°C. As a

flukicides rafoxanide, clorsulon and nitroxynil. This

result of the combination of fecundity and rapid infec-

should be coupled with movement to uninfected

tive development in favourable conditions, pasture can

pasture. Prevention can be achieved using similar

become quickly contaminated with huge numbers of

methods as those described for ostertagiosis.

infective larvae. In the subtropics acute infections can

therefore be found in susceptible young cattle, whereas

in temperate areas infections are more likely to be

Trematodes

chronic. Under adverse conditions in the tropics, e.g.

dry seasons, infective larvae can undergo hypobiosis in

Fasciolosis

a similar manner to Ostertagia spp., and resume development shortly before the rainy season commences.

Fasciolosis in cattle is a chronic wasting disease caused

Once ingested, larvae undergo two moults before *by the presence in the liver and bile ducts respectively*

becoming adult in 26–28 days, when infections become

of immature and adult trematodes of the genus Fasci-

patent. After the first moult, the L4 larvae and subse-

ola. The disease is found in vast areas of the world, with quent adults suck blood, leaving haemorrhagic spots on

the smaller F. hepatica (3.5 ¥ 1 cm) in temperate counthe abomasal epithelium, and the resultant blood loss is

tries and the larger F. gigantica (7.5 ¥ 1 cm) in tropical the major pathogenic sequelae. However, in large infec-regions the commonest species. Calves and yearlings

tions the pH of the abomasal contents may be increased

are most commonly affected but any age of animal may

in the same way as in ostertagiosis, with the resultant

be susceptible. Although it may take place at any time

digestive disturbance, raised plasma pepsinogen, possi-

of the year, infection is most prevalent during autumn

ble bacterial overgrowth and diarrhoea. Once patent,

in temperate areas, with the resultant effects of disease

peak egg production from females is normally reached

becoming apparent in winter and spring.

between six and seven weeks after infection and may

continue for a further six to eight weeks. Cattle, unlike

Aetiology and epidemiology

sheep, develop resistance to the worm and unless

immunologically compromised by intercurrent illness

F. hepatica: Multiplication of the parasite is partially or malnutrition the population decreases rapidly there-climatically regulated, since its life cycle involves an

after and the animal remains fairly resistant for the

intermediate host that requires adequate moisture and

remainder of its life.

a suitable ambient temperature. The intermediate hosts

are various species of snail of the genus Lymnaea, which are found on wet mud surfaces. In the British Isles, L.

Signs

truncatula is the species involved. It prefers a neutral or There are two types of clinical picture. The first occurs

slightly alkaline habitat, but can survive in fairly acid

in severe primary infections and presents severely

conditions such as peaty hills, although under such con-

anaemic, weak and sometimes diarrhoeic young cattle.

ditions individual snails remain small and the popula-

The second is found in chronic lesser infections and typ-

tion low. At its maximum it can have a shell length of

ically causes weakness, lethargy, weight loss, a less acute

1 cm. The snail population fluctuates, being least in

anaemia, hypoproteinaemia, submandibular oedema

winter and greatest in June and July, especially in years

and anasarca.

when late spring rainfall has been above average, when

large numbers accumulate and are therefore available

for transmission of F. hepatica.

Diagnosis

Briefly summarized the life cycle of F. hepatica is as Diagnosis can be confirmed if the infection is patent by

follows. The adult parasite in the bile ducts is a her-

the examination of faeces samples, which may reveal

maphrodite and can be self- or cross-fertilized. Large

very high faecal egg counts. The plasma pepsinogen

numbers of eggs are produced by each parasite, which

level may be raised. The grazing and past parasitic

pass from the ducts to the gall-bladder and are subse-

history may be helpful in differentiating from other

quently passed into the intestine on contraction of that

causes of anaemia or diarrhoea such as fasciolo-

organ. Eggs are then passed in the faeces, but will not *sis, bunostomosis, copper or cobalt deficiencies,*

hatch unless moist and until an ambient temperature of

babesiosis, coccidiosis, bacillary haemoglobinuria and

10°C is reached. Hatching at temperatures between

malnutrition.

22 and 26°C takes nine days, but under normal

temperatures in the months of May and June in the

F. gigantica: Although similar in many respects to F.

British Isles, it can take four weeks. On hatching, the

hepatica it is not found in western Europe, but is wide-released miracidium must locate and penetrate the foot

spread within tropical and subtropical climatic regions.

of L. truncatula within three hours. Once in the snail, The intermediate hosts are also snails of the genus

the parasite undergoes multiplication through stages of

Lymnaea, but the species are more aquatic than those

sporocyst and rediae and reaches the cercarial stage

transmitting F. hepatica and thrive in swamps, drainage after a minimum of two months, although in colder tem-channels and artificially flooded areas. As a result the

peratures it may take up to 16 weeks or should winter

epidemiology is closely tied to the periods of maximum *intervene complete development may cease until the*

rainfall, the snails being infected and development in

following spring. Under natural conditions within the

the snail completed within these periods. Cercariae are

British Isles, cercariae from summer infections are

shed towards the end of the wet season and encyst on

released from snails between late August and October,

herbage and even on the water surface at the start of

and in some areas from overwintered infections in

the dry season.

April or May. On release from the snail, which must

The parasitic life cycle is similar to that of F. hepatica take place in conditions of wetness, the cercariae

but each phase takes slightly longer with the result that

swim to the nearest plant, encyst on its leaves and

patency of primary infections take three or four weeks

become the infective stage, termed metacercariae,

longer than F. hepatica, eggs being found in faeces from several hundred of which can arise from one miracid-13 to 16 weeks after ingestion of metacercariae.

ium. Metacercariae on herbage can survive for several

months and therefore maintain the infection from one *year to the next.*

Signs

Cattle become infected by ingestion of grass on

which metacercariae are encysted. The metacercariae

In severe infections there is a progressive loss of weight

excyst in the small intestine, the wall of which they

with anaemia and occasionally oedema. Subclinical

penetrate to reach the peritoneal cavity where they

infections cause a reduction in milk yield and reduction

move to the liver and invade its capsule. At this point

in the growth rate of young cattle.

the flukes are very small (about 1 mm) but as they

burrow through the liver parenchyma they gradually

Diagnosis: The disease is characterized by a gradual

increase in size and in primary infections in cattle will

loss of condition that is exacerbated if the quantity and

reach the bile ducts after six to eight weeks, when they

quality of feeding are suboptimal. A chronic anaemia

mature and become egg-laying adults 10–12 weeks after

develops and the packed cell volume (PCV) drops to

ingestion. In response to the presence of fluke in the *approximately 20 per cent.*

Erythrocytes are

liver parenchyma, the liver of cattle produces a more

hypochromic but normocytic, and while the leucocyte

intense fibrous reaction than that of sheep, and the

count may be slightly raised, the percentage of

resultant cirrhosis is much more severe and is longer

eosinophils in a differential count is greatly increased

lasting. The liver cells of cattle do not regenerate as do

and may consist of up to 20 per cent of the total white

those of sheep, and the result of even moderate

cell count. In cows the total milk yield and the non-fat

infection in cattle is a more fibrous liver parenchyma

solids proportions may be reduced.

than in most other species.

Diagnosis can be confirmed by the presence of fluke

Within the bile ducts, the adult flukes suck blood

eggs in faeces samples, but detection is not always as

and the spines on their cuticle cause multiple small

simple as in sheep, especially in adults, since even in

haemorrhagic lesions. In cattle, the resultant fibrous *patent infections excretion of eggs is intermittent.*

reaction within the bile ducts is also more severe than

Examination of plasma shows a hypoalbuminaemia,

in sheep and the bile duct walls thicken and become

and during the migration phase the plasma glutamate

gradually calcified thereafter (Fig. 19.3). The result of

dehydrogenase (GLDH) is raised. Once the epithelium

the fibrous reaction during a primary infection in both

of the bile duct walls becomes diseased, the plasma

bile ducts and parenchyma of cattle shortens the life

concentration of gamma-glutamyl transpeptidase (GT)

span of adult flukes in the ducts to a maximum of 1.5

rises and this is a useful diagnostic indicator.

years and reduces the chances of flukes from subse-

quent infections being able to complete their life cycle.

Cattle therefore become largely resistant to further

Treatment (see pp. 1026, 1028)

infections, most of which do not become patent, and the

few flukes that do so may take much longer than normal

Affected cattle are treated by administration of a

to reach patency and survive in bile ducts for a rela-

fasciolicide. Of those currently used for cattle the com-

tively short time.

monest are triclabendazole, oxyclozanide, rafoxanide,

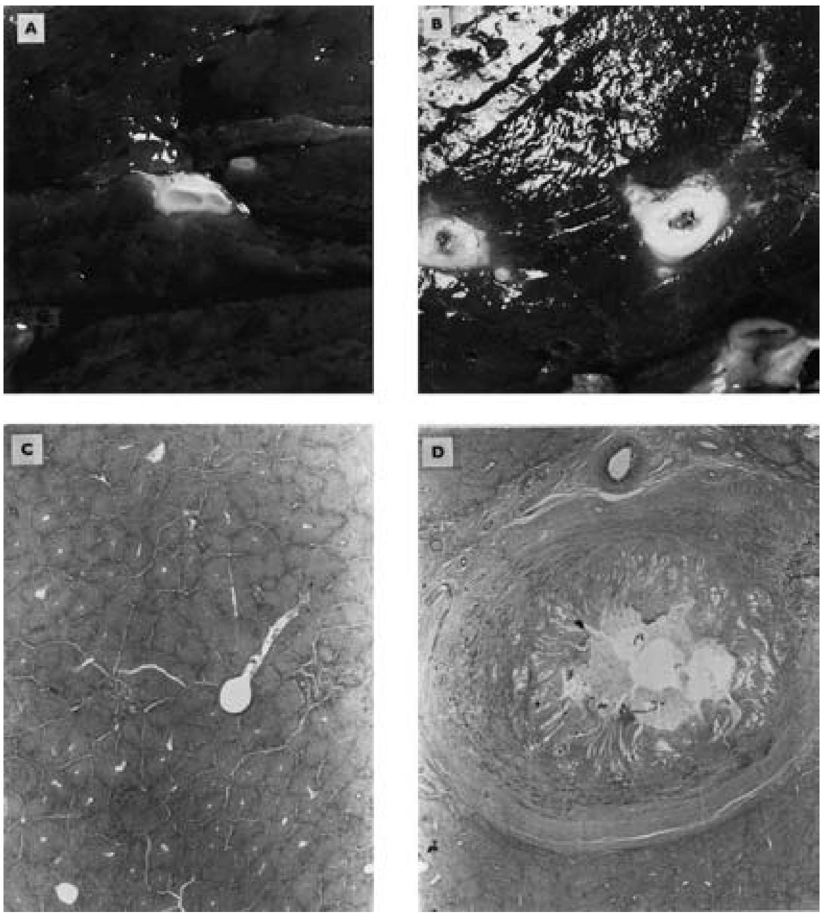


Fig. 19.3

(A) Normal and (B) liver fluke

infected bovine liver. (C, D) Microscopic

sections of the same stained to show

fibrous tissue.

nitroxynil, albendazole, netobimin and clorsulon. All

in an attempt to give a more rapid reduction in the

will remove more than 90 per cent of adult flukes from

prevalence of the parasite.

the bile ducts, but they have variable efficiencies against

• Prophylactic use of anthelmintics to reduce both

the immature stages migrating through the liver. The

the number of flukes in cattle and the number of

most effective is triclabendazole, which will remove

eggs excreted. This is by far the commonest prac-

developing flukes from a few days after ingestion.

tice and involves treatment of cattle once or twice

Rafoxanide, nitroxynil and clorsulon are effective

annually. In the British Isles such treatments take

against six-week-old flukes at normal dose rates and at

place in the autumn and late spring.

increased dose levels affect those four weeks old.

• If the areas of snail habitat are delineated and small

Albendazole, netobimin and oxyclozanide at normal

and they can be drained. This is usually not cost-

dose rates remove only adult flukes from the bile effective for fluke control alone if the sites are

ducts and are ineffective against immature flukes. All

extensive.

require withholding of meat and milk for human con-

• Small snail habitats can be fenced off during the

sumption for variable periods dependent on their

time of greatest infection.

pharmacokinetics (see p. 1026).

• Snail habitats can be treated with molluscicide.

There can be environmental objections since many

which were formerly in use were toxic to many

Prevention

species in addition to snails. The most satisfactory

There are four methods available that are used indi-

is N-tritylmorpholine, which although not available

vidually in suitable circumstances or can be combined

in the UK is used in many tropical countries.

Paramphistomosis (stomach fluke

Diagnosis

disease, intestinal amphistomiosis)

Most disease occurs with immature flukes and so it is

Aetiology and epidemiology

not easy to detect in the live animal but it can be missed

at post mortem. Often other parasitic infestations are

The cause of acute paramphistomosis in Africa is

present, which again causes paramphistomiosis to be

Paramphistomum microbothrium. Other Paramphisto-

overlooked. However, the history and area where the

mum spp. and Cotylophoron spp. are found in rumi-cattle are grazing can give some indications. There is a

nants in Africa and tropical and subtropical regions.

reduction in the red and white blood cells and a hypoal-

In Asia, Calicophoron spp. are found and one species

buminaemia. Differential diagnoses include copper and

occurs in Africa. Carmyerius spp. are seen in Africa, cobalt deficiencies, liver fluke, parasitic gastroenteritis,

India, Pakistan and the Middle East.

Johne's disease in the adult and poisoning.

It has been recorded in a severe form in Australia,

India and the USA. The life cycle is indirect and similar

to that of Fasciola. It involves aquatic snails that are Treatment (see p. 1028)

adapted to a variety of locations. Disease occurs only

Few of the modern trematocides have been found to be

where there is a massive concentration of the infected

effective against paramphistomosis. Oxyclozanide at

planorbid snails. The metacercariae are ingested and

18.7 mg/kg has variable efficacy from approximately 50

the immature flukes develop in the duodenum, where

to 90 per cent. Niclosamide at 100 mg/kg is highly effec-

they may be seen in the mucosa. The flukes are 3–4 mm

tive against intestinal paramphistomes but ineffective

long and 1–2 mm wide. They also develop in the abo-

for adults. Brotianide at 55 mg/kg is effective against

masum but are less common. They then migrate

adult flukes but less so against the immature stages.

through the abomasum to the rumen and reticulum,

where again few are found. The prepatent period is very

variable, being between one and a half to four months.

Control

Most outbreaks occur in the late summer, autumn or

Drainage of low-lying areas and destruction of the soil

early winter when pastures are being contaminated

will considerably reduce infestation. The most suscep-

with cercariae. Although all ages of cattle are suscepti-

tible animals, i.e. calves and immature cattle, should be

ble, infestation is most commonly seen in yearlings.

kept away from likely snail habitats. Routine treatment

Fewer infestations occur in the adult, suggesting some

against Paramphistomum before they mature and can

degree of immunity.

infect snails is of use.

Signs

Schistosomosis (bilharziosis)

Acute paramphistomosis is due to a massive infestation

Aetiology and epidemiology

in calves. There is a persistent fetid diarrhoea without

There are several parasites in the genus Schistosoma.

blood or mucus, anorexia, weakness, marked loss of

Schistosoma bovis is found in African, Asian and south-condition and then recumbency. In some cases there is

ern European cattle. Schistosoma mattheei occurs in

submaxillary oedema and a pallor of the mucosa. Death

cattle in central and southern Africa and can infect

occurs in about one to two weeks after signs develop.

man. Schistosoma indicum is found in India and

Pakistan as is also S. spindale, which can also occur in Chronic: In heavy infestations of adult flukes there is a south-east Asia and Indonesia. Schistosoma japonicum

chronic loss of weight, a dry coat and anaemia.

occurs in the Far East. Schistosoma nasale is again

found in India and Pakistan and is unusual in that the

adult occurs in the mucosal veins of the nose. Several

Necropsy

minor species occur involving S. curassoni.

In the acute case there is severe inflammation of the

Various species of the parasite are widespread and

duodenum and abomasum as the parasite penetrates

the adults live in veins. Unlike most flukes, Schistosoma

deeply into the mucosa and sometimes the muscularis

spp. are not hermaphroditic and the longer male carries

layer, and there is haemorrhage. There is muscular

the long slender female, which is up to 25 mm long, in

atrophy, subcutaneous oedema and fluid accumulation

a gyroectoplasmic canal. Infection can be via the skin

in the body cavities. Large numbers of small, immature,

or gut. After penetrating the skin the schistosomulae *flesh-coloured flukes are present in the lumen. In less*

(young flukes) pass via the lymphatic system to the right

acute cases the duodenum is thickened and congested.

side of the heart. They then go via the lungs into the cir-

There is fluid in the abdominal cavity.

culation and then to the liver. They mature in the portal

Table 19.3

Intermediate snail hosts of Schistosoma spp.

cally spiral. As the eggs hatch quickly they need to be

fixed in 10 per cent formalin.

Species

Intermediate snail host genus

Differential diagnosis involves coccidiosis, try-

panosomosis, poisoning and Johne's disease.

S. bovis

Bulinus and Physopsis

S. indicum

Indoplanorbis

S. japonicum

Oncomelonia

Treatment (see p. 1028)

S. mattheei

Bulinus

Trichlorophan, an organophosphorus compound, can

S. nasale

Lymnaea and Indoplanorbis

be used parenterally, or niridazole or thioxanthane

derivatives such as becanthane or hycanthane may be

used. Treatment must be performed carefully otherwise

a large number of dead schistosomes will produce

veins before migrating to their final area, usually the

emboli and lead to hepatic infarction or portal

mesenteric veins, but they are also found in the urinary

occlusion.

bladder veins in the case of S. mattheei and in the nasal mucosal veins in S. nasale. When infection is oral the Control

gut is penetrated and the immature stages pass to the

liver via the blood.

Immunity to the disease occurs but varies with the

Once mature, eggs are produced that can hatch

Schistosoma species. Control involves keeping cattle within minutes if conditions are right. The free-away from areas frequented by the intermediate host.

swimming miracidiae penetrate snail hosts producing

Molluscicides can be of some benefit. Some vaccines

sporocysts, daughter sporocyst and cercariae but there

are under development, e.g. a recombinant glutathione

are no redia. The cercariae must infect the final host

S-transferase derived from Schistosoma bovis has been within one or two days or they die off as there is no

shown to reduce both egg output and parasitic estab-

metacercarial stage. There are various genera of snails

lishment. Such vaccines can be expected to be available

involved depending on the species of Schistosoma

in the next year or two.

(Table 19.3). All the snails like mud except for

Oncomelonia spp., which are aquatic.

Cestodes

In many areas of Africa most of the cattle are

infected but there are very few signs. Young cattle are

Taenia saginata

more likely to be ill.

Taenia saginata is a cyclophyllidean tapeworm, for which Signs

man is the final host. It is transmitted to man by the *ingestion of the intermediate larval stage in under-*

The main signs are of diarrhoea, which may contain

cooked beef. Although the larval stage can be found in

blood and mucus and is intermittent. There is a loss of

any age of cattle, viable cysts are found mainly in cattle

condition and reduced resistance to other diseases.

up to two years of age. The presence of the parasite in the

Death occasionally occurs. Infestation with S. nasale

muscles of cattle does not cause clinical signs unless the

causes a mucopurulent nasal discharge with dyspnoea.

animal is very heavily infected and the myocardium is

Chronic cases develop nasal granuloma.

involved, but because it is a zoonotic infection its pres-

ence can cause significant losses to the beef industry,

Necropsy

especially in developing countries. In countries where

sanitation standards are high it is a decreasing problem

In severe infestation there are small grey-white

that on average is found in 0.5 per cent of bovine car-

granules in the gastrointestinal tract with petechial

casses, with occasional heavy infections occurring under *haemorrhages and ecchymosis. The ileocaecal body*

unusual circumstances. In those areas of Africa, Asia

may be enlarged and haemorrhagic. Granulomas may

and parts of Latin America where human sanitation

also be scattered through the liver parenchyma as well

methods are poor or non-existent and local customs

as the lungs and bladder. In S. nasale infestation there favour ingestion of raw or undercooked beef, the preva-may be nasal granulomas.

lence may be up to 20 per cent.

Diagnosis

Epidemiology

The signs and grazing history help but it is difficult to

The adult tapeworm inhabits the intestines of man. Its

diagnose unless faeces are taken or nasal discharge if S.

scolex has no hooks, and apparently moves up or down

nasale is present. The eggs are large and characteristi-the intestine depending on whether the host has eaten

recently or not. When the host's stomach is empty the

• If lightly infected they are frozen to a temperature

scolex moves back up the intestine towards the duode-

of -10° for a minimum of 10 days, after which any *num, and these movements produce hunger pains and*

previously viable cysticerci will have been killed.

vague intestinal discomfort. Fully grown the tapeworm

• Heavily infected carcasses are usually condemned

may reach a length of 8 m. Mature egg-filled (about

as unfit for human consumption and rendered after

25 000) proglottids are shed from its posterior end and

heat treatment into animal feedstuffs in some coun-

are passed in faeces or wriggle out of the host's anus

tries. The thermal death-point of cysticerci is 57°C

nocturnally. Anal pruritis and occasional diarrhoea are

and meat for human consumption should be raised

usually the only signs apart from the aesthetic and

to at least that temperature if the possibility of

hygienic conditions involved.

infection is to be avoided.

The eggs are resistant to external conditions. They

are inactivated within two weeks if desiccated, but are

known to survive for 16 days in raw sewage, 71 days in

Echinococcus granulosus

liquid manure, 159 days on pasture and 200 days in

and hydatid cysts

sewage sludge. No normal method of handling sewage

There are two species of the taeniid tapeworm E. gran-

can inactivate them other than total incineration or

ulosus. The first is E. granulosus granulosus: the adult extensive heat treatment. Extended periods of sludge

is found worldwide in the intestine of dogs and many

digestion with or without heat may affect viability but

wild Canidae but not the red fox. The intermediate

technical proof is lacking. Chemical disinfectants other

form, the hydatid cyst, is found in domestic and wild

than some containing copper at very high pH (11.5) are

ruminants, man and pigs, but not horses and donkeys.

not ovicidal.

The second is E. granulosus equinus, which is almost

Two-thirds of outbreaks in developed countries have

exclusively found in Europe: adults parasitize the dog

been shown to be associated with the spreading of

and the red fox, and horses and donkeys are the exclu-

sewage sludge on agricultural land. The remainder have

sive intermediate hosts.

been presumed to be caused by spread of seagulls

Cattle therefore are affected by hydatid cysts of E.

feeding at sewage plants and passing viable eggs

granulosus granulosus. The majority of hydatid cysts

through them on to grazing land, or by accidental flood-

cause little apparent disease as they are situated in the

ing of pasture by contaminated effluent streams from

liver or lung, their presence only becoming disclosed

sewage plants. Migrant labour from less developed

at abattoirs. Occasionally, they develop in sites where

countries and infected stockmen have been implicated

their gradually increasing size causes pressure on vital

in some isolated local multiple infections.

organs., the resultant disease being dependent on the

Once ingested, the egg hatches and the liberated

organ and system affected.

oncosphere travels via the bloodstream to striated mus-

cular tissue, including the myocardium. It develops in

the muscle and reaches infectivity three months after

Aetiology and epidemiology

ingestion, when it is recognizable as a whitish fluid-

filled cyst with a diameter of approximately 1 cm,

The adult worms parasitize the small intestine of the

known as a cysticercus. It becomes enclosed in a thin

dog. They are small worms, consisting of four segments

fibrous capsule. Cellular immune reaction around it

of length 0.6 mm. Large numbers may be present in

gradually increases and the capsule becomes thickened,

infected animals, each releasing one gravid segment

eventually leading to the death of a high proportion of

daily containing many eggs, which are resistant to

the cysticerci within 18 months and resistance to further

normal external climatic conditions and remain infec-

infection, although some may survive for several years.

tive for up to two years. After ingestion by cattle or

After death the contents of the cysts become caseous

other hosts the oncosphere penetrates the wall of the

and finally calcified. The masseter, tongue and heart

intestine and is carried via the bloodstream to the liver

muscles were generally considered preferential sites

or other organs where it lodges and starts to grow to

and are still examined carefully during meat inspection become a hydatid cyst. Growth is relatively slow and

at abattoirs, in preference to damaging more expensive

may take at least one year to reach a diameter of 20 cm.

cuts of meat by the multiple incisions that would

In restricted sites the cyst assumes the shape of the

otherwise be necessary.

space available, and daughter cysts may be formed and

spread to other organs. If growth takes place in the

omentum or mesentery, cysts can become very large.

Control (see p. 1028)

There is usually little cellular reaction around cysts in

There are no drugs suitable for ante-mortem treatment.

cattle. Since most cattle in developed countries are

Carcasses that are found to be infected are normally

slaughtered in abattoirs there is little chance of further

treated in one of two ways:

spread unless casualties are fed to farm dogs or packs

of hounds. In underdeveloped countries or where car-

oocysts to survive and become infective, but frequently

casses are not disposed of, wild Canidae ingesting the

occurs three or four weeks after groups of purchased
offal become infected; the brood capsules from within
calves are mixed. In North America it has also been
the hydatid cyst evaginate, the scolex attaches to the
associated with the sudden stress of extreme tempera-
intestinal wall and reaches adulthood and patency
ture reductions in midwinter.
some six weeks later. Infection in dogs is usually
After ingestion, the oocyst is disrupted, releasing
symptomless.
eight sporozoites each of which penetrates an intestinal
epithelial cell and develops into a trophozoite. Multiple
fission within the trophozoite produces a schizont,
Treatment and control (see p. 1028)
which after a few days ruptures the cell to release a
Affected cattle are not treated specifically for hydati-
large number of merozoites, which in turn invade other
dosis, principally because of the difficulty of diagnosis,
epithelial cells. There are up to four generations of
but also because anthelmintics are only now becoming
schizogony depending on the species involved. The

available for treatment of infected human beings.

location of the cells invaded is important for the

Activity against larval forms has been claimed for

pathogenicity of the species, e.g. E. zuernii and E. bovis praziquantel and albendazole, although most cysts are

both invade cells in the lower ileum and later schizo-

excised.

gony and gametogony (the term used to describe the

Prevention is directed to ensuring that dogs do not

sexual stages) take place in the epithelial cells of the

become infected, either by regular treatment, the most

caecum and colon. The gametocytes are formed deep in

effective anthelmintic being praziquantel, or by pre-

the epithelium and their rupture causes severe disrup-

venting the ingestion of infected offal.

tion of the lining of the caecum with resultant haemor-

rhage into the lumen. After gametogony, oocysts are

formed that subsequently are passed in faeces. They are

Protozoa

not immediately infective but require to undergo sporu-

lation, in which the sporocyts and sporozoites are

Coccidiosis

formed ready for further infection. The last process

requires adequate moisture and warmth and takes

Bovine coccidiosis almost invariably affects groups of

24–72 hours. The total life cycle from ingestion to

cattle less than one year old, although it does occasion-

patency occupies 15–17 days for E. zuernii and 15–20

ally occur in older animals. It is manifested by enteritis,

days for E. bovis. Oocyst production during infection

diarrhoea and in severe cases dysentery. Not all

with a single species lasts for five to twelve days, but

members of the group are equally affected and light

may be prolonged in multiple species infections. The

infections are self-limiting; severe infections can be fatal

oocysts are very resistant to external conditions and will

if untreated. The disease is caused by the ingestion over

survive for up to two years in suitable environments

a short period of large numbers of oocysts of Eimeria

with adequate moisture. They can resist moderate frosts

species by non-immune cattle; the greater the infective

down to -8°C for two months, but are susceptible to *dose, the more severe the signs produced. Eimeria are drought, high temperatures and the chemical action of*

species-specific, and although 13 species have been iso-

ammonia.

lated from cattle, E. zuernii, E. bovis and E. alabamensis are much the commonest and most pathogenic. They are

Signs

found everywhere in the world where cattle are farmed.

Cryposporidiosis is mentioned on pp. 204 and 286.

The presenting signs of diarrhoea or dysentery accom-

panied sometimes with severe straining in a group of

calves leads to suspicion of coccidiosis.

Aetiology and epidemiology

Diagnosis

The presence of large enough accumulations of oocysts

to cause disease is the result of farming practices that

Examination of faeces samples for the presence of large

allow groups of cattle, which frequently have been

numbers of oocysts can confirm the diagnosis. Care

stressed by transport and by mixing with others, to

should be taken in interpretation of oocyst counts since

ingest food or water contaminated by faeces. It can small numbers are present in the faeces of many normal

happen either indoors on straw bedding, which is both

calves, and in severely affected diarrhoeic calves the

damp and contaminated with faeces, or outdoors

main oocyst production phase may have passed or their

around drinking or feeding troughs. It can take place

numbers be misjudged due to the dilution factor of

at any time of the year so long as conditions prevail

liquid faeces. Occasionally, calves may exhibit nervous

that produce adequate moisture and temperature for

signs, the reasons for which are as yet obscure, and viral

diseases that have cerebral affects should be

as a ubiquitous parasite of cattle and dogs that also

considered.

affects many other species of animals. Although it is the

type species, recently, another species, N. hughesi, has been isolated from horses. Currently little is known of

Treatment (see p. 1029)

its development in animals that are naturally infected.

Two considerations need to be borne in mind. Firstly, *The dog is the intermediate host, and is also a final host*

severely affected calves will require individual treat-

in prenatal infections. Infection can be both vertically

ment with an anticoccidial and, if deemed advisable,

transmitted from dam to calf in utero and lactogenically, fluid therapy with electrolytes and injections of anti-naturally by ingestion of food and water contaminated

biotics to control secondary bacterial infections. Antic-

with dog faeces containing Neospora caninum oocysts,

occidial treatments include injections of sulpha drugs or

or from cow to cow. The mechanisms of repeat con-

the oral administration of sulphadimidine at 140 mg/kg

genital transmission are unknown at present.

body weight daily for three days, or amprolium at

10 mg/kg for four or five days. Amprolium has been

Signs

withdrawn from sale in many countries because of pos-

sible carcinogenesis, and it should be remembered that

It is a major cause of abortion in both dairy and beef

overdose with amprolium, which is a thiamine antago-

cattle, and has been observed in almost all countries

nist, has also been associated with production of cere-

in the world. Cows of any age can abort from three

brocortical necrosis (CCN), so care should be taken to

months of gestation to full term, although most abor-

give the correct dose in those areas where it is available.

tions occur at 5–6 months. Foetuses can be born alive

Secondly, prophylactic treatment for other calves in

or may die in utero and be mummified or reabsorbed.

the group should be assessed, depending on the

Calves that are infected may be born underweight and

numbers involved. Lasalocid at 1 mg/kg body weight

with neurologic symptoms such as ataxia, decreased

per day, monensin included in the diet at 16.5 ppm of

reflexes and exophthalmia.

the diet or decoquinate at 100 ppm, either continuously

to suppress all infection or for two cycles of medication

for a week separated by a week when it is removed, can

Necropsy

protect from the infection and allow sufficient immu-

Tachyzoites and tissue cysts are found intracellularly in

nity to be stimulated. A long-acting intraruminal bolus

affected cattle. Tachyzoites measure 6 ¥ 2 microns.

consisting of 1.6 g baquiloprim plus 14.4 g sulphadimi-

Tissue cysts are oval, 102 microns long, and are found

dine is also effective, and sulphadimidine itself can also

in the central nervous system and retina. Although

be used prophylactically at 35 mg/kg, but it should be

infection can be found in many organs, the commonest

borne in mind that as light infections are self-limiting

site is the brain. The characteristic lesion is a focal

such treatments may not be cost-effective.

encephalitis with necrosis and non-suppurative

Other measures should be taken to reduce the

inflammation. Hepatitis can also be found in epidemic

chances of infection, i.e. removal of food contaminated

abortions.

with faeces and better siting of feeding and water

troughs so that faecal deposition on food and in water

is made less likely. If the problem is a recurring event

Diagnosis

with each batch of calves, thought should be given to a

Ante-mortem diagnosis is by serologic methods.

short period of anticoccidial treatment after two weeks

Several methods of assay of serum antibody are avail-

of exposure to possible infection so that incipient

able, e.g. ELISA and indirect fluorescent antibody. A

infections are disrupted but sufficient stimulation of

PCR (polymerase chain reaction) diagnosis of antigens

immunity has been allowed to take place. A potent

is under development.

anticoccidial of a novel chemical type, toltrazuril, has

been used experimentally in this manner with great

success and may constitute a significant future advance

Treatment and control

in the prophylaxis of the disease.

At present treatments are largely experimental.

Sulphonamides, pyrimethamine and clindamycin have

Neosporosis *(see p. 584)*

been used in infected dogs, and decoquinate has been

shown to kill N. caninum tachyzoites in cultures. Dogs Aetiology

should not be allowed to eat aborted fetuses or fetal

The cause is Neospora caninum, a coccidial protozoan

membranes, and their faeces should be prevented from

discovered within the last decade, and now recognized *contaminating bovine feedstuffs.*

Toxoplasmosis

a seronegative status much more rapidly than do sheep,

which are as a result a more reliable indicator of the

Toxoplasmosis is a protozoan zoonosis that can infect

actual prevalence of the infection.

any species of vertebrate. It is mainly recognized as

being most pathogenic for sheep, however it occasion-

ally causes human illness, and it can cause significant

Diagnosis

disease in cattle, although abortion is not as common a

result as in sheep (see p. 895).

At autopsy or in abattoirs the most common findings

are multiple necrotic granulomatous foci in internal

organs. Histopathological examination is necessary for

Aetiology and epidemiology

confirmation. In vivo, cattle are presented with vague pyrexic disorders sometimes affecting the central

The parasite involved is Toxoplasma gondii. It has a

nervous system. If pregnant cows are affected, stillborn

two-host life cycle with both sexual and asexual stages.
or weak calves that die within a few days of birth may
The definitive hosts are cats, both domestic and wild,
result. Such calves frequently manifest nervous signs
which become infected by eating raw infected meat
such as tremors of the head or neck, teeth grinding or
from the intermediate host, which can be any other
convulsions.
species of vertebrate but is frequently a rodent. Once
Serological diagnosis can be made using a variety of
ingested the infective cysts are digested, each releasing
tests such as indirect immunofluorescence or enzyme-
large numbers of bradyzoites. They penetrate intestinal
linked immunosorbent assay (ELISA), or the Sabin-
epithelial cells and undergo a coccidia-like series of
Feldman dye test. Because of its ease of use, an ELISA
schizogonies and finally gametogony in the small intes-
using both anti-IgM and anti-IgG for detection of
tine to produce oocysts in faeces within one and a half
both acute and chronic infection is currently being
weeks after ingestion of cysts. The cat then excretes

developed.

oocysts for approximately two weeks. Oocysts remain

viable for 17 months on pasture and if they contaminate

animal feed any animal consuming it becomes infected.

Treatment and control

Within the intermediate host, development is

asexual. The oocyst wall is disrupted, releasing eight

Treatment of acutely infected animals can be attempted

sporozoites which reach the lymph and blood vessels

by the use of pyrimethamine and sulpha compounds

after penetrating the intestinal epithelium. The tachy-

such as sulphadiazine or sulphadimidine. Results in

zoites, as they are now called, are spread throughout the

animals have been disappointing compared with those

body to muscles, heart, lungs, liver, uterus and central

in mice and humans. These drugs affect tachyzoites but

nervous system, where they penetrate cells and multi-

not bradyzoites so that total elimination of the parasite

ply asexually. It is during this phase that the inter-

is not possible. Recent experiments with the ionophore

mediate host becomes ill. After each multiplication the *monensin have shown prophylactic activity in sheep,*

infected cells rupture, releasing 8–16 tachyzoites for

but there are no reports of its use in cattle (Buxton

further spread. After some days of such divisions the

et al. , 1987). Other preventative measures include pre-host develops some resistance to the organism and the

vention of cat faecal contamination of animal food and

spread of tachyzoites ceases, but is replaced by the for-

adequate destruction of infected carcasses.

mation of slow-growing cysts, each of which eventually

contains large numbers of bradyzoites. Normally these

remain until ingested, but should the host's immunity

Sarcosporidiosis (sarcocystosis)

be reduced by other disease the invasive process can

Aetiology

recommence. The tissue cysts are susceptible to freez-

ing and cooking to 70°C for 30 seconds and therefore

The cause is Sarcocystis, a coccidial protozoan that has consumption of adequately cooked infected meat is

a predator–prey life cycle. The indirect hosts are dogs,

harmless.

cats and man and each may contain several species of

The organism is ubiquitous. Blewett (1983) reviewed

sarcocyst, each one specific for a different intermediate

the serological surveys that have been carried out in

host. Sarcocystis hirsuta is present in the ox and cat domestic animals and came to the estimate that anti-species, S. cruzi in the ox and dog and S. hominis in body was present in 6.5 per cent of horses, 12.5 per cent

the ox and man. In the final host the Sarcocystis spp.

of cattle, 23.5 per cent of pigs, 30 per cent of sheep and

undergo an enteric cycle with oocysts in the cells

40 per cent of cats. He also postulated that different

producing sporocysts in the faeces. On entry to some

animals vary in susceptibility to infection and in the rate

intermediate hosts those infected via the dog undergo

of loss of antibody, and concluded that cattle return to

schizogamy in blood vessel endothelial cells before

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passing to the muscle. Those of the cat are not patho-

ineffective. The difficulty with any treatment is the

genic and are found in the oesophagus, and throughout

maintenance of sufficient concentrations of the drugs

the tissues of the intermediate host produce micro-

in the cerebrospinal fluid, and relapses are usually scopic cysts. If cattle are grazing and ingesting a few

ascribed to failure to do so.

oocysts this probably results in a strong immunity. Signs

develop about 26 days after infection (see p. 895).

Control

This is difficult but involves keeping carnivores away

Signs

from cattle. Infection in dogs and cats can be avoided

Usually no signs occur but, following ingestion of

by feeding them cooked meat.

massive doses, calves may develop anorexia, fever,

emaciation and anaemia. Adults can suffer pyrexia,

emaciation and abortion.

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This is usually based on post-mortem findings.

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Michel, J.F. (1968) The control of stomach worm infections

*in young cattle. Journal of British Grassland Society, **23**, Treatment*

165–73.

Michel, J.F. (1969) The epidemiology and control of some

Pyrimethamine at 1 mg/ml and trimethoprim at

*nematode infections. Advances in Parasitology, **7**, 211–82.*

5.0 mg/ml alone or in combination with sulphonamides

Urquhart, G.M., Armour, J., Duncan, J.L., Dunn, A.N. &

have been shown to inhibit the development of S.

Jennings, F.W. (1987) Veterinary Parasitology. Longman neurona in cell cultures. Sulphonamides alone were

Scientific, Harlow, pp. 1–286.

Chapter 20

Respiratory Diseases

A.H. Andrews

Shipping fever (transit fever, pasteurellosis)

286

induced with the participation of infectious agents. The

Infectious bovine rhinotracheitis (IBR)

289

infection has been thought to be primarily viral, mainly

due either to parainfluenza III (PI3) virus or infectious

bovine rhinotracheitis (IBR) virus, followed by sec-

Shipping fever (transit fever,

ondary infection with either Pasteurella multocida or ***pasteurellosis)***

Mannheimia haemolytica (Pirie, 1979). Mannheimia

haemolytica biotype A serotype 1 is considered to be

Epidemiology

the most common isolate although biotype T strains

The condition is an important respiratory problem in

have also been found. Mannheimia haemolytica biotype

groups of weaned suckled calves that have been sold,

A produces a heat-labile cytotoxin that is ruminant-

often via a market, hence the terms transit fever or ship-

specific destroying leucocytes (Sherwen & Wilkie,

ping fever. They are usually over six months old and

1982). Pasteurella multocida infection is only isolated under two years. During part of the sale transactions

occasionally. Recently, it has been proved experimen-

they will probably have been mixed and grouped with

tally that M. haemolytica biotype A1 can produce the

other batches of animals of similar age during transport,

disease as a primary agent in non-immune calves (Shoo,

at the market or following arrival at the finishing farm.

1989). Disease does depend on administering the

Most cases occur within the first month of their entry

organisms into the lungs either intratracheally (Friend

to the fattening unit and most cases are seen at least 10

et al., 1977; Gibbs et al., 1983) or intrathoracically days after arrival (Andrews et al., 1981). The disease (Houghton & Gourlay, 1984; Panciera & Corstvet,

is characterized by an illness of sudden onset with

1984). However, the exact mechanism by which the

dullness, pyrexia and anorexia. It is an acute exudative

organisms enter the lung and result in lesions is not yet

bronchopneumonia with toxaemia as well as much

known. Other evidence of M. haemolytica involvement

fibrin present in the exudate and often accompanied

is that calves previously exposed naturally to the infec-

by fibrinous pleurisy (Blood & Radostits, 1989). The

tion are much more resistant to experimental and

condition is common in North America, Europe and

natural pneumonic pasteurellosis (Confer et al., 1984).

Britain. It is particularly prevalent in the American

Although M. haemolytica can be isolated from the

cattle feedlot industry and is the largest cause of mor-

nasal passages it is only in small numbers when calves
tality in that system. In a Colorado survey 75 per cent
are healthy and unstressed. The organisms can be
of all clinical disease in yearling cattle and 64 per cent
present in low numbers in the tracheal air but are not
of all post-mortem diagnoses were due to respiratory
considered to be normal inhabitants of the lungs (Grey
disease (Jensen et al., 1976). The morbidity and mortal-
& Thomson, 1971). However, as the calves are trans-
ity rates vary considerably but a level of up to 35 per
ported, move to market and then enter the feedlot, the
cent and a mortality of 5–10 per cent of those affected
number of M. haemolytica biotype A1 increases in the
or 0.75–1 per cent of the susceptible population is often
nasal tract, the tracheal air and then the lungs, where
quoted (Blood & Radostits, 1989). More recently in
bronchopneumonia can result (Frank & Smith, 1983).
Britain, morbidity rates of 73–100 per cent with a mor-
Thus management factors are important. The effects
tality of 0–8 per cent of those affected and an average
of stress are extremely difficult to quantify and have

mortality of 4 per cent have been reported (Andrews,

not been successfully undertaken experimentally to

2000).

produce transit fever. However, transportation of year-

ling cattle does result in a rise in plasma fibrinogen

levels, which is indicative of stress (Phillips, 1984).

Aetiology

Increased fibrinogen levels also occur following con-

The aetiology of the condition is still open to disagree-

finement in unfamiliar surroundings and deprivation of

ment. It is considered to be stress or management

food and water. In addition, it seems that cattle sud-

denly introduced to a diet consisting of large amounts

Necropsy

of cereal are more prone to respiratory problems

Death is usually the result of anoxia and toxaemia

(Wilson et al., 1985).

although occasionally in young cattle there is septi-

The environment tends to be important in that *caemia. Usually, over one-third of the lung shows*

disease seems to be related to the season of the year

marked consolidation and the ventral parts of the apical

(Andrews, 1978), fluctuations in daily ambient tempera-

and cardiac lobes are most involved. Initially, there is

ture and increased concentration of airborne particles

lung congestion and then hepatitis with exudate and, in

2.0–3.3 mm in diameter (MacVean et al., 1986). Calves

some animals, emphysema. Bronchitis and bronchioli-

kept at a constant temperature of 16°C (60°F) showed

tis are usually catarrhal, often with serofibrinous

minimum levels of nasopharyngeal bacteria at a rela-

pleurisy and a fibrinous pericarditis. There is usually

tive humidity between 65 and 75 per cent. However,

much pleural effusion.

bacterial counts tend to rise at humidities on either side

of this range (Jones & Webster, 1981).

The interrelationship of different micro-organisms

Diagnosis

and transit fever still needs further elucidation.

However, cattle entering feedlots with low serological

This depends on the history of age, recent movement,

titres to IBR, bovine respiratory syncytial virus (RSV)

weaning or housing. The signs also help with severe

and Mycoplasma dispar were at greater risk of being

respiratory signs involving the anteroventral parts of

treated for BRD (Rosendal & Martin, 1986). It has also

the lungs and pyrexia. Post-mortem findings of lung

been shown that IBR, PI3, bovine virus diarrhoea

consolidation and pleurisy are present, and impression

(BVD) and RSV are all associated with acute respira-

smears show bipolar staining organisms with methylene

tory disease (Martin & Bohaz, 1986).

blue. Mannheimia haemolytica or P. multocida may In many outbreaks of transit fever it is likely that the

be isolated from nasal swabs in live animals or lungs

stress of movement plus mixing with other calves, the

at post-mortem and their antibiotic sensitivity

introduction to housing and a new diet are sufficient to

determined. Serology for antibody rise can be under-

initiate disease. The main organism involved is usually

taken, as also can haematology but often the findings *a Mannheimia species, especially M. haemolytica*

are variable.

biotype A1. Spread of infection is optimized by

crowded conditions in transport and markets. It is also

probable that as animals go down with disease and pass

Differential diagnosis

on the infection, the organism increases in virulence.

Differential diagnosis includes enzootic pneumonia

This can be seen in some outbreaks in which disease can

(see p. 242) but this usually occurs in younger calves

be traced from individual animals to other members

with a different history. Infectious bovine rhinotra-

of the same group and then to other groups (Andrews,

cheitis (see p. 289) usually shows mainly upper respira-

1976).

tory signs and a conjunctivitis. Fog fever (see p. 866) is

mainly apparent in older cattle at grass after a pasture

Signs (see p. 921)

move in the autumn. Parasitic bronchitis (see p. 272) is

present in cattle following grazing. Acute broncho-

The peracute form is unusual but results in sudden *pneumonia would be almost identical except for*

death with no premonitory signs.

bacteriological isolation. Contagious bovine pleuro-

In the acute form the animals are dull and inactive

pneumonia is severe in all age groups of cattle and the

with excessive oculo-nasal discharges, which may be

affected animals suffer severe pain and toxaemia with

mucupurulent. There is usually anorexia although

a high mortality (see p. 868).

the cattle still drink, and a marked fever (40–41°C,

104–106°F). There is rapid (40+/minute), shallow

breathing and a soft, productive cough, which tends

Treatment

to increase with exercise. On auscultation there are

bronchial sounds over the anterior and ventral parts of

Therapy for shipping fever is given in Table 20.1. Treat-

the lungs, which become louder as the condition con-

ment should begin early. Most cattle will usually show

tinues. In some cases squeaks and high-pitched sounds

some improvement within one to three days of initiat-

are heard, together with a pleuritic rub. Later signs can ing treatment. Complete recovery may take four to

include dyspnoea with marked abdominal breathing

seven days. Where severe outbreaks occur it may occa-

and an expiratory grunt. Diarrhoea occurs in a few

sionally be necessary to use mass medication by water

animals. There is usually a favourable response to

as most ill cattle still drink well. Anti-inflammatory

therapy.

agents are often useful in promoting a speedy recovery.

Prevention and control

ducing the calves hopes that by selling them at market

he will obtain a better price than by selling direct. In

Although the disease of transit fever is sporadic, many

addition, the first farmer will be little concerned about

of the conditions that predispose to the problem can be

the subsequent disease status of his calves once they

defined. This should mean that methods of prevention

have left his farm for sale. This makes the possibility of

should be relatively easy to institute. Ideally, the calves

vaccination prior to movement difficult.

would be weaned at least two weeks prior to leaving the

As cattle go through markets, disease prevention

farm of birth (Andrews, 1976). They would be intro-

tends not to be practised because many of the factors

duced to the type of feed to be provided on the rearing

enhancing the likelihood of a disease outbreak are

farm. In addition, they would be batched in groups that

outside the control of the purchasing beef rearers. Thus

would go direct from the farm of birth to the rearing

they cannot control the time before moving, the trans-

farm. In reality this does not happen as the farmer pro-

port of the animals from the farm of origin, their mixing

Table 20.1

Therapy for shipping fever.

Drug

Method of

Dose

Duration

administration

(mg/kg)

(mg/lb)

Amoxycillin trihydrate

s.c., i.m.

7

3

Daily for 3–5 days

Ampicillin trihydrate

s.c., i.m.

5–10

2.5–5

Daily for 3 days

Baquiloprim and

oral

4–8

2–4

Once or repeat

sulphadimidine

36–72

18–36

after 48 hours

Cefquinome

i.m.

1

0.5

Daily for 3–5 days

Ceftiofur

i.m.

1.1

0.5

Daily for 3–5 days

Chloramphenicol (some countries)

i.m.

10

5

3–4 times daily for 3 days

Danofloxacin

i.v., i.m.

1.25

0.6

Daily for 3–5 days

Enrofloxacin

s.c.

2.5

1.25

Daily for 3 days

s.c.

7.5

3.75

Once

Erythromycin

i.v., i.m.

5

2.5

Daily for 3 days

Florfenicol

i.m.

20

10

2 (48 hours apart)

s.c.

40

20

Once

Marbofloxacin

i.v., s.c.,

2

1

Daily for 3–5 days

i.m.

Oxytetracycline

i.v., s.c., i.m.

10

5

Daily for 3 days

Oxytetracycline (long-acting)

i.m.

20

10

Usually once

Penicillin/dihydrostreptomycin

i.m.

(20–30 000 iu/kg)

(10–15 000 iu/lb)

Daily for 3 days

20

10

Penicillin (long-acting)

benzathine

i.m.

5

2.5

Usually once

procaine

i.m.

6

3

Daily for 3–5 days

Spectinomycin

i.v., i.m.

10–20

5–10

Daily for 3–4 days

Spiramycin

i.m.

20

10

Daily for 2–3 days

Sulphadimidine

i.v., s.c., oral

150

75

Daily for 3 days

Tilmicosin

s.c.

10

5

Usually once

Trimethoprim and sulphadiazine

i.m.

4

2

Daily for 3–5 days

20

10

Trimethoprim and sulphadoxine

i.v., i.m.

3

1.5

Daily for 3–5 days

12.5

6

Tylosin

i.m.

4–10

2–5

Daily for 3–5 days

Mass medication

Oxytetracycline

oral

5

2.5

Daily for 5 days

Sulphamidine

oral

100

50

Daily for 5–7 days

Trimethoprim and sulphadiazine

oral

25

12.5

Daily for 5–7 days

Tylosin

oral

Daily for 5 days

All animals should be provided with good-quality feed and adequate ventilation. Corticosteroids, e.g. betamethasone, dexamethasone, are often found to help in reducing the level of exudation. NSAIDs may be useful in reducing inflammation, and Mannheimia antisera may also be helpful.

with other cattle or the conditions present at market.

however shown only a slight decrease in morbidity of

Likewise they will probably have little direct say as to

disease, with slight improvement in relapse rates and

how the animals are transported or their mixing with

response to treatment (Bateman, 1988; Jim et al., 1988).

other groups before their entry to the rearing farm. It

is only once the cattle reach the rearers that control

measures can be undertaken. Obviously, they can

Infectious bovine rhinotracheitis (IBR)

ensure that the animals are kept in as satisfactory an environment as possible and are only lightly stocked.

Aetiology

This is best done by having the animals outside but this is resisted by most farmers because of the incon-

Infectious bovine rhinotracheitis (IBR) is a highly

venience and extra labour required. The new ration for

infectious and contagious disease of cattle. It is caused

the cattle can also be introduced slowly.

by a virus known as bovine herpes virus 1 (BHV 1). It

The problem is worse in North America where calves

is generally considered that there are several strains of

often travel vast distances. Here various precondition-

the virus, although often the differences between the

ing programmes are undertaken. It is advised that

strains are not easily shown in the laboratory. The

calves should be fed prior to weaning and kept in the

disease is seen in North America, Europe and Africa. It

same place once the dams are removed. Following

is considered that the outbreak of severe respiratory

weaning, regular checking of the calves several times a *disease that occurred in Great Britain in the mid-*

day should be practised. When animals are travelling

1970s was due to a new strain being imported. Several

they should be given adequate periods of rest and

European countries are undertaking eradication cam-

offered feed and water. They should also be well

paigns, many of which are progressing satisfactorily.

bedded during transit. Some farmers inject multivita-

They often involve initial vaccination with marker vac-

min preparations before moving and vaccines can be

cines and then blood testing, and movement restrictions

used, including those against Mannheimia and PI

until the disease is no larger present.

3 virus.

In many countries antibiotics are used following the

While the disease is primarily one of cattle, it can also

move. These have given variable results mainly due to

infect deer, goats and pigs. The main sources of infec-

predicting when injections should be undertaken. This

tion between animals are nasal discharge (or eye dis-

is because most problems occur about seven to ten days *charge), when it is affecting the respiratory system, and*

after entry to the feedlot or farm. When used, it is prob-

vaginal or preputial discharges, semen, or the fluids

ably best to give long-acting preparations and initiate

and tissues of the fetus when the infection involves the

therapy when the first animals show disease. Use of

reproductive tract (see p. 579).

antibiotic medication in the feed or water is a common

practice in North America and while it appears to

Epidemiology

reduce mortality it has no effect on morbidity.

In most cases of respiratory infection disease is spread

by aerosol. The genital form of the disease is contracted

Vaccination

venereally. As respiratory infection is spread via the air,

If it is considered that M. haemolytica and at times P.

it can spread by direct contact between the animals or

multocida form an important part of the disease syn-

where the cattle are in the same air space, i.e. there is

drome of transit fever then it might be possible to

air contact. This can only be avoided by ensuring the *obtain some protection by vaccination. Various vac-*

walls extend from floor to ceiling and there is no contact

cines are present in Europe but currently only three

with other animals either at the front of the pens or with

are available in Britain.

other groups on either side. However, generally there

In North America various Pasteurella bacterins and

is a need for close sustained contact between groups.

viral vaccines have been used to assist with the control

This is why disease is often slow to spread within and

of transit fever. Their efficacy appears to be low and

between groups. It often takes two to five weeks to

literature reviews suggest that at present there is little

spread in a group. However, unexplained outbreaks of

evidence to show the efficacy of such vaccines under

IBR do occur on isolated farms.

feedlot conditions (Myers, 1984).

Recently in North America several new vaccines

Latent infection: There is a problem with BHV 1 in that have become available. One of these is a M. haemolyt-it is able to become a latent infection. Thus once an

ica vaccine/bacterial extract. This has been shown to be animal is infected with *a strain of the virus or vaccinated*

effective to controlled challenge provided two doses

with a live viral vaccine, the virus may remain in the

of vaccine have been administered prior to challenge

animal for the rest of its life without it showing any signs

(Sherwen & Wilkie, 1988). Response in a field trial has

of illness. The site of latency is arguable but the virus

can be found in the trigeminal nerve of clinically normal

(2)

Subacute disease. This is commonly seen in adult

cattle. However, if the animal is stressed at all, such as

cattle and often is of only short duration. There is a

when moved or calving, or becomes ill, the virus may

marked rise in temperature lasting only a day or two

be shed. Shedding can also occur in bulls when mating.

(40°C, 104°F). Often there is a marked drop in milk

This shedding may be, but is often not, accompanied

yield. Again the lining of the eyes is reddened with dis-

by any signs of disease. Corticosteroid injections may

charge and this also involves reddening of the lining of *promote virus shedding. The level of this latent infec-*

the nose with nasal discharge. The animals will salivate

tion is variable but can be up to 10 per cent of clinically

and there may be a short, expressive cough. Breathing

normal animals. In addition, while most of these cattle

is rapid and shallow. The animals recover in 10 to 14

will show antibody levels to the BHV 1 virus, some do

days.

not. Thus all cattle in herds where disease occurs have

(3)

Acute disease. The signs are as in the subacute

the capacity to spread disease even when there are no

form but the temperature tends to be higher (40–41°C,

clinical signs of disease present in the herd. The only

104–106°F). These signs are particularly present in

way of knowing whether or not disease is present is to

growing cattle between six months and two years old.

look at the results of milk or blood tests. If a blood test

The respiratory signs are more likely to include a cough

shows an antibody titre (positive response) to BHV 1

and there is some respiratory distress. The discharge *in cattle other than calves it means that the animal(s)*

from eyes and nose tends to become profuse, yellow,

have been exposed to infection and could possibly be

thick and purulent. The lining of the nose may show

carriers. If a blood test from an animal is negative it

grey areas, which consist of dead tissues that smell and

generally means that the animal is unlikely to have been

are shed. The signs tend to last a lot longer before

exposed to infection, but it does not completely rule out

recovery occurs.

the possibility that the animal is a latent carrier of

disease. Thus tests on individual animals are of limited

(4)

Peracute disease. The animals develop very high

significance; however, on a herd basis repeated negative

temperatures (42°C, 108°F) with eye and nasal dis-

tests indicate that it is highly unlikely infection is

charge, respiratory distress, cough and then death in

present. When tests show several animals with antibody

about 24 hours.

levels in the herd then infection is present. The calf that

Some cattle may die owing to complications and this

receives colostrum from its infected mother will also

is particularly so in the six month to two year age group.

show a positive antibody level to the test although not

Here mortality may reach 10 per cent or more.

necessarily being infected. The antibody provided from

However, it is usually only about 1 per cent. Some cattle

the colostrum will usually remain for one to six months,

keep a stertor (snoring breathing) for many months.

depending on the amount received from the mother.

Some become 'puffers' with bouts of respiratory signs

including distress when breathing, loss of appetite and

Incubation period: The incubation period for the

cough. These usually have a secondary bronchopneu-

disease is very variable. Experimentally, it usually takes

monia and die in weeks or months after losing condi-

three to seven days. However, in most beef units disease

tion. Often they become recumbent before death.

occurs about 10–20 days after introduction of infected

Characteristically, there is a sudden outbreak of

or susceptible animals. Longer incubation periods do *disease involving the respiratory tract. This will initially*

occur. This is quite likely when it is considered that

involve the group of cattle to which infection has been

latent carriers may not be shedding virus at a particu-

introduced. It will then tend to spread round all the

lar time.

other groups and ages of cattle. This can often take a

few weeks or many months, dependent on the strain of

Signs

virus, the level of infection and the degree of exposure

to infection of each group. Characteristically, an out-

Respiratory disease: This disease is the most common

break in a group reaches a peak at about two or three

form. It is usually seen in cattle over six months old but

weeks after its start and is over between the fourth and

can occur at a younger age. The signs vary considerably

sixth week.

but typically they tend to be worst in animals from

about six months to two years old.

Reproductive form: In most cases the reproductive and

respiratory forms are not seen together.

(1)

Mild disease. This is just a conjunctivitis, i.e. slight

reddening to the lining of the eye and eyelids with some

(1)

Infectious pustular vulvovaginitis. This is an infec-

discharge, usually watery and clear (see p. 921). This

tion of the vulva and vagina often lasting several weeks.

often occurs when the disease strain is mild or degree

It results in the discharge of pus from the vulva, usually

of infection is low, or the animal is resistant.

in small quantities. There is reddening of the lining and

pustule presence. In some cases infection causes irrita-

mucous membranes with a mucoid discharge to large

tion in the vagina resulting in frequent urination and

areas being covered by a necrotic layer of exudate

possibly increased straining (see p. 628).

(Pirie, 1979). In some cases there is pulmonary emphy-

sema and secondary exudative bronchopneumonia,

(2)

Infectious bovine penoposthitis. Bulls show a *which may be purulent or necrotizing. Histologically,*

small amount of purulent discharge from the prepuce.

the mucous membranes show acute catarrhal inflam-

The surface of the penis and prepuce may be reddened

mation and in some cases the epithelium and larynx

with haemorrhages and small necrotic areas.

tend to be infiltrated with neutrophils, lymphocytes,

(3)

Endometritis. Infection of the uterus, with dis-

plasma cells and macrophages. In naturally occurring

charge, poor conception rates and short returns to

infections, inclusion bodies appear to be absent.

oestrus, can occur if semen is infected.

Abortion: Aborted fetuses often show marked autoly-

(4)

Abortion (see p. 579). This is becoming increas-

sis and focal necrotic hepatitis.

ingly common and occurs some weeks or months after

the animal is infected. Abortion is usually at six to eight

Alimentary form: Epithelial necrosis of the turbinates, months of pregnancy and often the placenta is retained *oesophagus, rumen and abomasum. Inclusion bodies*

following abortion. In some cases of infection calves are

are often evident in the surviving epithelium.

born weak at the normal time.

Nervous form: A non-suppurative encephalitis occurs

Generalized/alimentary form: This is seen in young

particularly affecting the cerebral cortex and internal

newborn calves and is recorded mainly in America. It

capsule.

occurs when calves receive little or no immunity in

the colostrum and are then subjected to infection. The

animals show a severe temperature reaction, they do

Diagnosis

not eat and they salivate. The lining of the nose is red.

This will depend on the type but in the alimentary form

The eyes may show a conjunctivitis. In addition, the

it will depend on a history of IBR in the herd with virus

lining of the mouth and the soft palate (at the back

present in the faeces or nasal swabs and possible

of the throat) are reddened with mucus present. The

necrotic areas on the turbinates. The nervous form is *opening to the trachea, i.e. the pharynx, is also red-*

difficult to differentiate except that there is probably an

dened with much discharge present. There is usually

IBR outbreak in the herd. At post-mortem examination

severe respiratory distress with a bronchopneumonia.

the turbinates may show necrotic lesions.

Some calves show severe diarrhoea and dehydration.

In the respiratory form the history is that a new

animal or group has entered the herd. In most cases

Central nervous system/encephalitic form: This is seen several animals will be affected and besides varying

in calves under six months old and involves brain signs.

degrees of respiratory signs there will usually be a

The animals show incoordination with bouts of excite-

conjunctivitis with copious, initially serous, ocular dis-

ment and depression. In other cases there are convul-

charge. There may be necrosis of the nasal mucosa but

sions, bellowing and blindness with salivation. This

this is absent in the mouth. The virus can be isolated in

nervous form is rare.

upper nasal or ocular swabs and is detected by fluo-

rescent antibody staining. Otherwise paired blood

Other infections: Reports of infections of the udder and samples will show a rise in titre to the enzyme-linked

intestinal tract have been made. However, these are

immunosorbent assay (ELISA) test. Other tests used

rarely the only systems affected.

include the serum neutralization test, indirect haemag-

glutination test, complement fixation test and virus neu-

tralization test. Bulk milk testing will indicate the status

Necropsy

of a dairy herd.

Respiratory form: In uncomplicated cases, lesions are

restricted to the upper respiratory tract terminating at

Treatment

the upper bronchi. Inflammation of the muzzle and the

nasal cavities varies from some congestion and petechi-

There is a considerable divergence of opinion as to

ation with mucoid exudate, to a fibrinopurulent exudate

whether or not to use antibiotic treatment. If the

with necrosis of the nasal mucous membranes. The sub-

disease appears to be uncomplicated, and this is *mandibular and retropharyngeal lymph nodes tend to*

unusual, then there would appear to be little point in

be swollen and oedematous. There is a laryngotracheo-

therapy. If, however, as in most cases, there is second-

bronchitis, which varies from a mild congestion of the

ary lung involvement, then therapy is justified. At the

start of an outbreak all cases should be isolated as soon

can be used in an IBR eradication campaign. Live vac-

as possible because although it may not stop spread

cines, as other vaccines, can present a possible danger if

of the disease, the first animals are often clinically the

contaminated with other pathogens, such as BVDV.

worst affected. If antimicrobial agents are to be used,

Beef calves can be vaccinated about two weeks or so

all ill calves should be treated for three to five days with

before they are weaned. One vaccine is temperature

any one of a number of drugs, including penicillin and

sensitive and so only replicates in the upper parts of

streptomycin, oxytetracycline, ampicillin, trimethoprim

the respiratory tract. However, the vaccine can still pro-

and sulphadiazine, sulphadimidine, sulphamethoxypyri-
duce circulating antibody levels in some cattle, which
dazine and sulphapyrazole. The animal should be given
will preclude their export or their sale to AI centres.
good, wholesome feed and it should be encouraged
Another vaccine does replicate in organs other than the
to eat and drink. Some farmers have vaccinated their
lungs and produces a good systemic immunity. The vac-
calves with live vaccine after the start of an outbreak,
cines provide effective immunity but they do allow the
with good results, but to be successful infection must
replication and re-excretion of the IBR virus, which can
not have become established. It should be remembered
thus spread infection to non-vaccinated animals.
that for effective protection, vaccines should be intro-
Several countries within the EU have successfully
duced before the onset of infection. Several compounds
eradicated BHVI (IBR), including Denmark, Finland
have been found that are active against herpes viruses.
and Sweden. An EU-approved national compulsory
However, many are toxic, but one drug, acyclovir, has

eradication scheme is being undertaken in Austria.

been shown to be safe and may in the future be tried in

Control programmes are being pursued in the Nether-

animals.

lands, Belgium, France and Germany. A programme for

the monitoring, screening, eradication and accreditation

of freedom from IBR in being undertaken in the UK

Control

by Cattle Health Certification Standards (CHeCS).

Management: It is best to keep a closed herd. However, in America, and also Britain, infection has been found

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in closed herds. Any new animal entering a known un-

infected herd should be blood tested prior to entry. If

Andrews, A.H. (1976) Factors affecting the incidence of pneu-

the test is negative the animal should be isolated for a

*monia in growing bulls. Veterinary Record, **98**, 52–5.*

month and then retested. The use of corticosteroids

Andrews, A.H. (1978) Some factors influencing respiratory

may allow detection of virus in swabs of carrier animals.

disease in growing bulls and the effect of treatment on

If the tests are all negative the animal can be allowed

liveweight. In Respiratory Diseases in Cattle. Seminar in to enter the herd. The risks then of the introduction of

CEC Programme of Coordination of Research in Beef

infection are small. If the animal suffers a respiratory

Production, Edinburgh, 8–10 November 1977 (ed. by W.B.

problem while in isolation the second test should not

Martin), pp. 169–80. Martinus Nijhoff, The Hague.

be until two or three weeks after the end of the episode.

Andrews, A.H. (2000) Calf pneumonia costs! Cattle Practice, Some farmers may need to go to these lengths to keep

***8**, 109–14.*

their pedigree herds free from disease, because many

Andrews, A.H., Cook, G.L., Pritchard, D.G., Morzaria, S.P.

& Gilmour, N.J.L. (1981) Observations on a respiratory

European countries will not accept exports unless they

disease outbreak in weaned suckled calves. Veterinary

are shown to have a negative titre for IBR. The same

*Record, **108**, 139–42.*

conditions at present govern the entry of bulls to some

Bateman, K.G. (1988) Efficacy of Pasteurella haemolytica

artificial insemination (AI) centres.

vaccine/bacterial extract in the prevention of bovine respi-

ratory disease in recently shipped feedlot calves. Canadian Vaccination (see p. 1010): An inactivated multicompo-Veterinary Journal, ***29****, 838–9.*

nent vaccine has been available for a long time. The

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vaccine could be given as doses two to four weeks apart

losis of cattle (shipping fever pneumonia). In Veterinary

with a third injection at 10–12 weeks old. Its efficacy has

Medicine, 7th edn, pp. 663–73. Ballière Tindall, London.

at times been questioned. Subsequently, live IBR vac-

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cines have become available. They are given by

of prior exposure to Pasteurella haemolytica antiserum on experimental pneumonic pasteurellosis. American Journal

intranasal inoculation or injection and should be

of Veterinary Research, ***45****, 2622–4.*

administered 24–48 hours after entry to the farm.

Frank, G.H. & Smith, P.C. (1983) Prevalence of Pasteurella Ideally, calves should be vaccinated 10 days prior to any

haemolytica in transported calves. American Journal of movement. A gene-depleted live vaccine is available in

Veterinary Research, ***44****, 981–5.*

some countries and allows control of disease. The

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produced by the wild strain. This means the vaccination

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School.

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Sherwen, P.E. & Wilkie, B.W. (1988) Vaccination of calves with conditions associated with pneumonia incidence in feedlot *leukotoxic culture supernatant from Pasteurella haemolyt-*

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ratory syncytial virus and treatment for respiratory disease

*tory disease. Canadian Veterinary Journal, **26**, 335–41.*

Chapter 21

Trace Element Disorders

N.F. Suttle

Introduction

294

most common being malnutrition, which is likely to be a

Differential diagnosis

294

whole herd problem. A preliminary check must be made

Definitions

294

of the quantity and quality of available feeds (Sinclair & Cobalt disorders

295

Suttle, 2001). Trace element disorders usually afflict only

Copper disorders

298

a minority of the herd but a preliminary ‘audit’ of the

Iodine disorders

301

likely mineral inputs and needs may narrow the range of

Selenium disorders

302

possible culprits (Suttle & Sinclair, 2000). Responses to

Manganese and zinc disorders

305

a broad mix of micronutrients would confirm this line of

investigation. Depending on the history of the farm or

area, it may be beneficial to attempt an earlier definitive

Introduction

diagnosis by using a specific trace element supplement,

but proof of responsiveness amongst an affected minor-

The full impact that trace element disorders can have
ity may require unconventional statistical techniques
on the health of cattle was seen when Europeans
which take into account initial variation in performance
attempted to carry their methods of animal production
(Suttle, 2000). There may be cross-over between lines of
to the New World and to the Antipodes. The geologi-
investigation: correction of a gut parasite problem might
cally young soils bordering Australia, and forming the
improve trace element status, while improving the major
Florida peninsula and the interior of New Zealand's
nutrient supply of a herd (by improving ration digestibil-
North Island, were a graveyard for many an animal
ity) may lower status and increase the risk of trace
until the therapeutic effect of newly discovered essen-
element disorders. Seasonal and annual variations in
tial trace elements became known. Crop and pasture
incidence mean that it will always be necessary to review
growth was also limited by some of the deficiencies but
the need for any trace element intervention from time to
these were the more easily diagnosed because they pro-

time. Overall, following such a scheme should improve

duced characteristic foliar abnormalities. The animal's

the precision of diagnoses.

needs were more difficult to delineate because they

lacked clinical definition and persisted where the more

modest needs of the plant had been met. Since those

Definitions

pioneering days, trace element disorders have been

described in many areas of the world and they continue

Four terms will occur frequently in descriptions of the

to appear when new methods of production are intro-

sequence of events that occur when cattle are deprived

duced, but it is important to keep them in perspective.

of essential trace elements, and these require definition:

• Depletion: the reduction of body stores of the

Differential diagnosis

element.

• Deficiency: the presence of subnormal concentra-

tions of the element in blood or tissues.

Trace element disorders carry more than their fair share

• Disorder: the malfunction of trace element-

of blame for poor cattle performance, due to the non-

dependent body processes (subclinical disorder).

specificity of most clinical signs, the pressures on practi-

• Disease: the presence of visible, clinical

tioners to offer a quick diagnosis and the alacrity with

abnormalities.

which clients accept a diagnosis that may seem to exon-

erate them from blame. Figure 21.1 presents a scheme

They are particularly useful when describing the

for differential diagnosis of some common problems. Of

trace element status of cattle biochemically, and avoid

the three main lines of investigation shown, trace ele-

the confusion caused by using the one word 'deficiency'

ments are only part of the least probable explanation, the to describe all four stages, and as a 'tag' for interpret-294

NON-SPECIFIC DISORDER

(Ill-thrift, infertility, retained

placenta)a

INFECTION

MALNUTRITION

MICRONUTRIENT

Possible

(Microbial or

(Energy,

DEPRIVATION

cause

parasitic)

E/protein, P)

(Mineral or vitamin)

PATHOGEN

Preliminary

MINERAL/

AUDIT

FEED AUDITb

check

VITAMIN AUDITc

(WBC,APR, FEC, etc.)

Multi-mineral/vitamin

Broad spectrum

Preliminary

More feed and/or

mix (introduce,

antibiotic or

intervention

change E : P in feeds

provide more or

anthelminthic

reformulate)e

Definitive

Identify

Metabolic

Mineral/vitamin

test

pathogen (s)

profile

profiled

Sustainable

Sustainable

Targeted

Specific trace

drug

cropping, grazing &

intervention

element supplement

programme

feed purchase policy

DIAGNOSIS

Fig. 21.1

Scheme for the differential

a

diagnosis of trace element disorders with

Firstly, rule out 'exotic' (e.g. plant, agrochemical or industrial poisons) or common (poor oestrous detection, large calf) factors.

non-specific signs; proceed vertically with

b See Suttle (2002) for fuller details.

a given line of investigation only while test

c See Suttle & Sinclair (2000) for fuller details.

results are positive. WBC = white blood

d See Table 21.1 for best indices of trace element status.

e

cell count; APR = acute phase proteins;

Some untreated animals must be left to prove effecacy and allow specific follow-up FEC = faecal egg count.

tests to be made.

ing indices of mineral status which rarely reflect onset

molecules, methyl-(Me) and adenosyl-(Ado) Cbl, which

of disorder or disease. Throughout this chapter, use will

have contrasting functions in the body. MeCbl acts as a

be made of 'marginal bands' for diagnostic criteria

coenzyme to methionine synthetase and is linked to

(Table 21.1), which reflect the uncertainty of detecting

folate metabolism, through the use of methyltetrahy-

the onset of health-limiting conditions. The following

drofolate as the methyl group donor. Deficiencies of

descriptions of specific disorders concentrate on the

this coenzyme can theoretically impair methionine

more commonly encountered deficiencies of cobalt

synthesis and the bioavailability of folate and cause

(Co), copper (Cu), iodine (I) and selenium (Se).

formiminoglutamic acid (FIGLU) to appear in urine.

AdoCbl enables propionate to be used for gluconeoge-

nesis via succinate and the tricarboxylic acid (TCA)

Cobalt disorders

cycle, acting as coenzyme to methylmalonyl-CoA

isomerase: insufficiency causes methylmalonic acid

(MMA) to accumulate.

Aetiology

The anorexia and anaemia that are successive

The only known functions of Co arise from its place at

debilitating consequences of deprivation may reflect

the centre of the corrin ring of two cobalamin (Cbl)

the dysfunction of AdoCbl and/or MeCbl (Underwood

Table 21.1

Marginal bands for commonly used biochemical indices of micronutrient status in the diet, serum or tissues of cattle: mean values falling within bands indicate a possibility of benefit from trace element supplementation; the more extreme the value and the more parameters affected, the greater the possibility becomes; values below (above for Fe:Cu and thyroid weight) bands indicate a probable benefit.

Cu

Co or vit B12

I

Mn

Se

Zn

Dieta (mg/kg DM)

5–15

0.04–0.06

0.08–0.3

10–15

0.03–0.06

10–20

Serumb (mmol/l)

3–8

0.25–0.5 ¥ 10-3M

0.08–0.20

0.09–0.11

0.13–0.26B

6–9

Tissuec (mmol/kg DM)

150–300nL

0.2–0.4L

9.5–15.8 ¥ 103T

11–13H

0.6–1.3nL

765–1070R

a Higher values are appropriate for: antagonist-containing diets (for Cu, Cu:Mo < 1–3, Fe:Cu > 50–100; Cu:sulphur < 0.0025); for I, with high goitrogen intake); for low agonist intake (e.g. for Se, low vitamin E intakes); for all *elements when the digestibility of the ration is high.*

b The ranges are for adults; newborns often have different norms (e.g. 3–9 mmol/l then being adequate for serum Cu).

c Superscript letters indicate sample origin: B = whole blood, H = heart, L = liver, M = milk, R = rib, T = thyroid; for the latter, an organ weight range of 0.3–0.8 g FW/kg LW is marginal; for the newborn (n), ranges may again differ, L Se being up to 3¥ that in the adult and L Cu 7–10¥ higher.

Divide values by 3.3 (L) or 4.0 (H,T) for approximate fresh weight basis.

Conversion from mmolar to mg units requires multiplication by: 63.5 for Cu, 58.9 for Co, 126.9 for I, 54.9 for Mn, 79.0 for Se, 65.4 for Zn and 1355

for B12; division by these factors converts mg to mmol units.

& Suttle, 1999). Loss of appetite was initially linked

Clinical signs

to Adocbl dysfunction and increased blood propionate

All ruminants require a dietary supply of Co for the

concentrations, but disturbances of rumen fermenta-

synthesis of the essential vitamin B

tion (McDonald & Suttle, 1986; Kennedy et al.,

12 by rumen micro-

organisms. Cattle are less susceptible to a lack of Co

1991) and the accumulation of other metabolites

than sheep, but when they succumb, they develop essen-

(e.g. MMA, Rice et al., 1989; succinate, Kennedy et al., tially the same clinical abnormalities in the same order:

1991; homocysteine, Stangl et al., 2000) may also affect anorexia, loss of body condition, muscular wasting and

appetite. Loss of appetite would compound the effect

finally an anaemia that is both normochromic and

of a diminishing supply of the glucose precursor,

normocytic. In the early stages of the disease, the hair

propionate. The anaemia of Co deficiency may reflect

coat can become rough and discoloured (Judson et al.,

the role of MeCbl in DNA synthesis and red cell

1982) and may be repeatedly licked. Appetite may

maturation.

become depraved (pica). Eventually, the skin becomes

The basic cause of cobalt-responsive disorders is a

thin and fragile and the mucous membranes pallid. The

simple nutritional deficit that can be traced to

clinical picture is thus one of a ‘pining’ or ‘wasting’

impoverished soils in which crops or pastures have

disease, indistinguishable from many other causes of ill-

grown. Interactions can occur in the soil that leave

thrift. Cobalt-deprived cattle may be more susceptible

most of the Co adsorbed in unavailable forms onto *to infections than normal cattle (MacPherson et al.,*

manganese oxides, particularly at alkaline soil pH with

1987a).

soil Mn >1 g/kg (Suttle, 2000). If extraction with 0.43 m

There is a neurological disease that affects cattle in

acetic acid yields <0.3 mg Co/kg air-dry soil, deficiencies Australia when they graze Phalaris tuberosa pastures

may develop. The diet should contain >0.05 mg Co/kg

called 'Phalaris staggers'; it can be prevented by Co

dry matter (DM) (Underwood & Suttle, 1999). Inter-

dosage but not by administration of vitamin B

actions in the animal have been postulated because

12 and is,

therefore, not a classical 'deficiency' syndrome. The

Co can be incorporated into various analogues of

response to Co may arise through the neutralization of

B12 by the rumen microbes. There is thus competition

fungal neurotoxins by the element (Underwood &

for Co in the rumen between different forms of the

Suttle, 1999).

vitamin. Cobalamins are selectively absorbed in associ-

ation with intrinsic factor but if analogues find their

way into the bloodstream or tissues, they might com-

Necropsy

plicate the assessment of vitamin B12 status and com-

promise functions of the vitamin. However, protective

At necropsy, cattle suffering from Co deprivation show

mechanisms would probably have evolved, if they are

the hallmarks of starvation. There is little body fat

needed, against analogues so copiously produced in the

except occasionally in the liver, which may be pale

rumen.

and friable due to fatty infiltration; this condition is,

however, far less common in cattle than in lambs or goat

shows better fit at low than at high levels (Mitsioulis

kids. In severely affected, anaemic individuals, bone

et al., 1995; Suttle, 1995); values between 0.06 and

marrow hypoplasia and splenic haemosiderosis will be

0.08 mg Co/kg DM can be regarded as 'marginal'

found.

(Underwood & Suttle, 1999).

The diagnosis of Co disorders from the presence of

abnormal metabolites in the blood and urine was devel-

Diagnosis

oped in sheep and non-ruminants and extended to

Cobalt-responsive disorders are best diagnosed through cattle. Quirk & Norton (1988) found that heifers

responses in growth or health to Co or B12 supplemen-

grazing pastures low in Co (0.036 mg/kg DM) remained

tation in controlled trials (e.g. Duncan et al., 1986). Bio-healthy and excreted no MMA or FIGLU in urine,

chemical confirmation of subclinical or clinical disease

despite low plasma B12 concentrations (96 pg/ml). After

from the assay of plasma B12 is more difficult in cattle

calving, milk yield was unaffected but very low B12

than in sheep. Plasma B12 concentrations appear to

concentrations in the milk (42–86 ng or 31–63 pmol/l)

respond feebly to Co supplementation in cattle. Oral

caused depletion of plasma B12 in their calves (59–

doses of Co ten times higher on a body weight basis

74 ng/l) and growth retardation, which was accompa-

than those that increase plasma B12 in sheep were

nied by increased urinary excretion of FIGLU. They *apparently ineffective in cattle (N.F. Suttle & J.*

concluded that MMA was less reliable than FIGLU as

Brebner, unpublished data). High plasma B12 concen-

an index of dysfunction but their method for MMA was

trations (>500 ng/l) are rarely found in cattle yet they

relatively insensitive (30 mmol/l). Assay of plasma

are commonplace in sheep and values have often fallen

MMA has been advanced as a measure of functional

to exceedingly low levels (<100 ng/l, e.g. Reid &

B12 status in sheep, with concentrations >5 mmol/l taken

McQueen, 1985) before cattle failed to thrive, though

to be abnormal (Rice et al., 1987): as yet plasma MMA

there are exceptions (e.g. Duncan et al., 1986). The assay has not been tested for the confirmation of Co dys-of B12 by the more favoured radioisotope dilution

function in cattle but a marginal band of 5–15 mmol/l

(RID) method is susceptible to interference from non-

may well prove useful. Increases in plasma homocys-

specific binders (Millar et al., 1984; Schulz, 1987a, b); teine are found after prolonged Co deprivation (Stangl

these include the transport proteins for B12 in bovine

et al., 2000).

plasma (transcobalamins), which show quantitative dif-

ferences from man (Schulz, 1987a) as well as seasonal

Treatment or prevention

anomalies (Millar et al., 1984). Since binding affects the recovery of B12 after deproteinization of plasma or

Although there are clearly differences in B12 metabo-

serum, it can impair assay by both microbiological and

lism between cattle and sheep, there is no evidence that

RID methods. The results of assays of B12 in bovine

these affect the methods of treating and preventing dis-

plasma can vary substantially between laboratories

orders. The injection of B12 as cyano- or hydroxycobal-

(Schulz, 1987b) and assays of the analogue component

amin, 2–6 mg/50 kg liveweight, provides protection for

by difference, using specific and non-specific binders,

several weeks, even though responses in plasma B12

are particularly prone to error. Extraction of the

soon dissipate. Slow-release, injectable preparations of

vitamin at alkaline pH overcomes the problem and

B12 are being developed in the Antipodes.

modified assay kits are now available (Stangl et al.,

Heavy cobalt oxide pellets given orally, in pairs or

2000).

singly with a ‘grinder’, improve the B12 status of growing

Assays of vitamin B12 in skimmed milk and liver are

and adult cattle for several months (Judson et al., 1981; far more reliable than those in plasma and values for

Quirk & Norton, 1988), even when a change in formu-

milk and liver from the same individual correlate rea-

lation halves their Co content (Judson et al., 1997b); the sonably well with each other, particularly at low levels

soluble glass bolus can also give sustained protection

that have diagnostic significance; milk B

<

12

0.5 nmol

(Allen et al., 1985). The effectiveness of infrequent oral (678 ng/l) indicates a possibility of ill health (Judson

doses of Co in anthelmintics has not been tested but

et al., 1997b) (Table 21.1). By contrast, the relationship weekly doses of 35–70 mg Co without anthelmintic are

between plasma and liver B12 values is poor, particularly

said to be effective (Underwood & Suttle, 1999). Cobalt

at low levels (Judson et al., 1997a). Diagnostic thresh-supplementation via the drinking water can be prac-

olds for liver B12 in sheep have long been extrapolated

tised where there is a piped water supply (MacPherson,

to cattle; thus values <0.10 mg/kg fresh liver have been

1983). Use of 'protected' or chelated forms for oral use

taken to indicate moderate to severe deficiency and

is contraindicated because Co must be given in forms

values >0.19 mg (>140 pmol)/kg have been regarded as

which can be rapidly incorporated into vitamin B12 by

normal. There is a curvilinear relationship between Co

rumen microbes. Evidence that volatile fatty acid

and vitamin B12 concentrations in bovine liver which

(VFA) production by rumen microbes is influenced by

Co deficiency (McDonald & Suttle, 1986; Rice et al., been suggested that they may reflect direct effects of

1989; Kennedy et al., 1991) suggests a possible advan-Mo on the central control of appetite (Phillippo et al., tage for the oral route over the injection route, since

1987b). It is, however, premature to discount the role of

only the former meets the needs of the microbes for B12.

Cu (Suttle, 1988; Underwood & Suttle, 1999) and other

Comparisons between methods have rarely been con-

factors that influence Cu status should not be ignored.

ducted but one at least showed no advantage in calf

Copper absorption in cattle is as sensitive to Mo inhi-

growth for oral Co versus injected B12 (Judson et al., bition as it is in sheep and the equations derived for

1981).

grazing sheep to predict Cu absorption (Suttle, 1983b)

Administration of Co on a group basis via licks con-

should give an approximate weighting for cattle. High

taining 0.1 per cent Co or mineral mixes containing up

S intakes from the diet (Suttle, 1983a) or drinking water

to 0.4 per cent Co may provide an inexpensive means

(Smart et al., 1986) also suppress Cu absorption. Poor of prevention but could not be guaranteed to protect

Cu absorption, and hence disorders, will therefore be

all individuals. The best long-term strategy on certain

more common on lush, immature, S-rich swards than on

soil types will be to apply Co salts, such as hydrated

brown, mature swards and in wet than in dry seasons.

$CoSO_4$, at 2–3 kg/ha, every three to four years.

Copper is also absorbed better from hay than from

Responses may, however, be short-lived on sandy soils

fresh grass of similar S content (Suttle, 1983b). Ensiled *and negligible on calcareous or recently limed soils con-*

grass is a good source of absorbable Cu while S con-

taining >1 g Mn/kg DM because most of the Co

centrations are low (about 2 g/kg DM), but availability

becomes 'fixed' in the soil.

probably falls rapidly as concentrations rise to 3 g/kg

There is virtually no risk of overdosing with cobalt,

DM if cattle share the characteristics of sheep (Suttle,

but this should not be used as an excuse to overfeed Co

1983a). High iron (Fe) concentrations also lower Cu

to animals whose capacity to synthesize and absorb B12

status in cattle (Bremner et al., 1987; Phillippo et al., is strictly limited.

1987b; Gengelbach et al., 1997), are often raised in

spring and autumn pastures and have been implicated

in incidents of hypocuprosis (Jarvis & Austin, 1983;

Copper disorders

McFarlane et al., 1990). There is debate over whether

(see also Chapter 18)

or not the Fe ¥ Cu antagonism requires the presence of

moderate amounts of dietary S (Suttle, 1988).

Aetiology (see p. 254)

The principal determinants of hypocuprosis in

Most Cu-responsive disorders in cattle are induced:

grazing cattle are therefore raised soil Mo, alkaline soil

they are induced in the rumen where the anaerobic

pH (which encourages Mo uptake), sward immaturity,

degradation of sulphur(S)-rich, fibrous feeds leaves

high rainfall (or irrigation), heavy fertilizer N use and

little of the ingested Cu in a soluble form. After

high soil ingestion, rather than the Cu content of the

weaning, less than 10 per cent of the total Cu input is

soil or herbage, on all but the most impoverished, sandy

absorbed during passage down the gastrointestinal tract

soils.

and the percentage can be reduced to as little as 1–2 per

Shortage of absorbable Cu leads to (i) rapid deple-

cent by small increments in dietary Mo (Underwood &

tion of liver stores, (ii) a lowering of caeruloplasmin Suttle, 1999). Again it is transformations in the rumen

synthesis and a drop in plasma Cu (i.e. deficiency) and that are pivotal: extrapolating from sheep, it appears

(iii) a reduction in cuproenzyme activities in the ery-

that the progressive substitution of S2- for O2- in molyb-

throcyte and tissues (dysfuntion). Although cytochrome date creates thiomolybdates, which complex Cu and

oxidase and superoxide dismutase have been the most

bind it to the solid phase. Surplus trithiomolybdate

studied, others such as lysyl oxidase and dopamine

(MoOS3) is absorbable and capable of changing the dis-

hydroxylase will almost certainly follow the non-

tribution of Cu in the blood and tissues (Underwood &

ruminant pattern in showing disorder (Suttle, 1988).

Suttle, 1999). Just how important the systemic effects of

Effects on growth, cardiac function and bone develop-

thiomolybdates are under normal grazing conditions

ment cannot be attributed to a particular enzyme defi-

has yet to be determined. The 'tell-tale' appearance of

ciency with certainty. Even the depigmentation once

abnormal plasma fractions, such as TCA-insoluble Cu,

attributed to diminished tyrosinase activity must be

has been restricted to experimental situations, involv-

open to other explanations now that it is known to be

ing high levels of dietary Mo (35 mg/kg DM; Wang et al., produced by Co as well as Cu deprivation (Judson et al., 1988), and they may serve as slow release pools of Cu

1982). Connective tissue defects, including those in the

in the long term (Underwood & Suttle, 1999).

ligamentum nuchae, are probably due to lysyl oxidase

Most cases of Cu-responsive growth retardation in

deficiency leading to defective cross-links in elastin.

cattle are associated with abnormally low ratios of

Digestive disturbances may result from disruption of

Cu : Mo in the herbage (<3.0; Phillippo, 1983) and it has

mitochondrial respiration and villous atrophy, but

enhanced inflammatory reactions to gut parasites

the clinical signs, like the signs themselves, are non-

cannot be ruled out in grazing animals (Underwood &

specific. The earliest and most dramatic lesions are

Suttle, 1999).

likely to be those affecting the epiphyseal growth plates

in the costochondral junctions and metatarsal/

metacarpal bones. These can become overgrown to the

Clinical signs

point that they spill over to leave islets of collagen distal

The sequence and severity of signs associated with a

to the plate in various states of irregular calcification
lack of dietary Cu in cattle (hypocuprosis) depend upon
and fibrotic replacement (Suttle, 1988). Gross degener-
the rate and stage of development at which it occurs.
ative changes are also seen in connective tissues such as
There are no definitive reports of teratogenic or neu-
the ligamentum nuchae. In severe cases showing
rological effects, comparable with swayback in sheep
diarrhoea, villous atrophy in the duodenal and jejunal
(cf. Richards & Edwards, 1986). In the growing calf, loss
regions is likely to be seen (Suttle, 1988) but is
of hair colour, growth retardation and changes in
indistinguishable from that caused by gut parasites.
metatarsal conformation are the earliest signs of abnor-
The anaemia of Cu deficiency in the bovine is
mality followed by diarrhoea and finally anaemia.
similar to that of Fe deficiency, i.e. macrocytic and
Black hair usually turns grey and red/brown hair
hypochromic. Cardiac lesions including fibrosis of the
becomes light brown. The ‘foxy brown’ discoloration of
myocardium have been reported in natural outbreaks

the Friesian is not attributable to copper deprivation

only once, over 40 years ago, in Australia. While cardiac

(Mee, 1991). Cardiac hypertrophy has been reported in

hypertrophy was seen in some experimentally depleted

experimentally depleted calves and this may be an early

calves, which took a long time to develop clinical signs;

manifestation of the myocardial degeneration that can

it was not present in others that were depleted more

cause sudden death after prolonged deficiency in the

rapidly (Suttle, 1988).

field (Suttle, 1988). Addition of small amounts of the Cu

Attention switched from the lesions that underlie

antagonist, molybdenum (Mo), to the diet (2 mg/kg

the expected and familiar clinical signs to those which,

DM) accelerates rather than changes these clinical

though less spectacular, occur earlier and may underlie

manifestations of disorder. At much higher Mo con-

the debilitating effects of the disorder. Fell and his asso-

centrations (>10 mg/kg DM), animals may develop diar-

ciates (Fell et al., 1985; Fell, 1987) found basement mem-rhoea immediately upon exposure to the antagonist *brane defects in the pancreatic acinar cell, the duodenal*

(Suttle, 1988).

enterocyte and kidney tubule, pointing to perhaps a

Infertility has long been associated with Cu depriva-

common early failure of proteoglycan organization.

tion in cattle but there is little published evidence that

It remains to be seen whether Mo can cause distinc-

deficiency leads to impaired reproduction unless Mo is

tive histological or ultrastructural changes at central

involved (Phillippo et al., 1982, 1987a). Molybdenum-

sites such as the pineal body which may be crucial to

induced deficiency is associated with delays in the onset

the development of disorder (Phillippo et al., 1987a)

of oestrus, impaired conception rate and anoestrus:

and whether or not these are Cu-dependent.

these abnormalities have yet to be induced experimen-

tally by other antagonists of Cu, such as Fe (Phillippo

Diagnosis

et al., 1987a). Copper-responsive infertility in cattle given Mo, therefore, may result from the direct or indi-Since none of the clinical signs of Cu deprivation given

rect suppression of the release of luteinizing hormone *above is specific, diagnosis must be supported by*

(Phillippo et al., 1987a).

biochemical tests showing subnormal tissue Cu status.

Anaemia is a late sign of Cu dysfunction in growing

Because availability has such a major effect on Cu

calves (Suttle, 1988) and may be associated with Heinz

uptake, herbage or dietary Cu concentrations alone are

body formation in the periparturient cow (Black, 1981).

almost worthless and should be accompanied by meas-

The in vitro viability and/or function of neutrophils ures of Mo and S and predictions of available Cu

from Cu-deficient cattle is poorer than that of cells from

(Suttle, 1983a). In green swards, which contain enough

normal cattle (Suttle, 1988) but exposure to Mo can

sulphur to potentiate the Mo antagonism, Cu : Mo ratios

increase leucocyte counts (Gengelbach et al., 1997);

<3.0 indicate a risk of hypocuprosis. Even then, other

there is no evidence yet for impaired resistance to infec-

factors such as initial Cu reserves, other dietary antag-

tions in vivo (Arthington et al., 1996).

onists (Fe and ingested soil) and the rate of animal pro-

duction may determine the outcome of events. Genetic

variation in bovine Cu metabolism is far less

Necropsy

pronounced than that found in sheep (Underwood &

The pathology of bovine hypocuprosis is largely

Suttle, 1999). Fe : Cu ratios in the range 50–100 indicate

unhelpful because the histological changes underlying

the possibility of a Cu-responsive disorder; these and

other guidelines for the biochemical assessment of risk

viding protection for several months (Judson et al.,

are summarized in Table 21.1.

1985; Rogers & Poole, 1988). Soluble glass boluses are

The conventional criteria of Cu status in the animal,

likely in time to give equally sustained protection and

i.e. liver and blood Cu concentrations, are most depend-

are particularly suited to the extensive grazing situation

able when herbage Mo concentrations are low (<5 mg/

(Allen et al., 1985; Judson et al., 1985; Givens et al., kg DM). Under these circumstances the ranges

1988). During periods of supplementary feeding or

150–300 mmol (10–20 mg) Cu/kg DM for liver and 3–

housing, the use of Cu salts as forage additives or cereal

9 mmol (0.2–0.6 mg) Cu/l for plasma can be regarded as

supplements commends itself. Where food supplements

‘marginal’, except for the newborn (Table 21.1): as group

are not given, a free-access mineral mixture containing

means, they indicate that some individuals are likely to

>500 mg Cu/kg is likely to afford protection to the

benefit from Cu supplementation and that cheap meas-

majority of the individuals that take to it in a given

ures to improve Cu status would be prudent. Newborn

herd. If Cu proves to be useful as an antidote to Mo

calves require higher marginal ranges for liver (790–

rather than an essential nutrient in some situations by

3150 mmol Cu/kg DM) and lower ranges for plasma

rendering toxic thiomolybdates less available, the pro-

(3.0–4.5 mmol Cu/l). At very high dietary Mo concentra-

vision of Cu by slow rumenal release or steady dietary

tions (35 mg/kg DM), changes in the distribution of Cu in

supplementation may have advantages over other

the plasma and liver may complicate the assessment *forms of supplementation. The use of chelated forms of*

of Cu status (Wang et al., 1988). With less extreme

copper, such as 'proteinates' or copper lysine, as dietary

though still unusual Mo concentrations (>5 mg/kg DM)

supplements has given no consistent advantage over

in pasture, 'teart'-like conditions may operate for

simple, cheap inorganic forms and cannot be relied

critical periods, with animals responding to Cu

upon to 'protect' copper from molybdenum or other

while normocupraemic.

Low caeruloplasmin : Cu

antagonists (Underwood & Suttle, 1999).

ratios in plasma have been claimed to indicate the

antagonistic influence of Mo, but they can be low when

Toxicity *(see p. 948)*

the antagonist is Fe (Gengelbach et al., 1997). The relationship between caeruloplasmin and total Cu in bovine

Copper poisoning rarely occurs through the ingestion of

plasma is not perturbed in molybdeniferous areas of

excess Cu in weaned cattle because of poor absorption

Scotland (N.F. Suttle & J. Small, unpublished data). It and a well-developed capacity to excrete surplus Cu via

remains to be seen whether supplements that achieve

the bile. Tolerance of diets containing >250 mg Cu/kg

normocupraemia invariably provide a sufficient

DM for several months has been reported in Friesian

defence against Mo-induced infertility and whether

steers (Felsman et al., 1973). Much higher absorptive

other parameters such as plasma Mo or plasma Fe con-

efficiencies prior to weaning mean that calves reared

centrations have merit for diagnosing Mo-induced ill

on milk substitutes are relatively vulnerable, but they

health (Phillippo et al., 1987a, b). In establishing Cu as a can tolerate up to 500 mg Cu/kg DM for brief periods (6

limiting factor to production in a new area, a response to

weeks; Jenkins & Hidiroglou, 1989). Oral drenching with

a specific Cu treatment affords the best assessment,

$CuSO_4$ solutions can cause haemolytic crises similar to

though not necessarily showing Cu deprivation to be

those found in the more vulnerable sheep, but slower

the primary cause (see p. 254).

rates of exposure via the diet may sometimes cause or *contribute to hepatic crises. Rapidly growing bull calves can die suddenly and show biochemical evidence of liver*

Treatment or prevention

injury, in the form of raised AST activities, and Cu over-

The treatment of Cu deficiency is achieved readily by

load, in the form of raised kidney Cu levels, without evi-

single oral doses of Cu or parenteral injections of the

dence of haemolysis (no jaundice or increase in kidney

element. In animals close to market weight the use of

iron) and only marginally raised liver Cu (C. Low, pers.

chelates of Cu with ethylene diamine, tetra-acetic acid

comm.). Diagnosis of toxicity becomes possible when

(EDTA), glycine or methionine may result in unac-

'liver enzyme' values in serum are raised and values for

ceptable, 'cold' abscesses at the injection site, whether

indices of copper status enter the following 'marginal'

given subcutaneously or intramuscularly. Use of

ranges: serum, 0.018–0.020 mmol Cu/l; liver 6.4–16.0,

water-soluble complexes such as the hydroxyquinoline

kidney 0.6–0.8 and diet 1.57–3.14 mmol Cu/kg DM (mul-

sulphonate and heptonate will avoid abscess formation tiply by 63.5 to obtain mg or ppm units). False ‘highs’ for

but increase risks of acute toxicity (e.g. Suttle, 1981).

plasma Cu during acute infections will be accompanied

Prevention of deficiency and disorder can be

by Cu : Zn ratios >3–4. Acute Cu poisoning can be caused

achieved to varying degrees of precision and duration

by overdosage via the parenteral route (Mylrea &

with oral and parenteral supplements. Copper oxide

Byrne, 1974) and is characterized by haemolytic crises

particles are more effective than serial injections, pro-

and jaundice.

Iodine disorders (see pp. 257, 586)

there is no need to weigh the gland. Problems of inter-

pretation arise when the degree of iodine deprivation

Aetiology

and associated changes are less pronounced. In the UK,

the limit of normality for thyroid weight was 0.33 g

Iodine has only one function in the body, as a con-

FW/kg LW, but recent work in Northern Ireland has

stituent of the hormone tri-iodothyronine (T3), which *shown that a higher margin is necessary. Iodine depri-*

regulates basal metabolic rate. The hormone is formed

vation can cause thyroid weights to reach 0.79 g/kg LW

by the removal of iodine (deiodination) from thyroxine

without causing stillbirths (McCoy et al., 1997) and

(tetra-iodothyronine, T4), the physiologically inactive

iodine supplementation of beef cows significantly

form synthesized in the thyroid gland. Disorders can

reduced thyroid weight without reducing calf mortality arise either from a simple lack of iodine in the diet or

or stillbirths (Smyth et al., 1992). Sound interpretation from the impairment of iodine metabolism by ingested

requires a marginal band of 0.3–0.8 g/kg LW (Table

goitrogens. Simple iodine deprivation rarely occurs in

21.1). Spurious increases in thyroid weight may occur

coastal regions or on small islands because of the large

during the trauma of a difficult calving as part of a gen-

atmospheric inputs of iodine of marine origin. Diets

eralized oedema.

containing <0.1 mg I/kg DM are inadequate, those with

0.1–0.2 mg/kg DM marginal; levels are usually much

higher in spring than in summer pasture (Underwood

Diagnosis

& Suttle, 1999). In areas where winter temperatures are

Biochemical and histological criteria can contribute to

low, iodine requirements probably increase in propor-

diagnosis in cases of marginal deprivation, but the most

tion to energy expenditure/kg LW, making the newborn

commonly used criteria present the greatest problems

particularly vulnerable. Selenium deprivation may

of interpretation.

increase the risk of iodine disorders through its role

as an activator of several deiodinase enzymes (see

Thyroxine: T4 is transported in plasma bound to pro-

‘Selenium disorders’ on p. 302).

teins, but concentrations in the blood are a poor and

Ingestion of inorganic, cyanogenetic goitrogens in

unreliable index of functional iodine status. Proper

certain grasses (e.g. Paspalum spp., Cynodon aethiopi-assessment of iodine dysfunction requires measure-

cus), legumes (e.g. Trifolium repens, Medicago sativa), ments of T3, T3 : T4 ratios and thyroid-stimulating

brassicas (e.g. B. oleracea) and by-products (e.g. cassava hormone (TSH), the hormone secreted by the pituitary *meal) leads to the formation of thiocyanate in the*

in response to iodine deprivation. The detection of

rumen which impairs iodine uptake by the thyroid.

raised TSH concentrations in the bloodstream indicates

Organic,

thiouracil-type goitrogens (e.g.

in B.

that an animal needs more T3 and is prompting the

campestris, Leucena leucophela and rapeseed meals) thyroid gland to increase hormone synthesis. A recent

can impair iodine incorporation into T4 in the thyroid

experiment (McCoy et al., 1997) confirms the unrelia-

and its conversion to T3 in the tissues. Exposure to both

bility of T4 assays. Pregnant heifers were fed a diet suf-

types of goitrogen increases risk of disorder and only

ficiently low in iodine to cause a 2.5-fold increase in

the former type can be countered by providing more

thyroid weight of their newborn calves when compared

iodine.

with an iodine supplemented control group. No signifi-

cant differences in plasma T4 concentrations were found

Clinical signs

between the two groups in either mother or offspring

and mean values (60–202 nmol/l) were in the normal

Iodine deprivation is no longer synonymous with goitre.

range. There is also a spontaneous fall in plasma T4

While goitre in the newborn remains the commonest

during early lactation to values that are subnormal for

manifestation, lack of iodine also has a specific effect on

other stages (20–40 nmol/l).

brain development and non-specific effects on growth,

fertility, milk yield and on the skin and its appendages

Serum iodine: The element has been measured in toto (Underwood & Suttle, 1999).

and in protein-precipitable and butanol-extractable

forms in serum, but rarely in proven clinical or sub-

clinical cases of iodine deprivation, and diagnostic

Necropsy

limits can only provisionally be set. Each parameter is

Thyroid enlargement occurs as an adaptive response to

a better measure of the degree of excess than of inad-

iodine deprivation and undoubtedly provides a simple equate iodine supply (Table 21.1).

first measure of the possibility of iodine deficiency. In clinically significant, chronic pre- or postnatal iodine

Thyroid iodine: Thyroid iodine concentrations largely

deprivation, enlargement of the thyroid is gross and

reflect the amount of iodine in thyroglobulin which is

lying in store. Since iodine stores can be depleted

microflora in isolated populations can limit endogenous

before cellular changes occur and cellular changes

goitrogen synthesis from mimosine-containing shrubs

increase the size of the thyroid, tissue iodine concen-

such as L. leucophela (Jones & Meggarity, 1983).

tration alone will be of limited value in determining the

total amount of iodine present in the gland. Many

authorities use the yardstick proposed in the 1930s that

Toxicity (see pp. 261, 823)

clinical goitre is associated with thyroid I <

2

1.2 g/kg DM

Iodine is a cumulative poison which eventually sup-

and 1.2–2.0 g I2/kg DM becomes a marginal range (Puls,

presses thyroid activity. Tolerable exposure is therefore

1994; Table 21.1).

a multiple of daily intake ¥ length of exposure, rather

than a set dietary concentration. The marginally toler-

Milk iodine: Concentrations of iodine in bovine milk

able concentration over three to four months' exposure

are linearly related to iodine intake (Underwood &

is 25–50 mg I/kg DM (Newton et al., 1974) and is rarely Suttle, 1999) and have proven diagnostic value in the

encountered under farm conditions unless there is

ewe. Puls (1994) suggests that values <25 mg I/l indicate

access to seaweed (4–6 g I/kg DM). Iodosis is charac-

'deficiency' in cows, much lower than the corresponding

terized by poor growth and respiratory disorder in

value for ewes (<80), yet this probably overlaps the

calves (Newton et al., 1974) and by perinatal mortality

'marginal' range.

in offspring of the adult cow (Fish & Swanson, 1983).

Once lactation has begun, the cow herself becomes less

Histological criteria: A sequence of microscopic cellu-vulnerable because she is able to secrete much of any *lar changes occur in the thyroid as the organ responds*

excess dietary or therapeutic iodine in milk. Use of

to the stimulus from TSH. Firstly, stores of surplus thy-

iodine in the form of ethylene diamine dihyroiodide

roxine in colloidal form are removed – some patholo-

(EDDI) for treating foot rot and 'lumpy jaw' in the

gists call this 'colloidal goitre', but this does not mean

USA has resulted in many cases of iodosis (see page

that the abnormality has reached a clinical or life-

261 and Underwood & Suttle, 1999, for further details).

threatening stage, rather that depletion is complete.

With stores of thyroglobulin denuded, the epithelial

cells which produce thyroxine increase first in number

***Selenium disorders** (see p. 258)*

(hyperplasia: 'hyperplastic goitre') and then in size

(hypertrophy); it is the latter process which lies behind

Aetiology

visible, clinically significant goitre. Hyperplasia can

occur in calves which are normal at birth (McCoy et al., The principal function of Se in animals relates to its

1997) and may be caused by the stress of a prolonged *intracellular presence in the glutathione peroxidases,*

calving. Undue diagnostic significance should not be

a family of antioxidant enzymes (once GSHPx, now

attached to thyroid abnormalities, although these may

GPXn with n ≥ 6), which use various potentially dan-

be the only post-mortem 'abnormality' to be recorded.

gerous peroxides as substrates. Selenium has been

linked with iodine metabolism in ways that indicate a

separate function, independent of GPX (Arthur et al.,

Treatment and prevention

1988). While the basic cause of Se disorders is obviously

Congenital goitre must be prevented because there is

a shortage of the element in the diet, which in turn

no response to treatment and only the chronic forms of

can be traced to soil formations also deficient in Se

iodine disorders in older animals are amenable to treat-

(Underwood & Suttle, 1999), other factors are proba-

ment. Simple and thiocyanate-induced deprivation can

bly involved in field outbreaks of Se-responsive disease.

be prevented by providing inorganic iodine supple-

Calves fed experimental diets of exceedingly low Se *ments in iodized salt licks or mineral mixes containing*

content (0.01–0.02 mg/kg DM) indoors can be depleted

c. 0.1 g I/kg. Substantial losses can occur by volatiliza-of Se to the point that they have undetectable activities

tion in hot climates and the use of less volatile forms

of GPX1 in their blood and yet do not develop myo-

such as periodates is then indicated. Slow-release

pathy (Arthur, 1988; Reffett et al., 1988). In one study boluses are being developed and a long-lasting form for

(Arthur, 1988), the failure to induce myopathy was the

parenteral administration (iodized poppyseed oil) has

more surprising because the diet was also low in vitamin

long been used, although it is no longer obtainable in

E, which also contributes to antioxidant defence in the

some countries due to a failure to update product

tissues.

licences. Problems induced by organic goitrogens can

The importance of dietary sources of oxidant stress

be avoided by using cultivars selected for low glucosi-

was demonstrated by workers in Belfast (Rice &

nolate content and by-products of such crops (e.g.

McMurray, 1982), who showed that the addition of *canola rapeseed meals). Manipulation of the rumen*

polyunsaturated fatty acids (PUFA, progenitors of lipid

peroxides) to diets deficient in vitamin E and Se, simu-

gestions have not always been confirmed in experi-

lating the composition of PUFA-rich spring grass,

mental studies (Reffett et al., 1988). There are several will precipitate myopathy. Other stressors may yet be

reports of inverse relationships between blood Se or

required to induce myopathy because Arthur (1988)

glutathione peroxidane (GPX) activity with somatic

has shown that feeding of PUFA-rich grass indoors to

cell counts in bovine milk (e.g. Erskine et al., 1989) and calves deficient in Se and vitamin E did not precipitate

experimental evidence that addition of Se to diets of

the disorder, whereas grazing the same grass produced

marginal Se concentration decreases the duration of

acute myopathy. He suggested that exercise or some

clinical mastitis (Smith et al., 1984). Similar responses other component of the environmental change at

can be obtained with supplements of vitamin E (Weiss

turnout contributed to the development of muscle *et al., 1997), making interpretation of responses to Se damage. The excitable behaviour of the calf will of*

combined with vitamin E (the commonest approach)

course result in increased activity of muscles involved

either difficult or impossible. Improvements in calf

in locomotion, circulation and respiration: muscular

survival in herds on diets of marginal Se concentra-

exercise is known to induce oxidant stress and exacer-

tion (0.03–0.05 kg Se/kg DM) have been reported, but

bate the effects of vitamin E deficiency (Jackson, 1987).

vitamin E as well as Se was given and the role of Se

It is highly likely that the intense and sometimes pro-

alone is again unclear (Spears et al., 1986).

longed muscular activity of the uterus at parturition

makes it particularly vulnerable to Se (and vitamin E)

Diagnosis

deficiency. Adverse weather conditions have been

implicated in outbreaks of acute myopathy and the

The differential diagnosis of Se-responsive disorders is

cause of Se-responsive disorders is thus multifactorial

complicated by the non-specific clinical signs of disease:

(Underwood & Suttle, 1999).

most can also be attributed to vitamin E deficiency

while others, such as retained placenta and growth

retardation, have many possible causes of both nutri-

Clinical signs

tional and non-nutritional origin. The tolerance of low

Selenium deprivation in cattle can impair development

plasma and blood Se (or GPX1) concentrations in the

throughout life. The suckling calf can develop chronic

absence of exacerbative factors confirms that measures

skeletal and cardiac myopathy if the dam's diet is low

of Se (or GPX) alone cannot confirm a selenium dis-

in Se (Hidiroglou et al., 1985), while the calf on pastures order. Neither is there likely to be a simple relation-deficient in Se can suffer growth retardation before

ship between dietary Se concentration and incidence of

(Morris et al., 1984) and after weaning (Gleed et al., disease.

1983). In spring, calves can develop acute myopathy

In monitoring Se status, the assay of GPX once

with myoglobinuria when turned out to graze. Selenium

largely replaced that of whole blood Se because it was

supplementation has improved conception rate in cows *easier to assay, yet highly correlated with blood Se con-*

(McClure et al., 1986) and heifers (MacPherson et al., centration. Enzyme activities were converted to blood

1987b). At parturition, cows of low Se status are more

Se equivalents for comparative purposes. Interpreta-

likely to retain the placenta than Se-supplemented cows

tion of blood GPX activities is, however, complicated

and they are the more susceptible to metritis and cystic

by many factors. The measurement of GPX activity

ovaries (Harrison et al., 1984). Selenium deprivation

is subject to wider interlaboratory variation than most

also affects the circulatory system: the growing calf

analyses in the clinical context: Blanchflower et al.

can develop a Heinz-body anaemia (Morris et al., 1984) (1986) identified some important variables. The use of

and when calving coincides with turnout, the cow

an assay kit helped to standardize results, but dif-

which is both Cu and Se deficient may be vulnerable

ferences can still arise and each laboratory should

to haemolysis and haemoglobinuria (Black, 1981).

determine and quote its own Se equivalence for GPX

Despite the variety of clinical signs caused by a lack *activity. Results are variously reported per ml blood,*

of Se, it is rare for more than one sign to appear in a

per g haemoglobin and per ml cells: while these will be

single herd. Problems of muscular dystrophy have not

highly correlated with each other within laboratories,

been reported in the many studies of retained placenta,

the use of common conversion factors for comparative

which is probably the commonest Se-responsive con-

purposes may introduce errors. The slow turnover of

dition in cattle. Similarly, growth retardation and mus-

erythrocytes ensures that blood GPX activity reflects

cular dystrophy have not been reported in the same

past rather than present Se supply. The data of

outbreak of disorder. Selenium deficiency in cattle has

Hidiroglou et al. (1985) indicate that it may take four been associated with impaired phagocyte function in

months for blood GPX (and Se) fully to reflect an

vitro, prompting speculation that Se deficiency would

improved Se supply and just as long to reflect a waning

lead to decreased resistance to disease, but these sug-

supply. It should be noted that the GPX in blood is now *regarded as a dispensable, storage form of the element*

oxidative stress but has yet to be tested in ruminants

and indicative of depletion rather than dysfunction.

and would not be a specific test for Se (Suttle, 2000). As

Plasma Se responds immediately to changes in dietary

with other trace elements, the surest diagnosis is often

supply and is a useful adjunct to blood GPX in assess-

provided by responsiveness to effective Se supple-

ing Se status concentrations of 100–120 nmol (8–10 mg/l

ments. By plotting a measure of final performance

being ‘marginal’ and suggesting possible benefits from

against performance prior to supplementation (e.g.

Se supplementation (Underwood & Suttle, 1999).

LWG), it is sometimes possible to identify a small

Very small differences in Se status may determine

minority of a population which would benefit from

vulnerability. In the study of Hidiroglou et al. (1985) for additional Se, while mean performance remains

example, myopathy occurred in calves in one year when

unchanged (Suttle, 2000).

blood GPX1 declined from 29 to 19 iu/g haemoglobin

(Hb) and plasma Se from 11 to 6 mg/l, but not in the next

Treatment or prevention

when the respective falls were 51 to 28 iu/g Hb

and 16 to 13 mg/l. Pasture Se was consistently low at

The many different methods for administering Se orally

0.02–0.04 mg/kg DM. In a survey of the Se status of

and parenterally have been reviewed (Allen, 1983;

cattle in north-east Scotland (Arthur et al., 1979), 85 per MacPherson, 1983) and three were compared by

cent of herds had a blood Se status 50 mg/l, a threshold

MacPherson and Chalmers (1984). Long-term supple-

below which a risk of clinical disease was once sug-

mentation can be achieved by both routes. By adminis-

gested, but only 10 per cent had a recent history of

tering heavy metal (iron oxide) (e.g. Hidiroglou et al., myopathy; the winter diets mostly contained <0.05 mg

1985; McClure et al., 1986) or soluble glass boluses

Se/kg DM. In New South Wales, herds of growing cat-

(Judson et al., 1985) orally and by injecting a relatively tle with blood Se concentrations usually <20 mg

insoluble Se salt, barium selenate, in an oily base

(0.25 mmol)/l rarely benefited from Se supplementation

(MacPherson & Chalmers, 1984; MacPherson et al.,

and those that did were not distinguishable from their

1987b), blood Se concentrations have been increased

blood Se levels (Langlands et al., 1981). Studies in

for at least five months. Supplementing the drinking

New Zealand with dairy cows indicated a critical blood

water (MacPherson & Chalmers, 1984), the pasture

Se concentration as low as 12 mg/l below which milk

(by slow-release fertilizer application; Sanson, 1990;

fat yield fell (Fraser et al., 1987). The latter studies Whelan et al., 1994) or the winter diet (Stowe et al., both involved grazing animals with plentiful supplies of

1988) with Se can also provide long-term protection.

vitamin E.

Stowe et al. (1988) concluded that a supplement of 2 mg The clinically significant thresholds for dietary and

Se/day upon an estimated basal intake of 0.51 mg/day

blood Se concentrations probably vary with the Se-

was not sufficient to raise plasma Se in the periparturi-

responsive condition and the dietary supply of vitamin

ent cow to 'acceptable levels' (>60 mg/l); nevertheless

E. Incidence of retained placenta can be reduced in *retained placenta and metritis was only half as preva-*

cows receiving diets of higher Se content (0.04–0.05

lent in treated as in untreated cows. Oral supplementa-

mg/kg DM) than those giving freedom from myopathy.

tion prior to calving (13–45.5 mg/day for 15 days) can

Higher thresholds for blood GPX activities and Se con-

raise the Se status of offspring substantially and for

centrations of 50 mg/l may sometimes be needed for

several months (Enjalbert et al., 1999). Use of organic normal reproduction (McClure et al., 1986; Underwood

forms of selenium such as yeasts or selenomethionine

& Suttle, 1999), but studies with grazing heifers in New

can change the partition of the supplement in weaned

Zealand show possible tolerance of much lower values

or adult cattle and increase the transfer of selenium to

(Wichtel et al., 1996). Marginal bands must therefore be milk when compared to inorganic sources but is

used (Table 21.1).

unlikely have any therapeutic, nutritional or economic

The greatest limitation of blood GPX for monitoring

advantage in the treated animal (Underwood & Suttle,

disorder is that the target tissue in Se deficiency is often

1999).

muscle not blood. Furthermore, there are wide vari-

It is questionable whether long-term Se supplemen-

ations between muscles in their GPX content and in

tation is the most cost-effective way of treating what are

the lipid composition of their membranes (Rice &

usually short-term problems. The Se-responsive dis-

Kennedy, 1988). Measurement of blood GPX alone is

eases associated with parturition and turnout are acute

unlikely to reflect the risk of lipid peroxidation and

conditions that can be effectively treated or prevented

hence myopathy in crucial muscles. Guidelines for the

by single injections of Se as selenite or selenate (e.g.

interpretation of selected indices of Se status are given

Eger et al., 1985; McMurray & McEldowney, 1977).

in Table 21.1. The assay of a peroxidation product in

There is considerable variation in dosage practice. For

accessible membranes (e.g. malondialdehyde in ery-

example, for the prevention of retained placenta, Se

throcytes) may provide an integrated measure of net

doses have varied from 2.3 to 50 mg: the highest dose *rate, equivalent to 0.1 mg/kg liveweight, is the most*

species from pastures, treatment of soils with fertilizers

commonly used.

which lower selenium uptake (ammonium and calcium

Selenium has generally been given with vitamin E

sulphates) by plants, rotational grazing with less sus-

and it is impossible to assess retrospectively whether

ceptible species such as sheep and improved soil

there was invariably a need for both nutrients. The

drainage. Oral administration of sulphate-rich mixtures

limited studies in which only one nutrient was given

may prevent or alleviate signs (Arora et al., 1975)

to some animals show that the benefit of providing

vitamin E with Se varies from farm to farm. The need

for dual supplementation may also depend on the

Manganese and zinc disorders

nature of the clinical problem. A combination of oral

(see p. 260)

vitamin E with parenteral Se reduced the incidence of

retained placenta in one instance in which the separate

Cattle deprived of elements such as Mn and Zn under
treatments were ineffective, but Se alone reduced the
experimental conditions develop diverse clinical symp-
prevalence of metritis and cystic ovaries (Harrison
toms, but the diets used contained far less Mn and Zn
et al., 1984). In the treatment of acute myopathy at
than the levels provided by the vast majority of natural
turnout, McMurray and McEldowney (1977) found that
diets (Underwood & Suttle, 1999). Field cases of Mn
vitamin E (2.8 mg/kg liveweight) was less effective than
and Zn deprivation would require either an abundance
Se (0.0625 mg/kg liveweight) and added nothing when
of dietary antagonists which impair the utilization of
given with Se. In this situation cattle of low vitamin E
the element or other factors which massively increase
status were turned onto grass of naturally high vitamin
animal needs for Mn and Zn. There is a possibility that
E concentration. The variable responses to vitamin E
'protection' of protein sources from rumen degradation
given with Se will be due largely to the wide variations
might allow phytate to escape and lower absorption of

found in the vitamin E status of housed cattle.

both elements and that fine grinding of cereals might

have a similar end result (Suttle, 2000). In the field, soil

Selenium toxicity (see p. 943)

ingestion provides a rich adventitious source of man-

ganese while access to galvanized feed and drinking

Disorders occur naturally either when pastures contain

troughs provides additional Zn, further reducing the

plant species (e.g. Astragalus) which accumulate sele-

risk of disorders. Little attention has therefore been

nium avidly from normal soils (‘Blind staggers’) or

given to reliable assessment of Mn and Zn status in the

when a combination of selenium-rich soil and high pH

animal. Serum Mn and Zn concentrations are probably

allows high levels of selenium to accumulate in normal

reasonable indices of deficiency (Table 21.1), but mar-

plant species (‘Alkali disease’) (O’Toole & Raisbeck,

ginal concentrations cannot yet be set with certainty for

1995). Accidental toxicity can be caused by errors in

the former; liver values are poor indicators of status for

adding the small amounts of selenium needed to sup-

both Mn and Zn (Underwood & Suttle, 1999). Assess-
plement feeds, exposure to multiple supplementary
ment of hypozincaemia is complicated by the fall in
sources and multiple doses (e.g. Se-supplemented
values which accompanies the acute phase of microbial
anthelmintics) and failure to scale oral drenches or par-
infections; this complication can be ruled out by dis-
enteral injections carefully to liveweight. Because sele-
carding results for samples with raised haptoglobin or
nium is well absorbed, the oral route poses almost as
fibrinogen levels or high Cu : Zn ratios (>3–4). Inter-
big a threat as the parenteral route. Selenium is a cumu-
vention with Mn and Zn supplements is rarely neces-
lative poison and tolerable daily intakes and dietary
sary and use of expensive chelated sources is unlikely
concentrations decrease as duration of exposure in-
to improve animal status or performance any more
creases. Lesions occur principally in the hoof, which
than inorganic Mn or Zn sources (Olson et al., 1999;
overgrows to the point where it may be shed, causing a
Underwood & Suttle, 1999). Toxicities of Mn or Zn

severe, debilitating lameness. The disorder can be dis-

rarely occur.

tinguished from laminitis (see p. 420) by the fact that

the lesions are epidermal rather than dermal (O'Toole

& Raisbeck, 1995). The marginal ranges for indices of

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selenium status within which toxicosis becomes a

possible diagnosis are as follows: diet, 50–75; liver,

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30–50; hoof, 25–63 and hair 63–126 mmol Se/kg DM

supplementation. British Society of Animal Production

(Underwood & Suttle, 1999; multiply by 79 to obtain

Occasional Publication No. 7, pp. 87–92.

values in mg): the corresponding range for blood is

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measures include the removal of 'Se-accumulator'

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Adult Cattle

Mastitis and Teat Conditions

Chapter 22

Anatomy, Physiology and Immunology

of the Udder

K.G. Hibbitt, N. Craven and E.H. Batten

Anatomy of the udder

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Early development of the udder

Introduction

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Early development of the udder

311

The first trace of mammary development appears in

The adult bovine mammary gland

313

bovine embryos of 1.5 cm length as two short lines in the

The physiology of lactation

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ectoderm running from the umbilicus caudally into the

Introduction

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groin. Each line is several cells thick, but intense prolif-

Mammogenesis

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eration of cells in the basal layer at focal points produces

Lactogenesis

317

an ingrowth, the mammary hillock (Fig. 22.1a). This

Milk synthesis and secretion

318

soon enlarges into an ovoid mammary bud (Fig. 22.1b)

Milk ejection

319

invested by a condensation of inductive mesenchymal

Galactopoiesis

320

cells. As the rudiment of the duct system each mammary

Manipulation of lactation

321

bud determines the site where a gland will form. By the

Immunology of the udder and teat

321

Non-specific immunity

321

seventh week of gestation in fetuses 9 cm long, four

The teat canal as a mechanical barrier

322

primary mammary buds are usually present, two on

Antimicrobial substances within the teat canal

322

each side, defining the future quarters of the udder.

Antimicrobial substances in mammary secretions

322

Extra buds occasionally form and develop into supernu-

Specific immunity: lymphocytes

323

merary teats. Active proliferation of mesenchymal cells

Immunoglobulins in mammary secretions

323

around the mammary bud lifts the epidermis into a rudi-

Phagocytic cell mobilization in the mammary gland

mentary teat by the 8-cm stage. Simultaneously, vigorous

and phagocytosis

324

proliferation of cells near the inner end changes the

mammary bud into a solid cellular column, which elon-

gates vertically into the mesenchyme (Fig. 22.1c) as the

rudiment of the duct system, the future single galac-

tophore. Meanwhile, division among the epidermal cells

Anatomy of the udder

below the original bud produces an epidermal cone at

the base of the duct primordium.

Introduction

By the 19-cm stage the growing duct primordium is

longer than the teat and slightly swollen at the inner

The mammary gland is essentially a skin gland. It is

end. Here a cavity or lumen appears and soon spreads

believed to have evolved by modification of a

proximally towards the teat apex. On reaching the epi-

sweat gland and retains two common features: devel-

dermal cone the split remains narrow as the lumen of *opment by ingrowth of ectoderm; and a bilayered*

the future teat canal. Later this will open on the teat

epithelium of inner secretory cells and outer myoep-

apex and both teat canal and superficial epidermis will

ithelial cells, which by contracting promote flow of milk

be lined by a common, thick, stratified squamous, kera-

from the peripheral alveoli into the major ducts.

tinizing epithelium.

Assuming the new function of catering for the immune

By the 35-cm stage (Fig. 22.2) the growing duct rudi-

welfare and nutrition of the neonate, the mammary

ment has differentiated into three distinct regions:

gland has evolved into a highly branched compound

structure with enormous numbers of dilated alveoli.

(1)

An upper spheroid chamber distended with fluid

This pattern allows for both synthesis and storage of

represents the future gland sinus or milk reservoir.

milk on a large scale. Yet neither function is possible

(2)

A slightly longer mid-portion forms the more *until the cow becomes pregnant, when the rudimentary*

slender teat sinus.

and inactive gland undergoes massive growth to

(3)

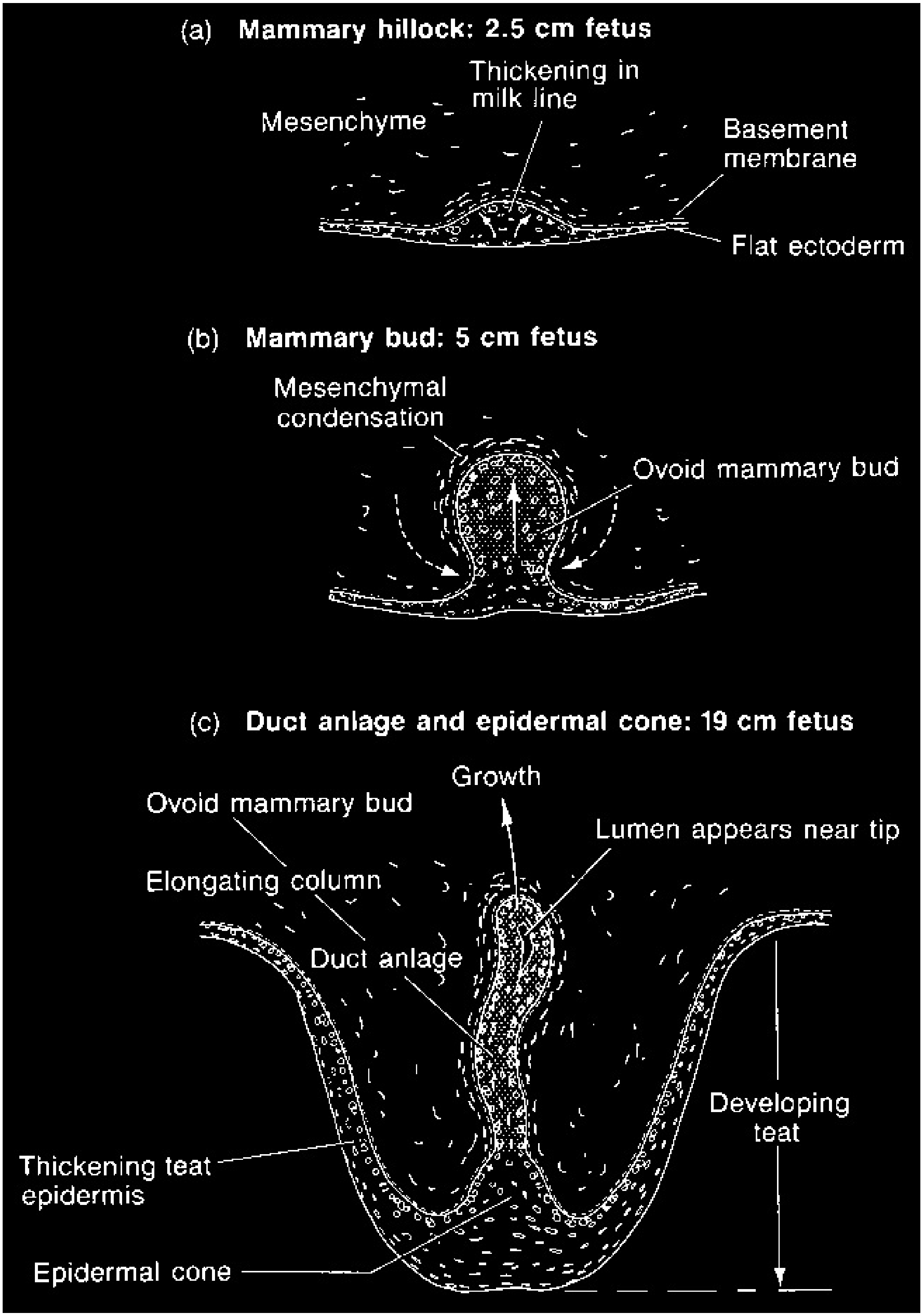
A narrow teat canal within the epidermal cone,

definitive structure and only then begins to synthesize

but still closed from the exterior by a plug of horny

secretion.

cells.


(a) Mammary hillock: 2.5 cm fetus
Thickening in milk line
Mesenchyme
Basement membrane
Flat ectoderm
(b) Mammary bud: 5 cm fetus
Mesenchymal condensation
Ovoid mammary bud
(c) Duct anlage and epidermal cone: 19 cm fetus
Growth
Ovoid mammary bud
Lumen appears near tip
Elongating column
Duct anlage
Developing teat
Thickening teat epidermis
Epidermal cone

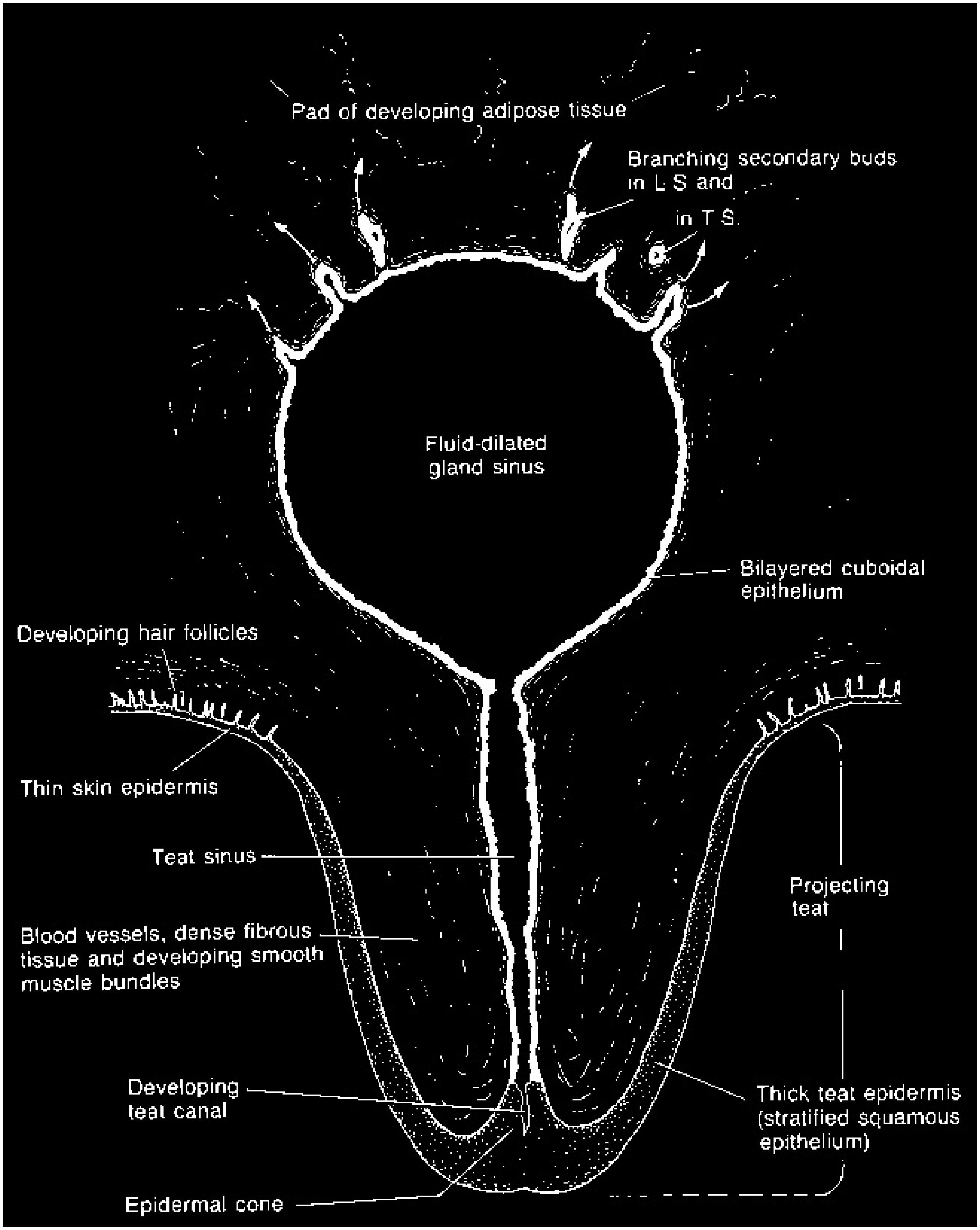

Pad of developing adipose tissue
Branching secondary buds
in L S and
in T S.
Fluid-dilated
gland sinus
Bilayered cuboidal
epithelium
Developing hair follicles
Thin skin epidermis
Teat sinus
Projecting
teat
Blood vessels, dense fibrous
tissue and developing smooth
muscle bundles
Developing
teat canal
Thick teat epidermis
(stratified squamous
epithelium)
Epidermal cone

Fig. 22.2

Diagrammatic vertical section of the teat and

mammary rudiment in a 35-cm fetus. Stratified epithelium is

shown dotted. It appears distinctly thicker in the epidermal cone, ***Fig. 22.1***

(a) Transverse section of a mammary line at the level

where the teat canal lumen is forming, and over the surface of of a localized cellular proliferation, which forms a mammary

the teat rather than above it where hairy skin is differentiating.

hillock and determines where a gland will develop. (b) Later

Derivatives of the original mammary bud are lined by double

stage showing an ovoid mammary bud with cells more basophilic

cuboidal epithelium (black) and comprise the narrow teat sinus (stippled) than in the epidermis. A condensation of mesenchy-leading from the fluid-distended gland sinus. Up to 10 short sec-mal cells surrounds the bud. Curved broken arrows indicate

ondary buds project from the dome of the sinus and later will

growth of mesenchyme, which elevates a rudimentary teat. (c)

branch to form major ducts as they grow into the overlying

Sustained proliferation (upper arrow) near the tip converts the cushion of fat. LS, longitudinal section; TS, transverse section mammary bud into a columnar vertical ingrowth, the precursor

(from Turner, 1952).

of the axial duct and storage sinuses. Meanwhile, division among the subjacent epidermal cells produces a cone, which later splits to form the lumen of the teat canal (from Turner, 1952).

stratified squamous epithelium continuous with and
identical to the glabrous epidermis of the teat. The
From the domed roof of the gland sinus several short
latter is distinctly thicker, even in the fetus, than the epi-
solid epithelial cords, the secondary sprouts, project
dermis above the teat where hair follicles differen-
dorsally into the overlying pad of differentiating
tiate from solid cellular ingrowths. The mesenchyme
adipose tissue. When canalized these secondary sprouts
around and between the rudimentary epithelial
represent the bases of the 10 or more major lactiferous
ducts differentiates to provide blood vessels, lymphat-
ducts, which in the adult deliver milk into the gland
ics, small amounts of smooth muscle and an extensive
sinus for storage. The teat sinus, gland sinus and duct
fibroelastic stroma. Tracts of denser white fibrous and
bases are lined by a bilayered cuboidal epithelium. As
elastic tissue form the suspensory ligaments and dor-
also in the terminal alveoli, which differentiate later
sally numerous lobules form in the pad of adipose
in pregnancy, the inner cells are potentially secretory,

tissue.

while the outer differentiate into myoepithelial ele-

Just before birth tertiary sprouts develop as short

ments. In contrast the lowest and narrowest part of the

side branches from the secondary ducts, but thereafter

axial lumen, forming the teat canal, is lined by thick,

the gland remains in an arrested state of development

until puberty. Some extension to the ducts occurs

Innervation

during oestrous cycles, but full structural differentiation

The principal nerve supply derives from branches of

of the mammary gland is completed only during preg-

the third and fourth lumbar nerves, which traverse the

nancy under the influence of progesterone from the

inguinal canal. Contributions from the first and second

corpus luteum and other hormones. During the first half

lumbar nerves supply the cranial, and from the perineal

of pregnancy, intense cell proliferation at the blind ends

nerves the caudal regions respectively. These are mainly

elongates the ducts, which branch repeatedly estab-

sensory nerves, but they carry from the caudal mesen-

lishing an extensive tree. At the peripheral tips of the

teric plexus sympathetic fibres, which modulate blood

large number of fine ducts thus formed narrow tubular

flow by direct action on the arterioles. Whereas the skin

prospective alveoli then differentiate. In the second half

and particularly the teats receive a rich sensory supply,

of pregnancy, protein secretion and lipid droplets slowly

nerves are sparser in the glandular parenchyma and

accumulate, dilating the alveoli into saccular chambers

chiefly, if not entirely, vasomotor: the secretory alveoli

120 mm across and filled with stored colostrum awaiting

lack a nerve supply. After the skin is anaesthetized the

release in the first sucking after birth.

deeper mammary tissue may be incised without appar-

ent sensation.

The adult bovine mammary gland

The cow's udder comprises four quarters, each an in-

dividual gland drained by a teat. The four secretory

Mammary gland: histological organization

glands are structurally separate and function independ-

Histologically classified, the lactating udder is a large,

ently, without flow of milk between them. Receiving a

lobulated, compound exocrine gland with dilated

large flow of blood and laden with stored milk, the lac-

alveoli storing milk. Each alveolus is a single or bifid

tating udder often weights 50–60 kg. Support for this

sac, slightly longer than wide and distended to an inter-

massive weight is provided by dense fibrous suspensory

nal diameter of 120–150 mm by milk (Fig. 22.3). The

ligaments that insert into the pelvis and tendons of the

lining epithelium is bilayered. The inner secretory or

abdominal wall. The ligaments spread laterally and

alveolar cells vary from tall cuboidal (8 mm) in the par-

ventrally over the udder, then coverge inwards to join

tially empty gland to stretched squamous (3 mm) in full

paired median ligaments. These form a double vertical

distension state. Synthesis and release of milk con-

partition separating glands on the left from those on

stituents (fluid, casein, lactose and lipid) is continuous,

the right. Septa of interlobular connective tissue span

until temporarily arrested by negative feedback. The *between the lateral and medial ligaments and support*

outer contractile myoepithelial cells are indistinct in

the heavy lobules of parenchyma. As the medial liga-

routine sections, but staining for alkaline phosphatase

ments contain relatively more elastin than the predom-

reveals their spider shape, with branching processes

inantly collagenous lateral ligaments the full udder

embracing the curved contour of the alveolar wall (Fig.

drops in the midline and the teats become splayed

22.4). Towards term and during lactation the large

outwards.

alveoli have a rich capillary supply and are packed

closely together into polyhedral lobules about 2 mm

across. The alveoli drain into intralobular ducts which,

Blood supply

unlike those in salivary or lacrimal glands, are indistinct,

since they resemble the alveoli in size, milk content and

During the production of 20 kg of milk each day

secretory lining. The heavy lobules are enclosed and

9000 kg of blood circulate through the udder of the cow.

bound together by thin septa of supportive connective

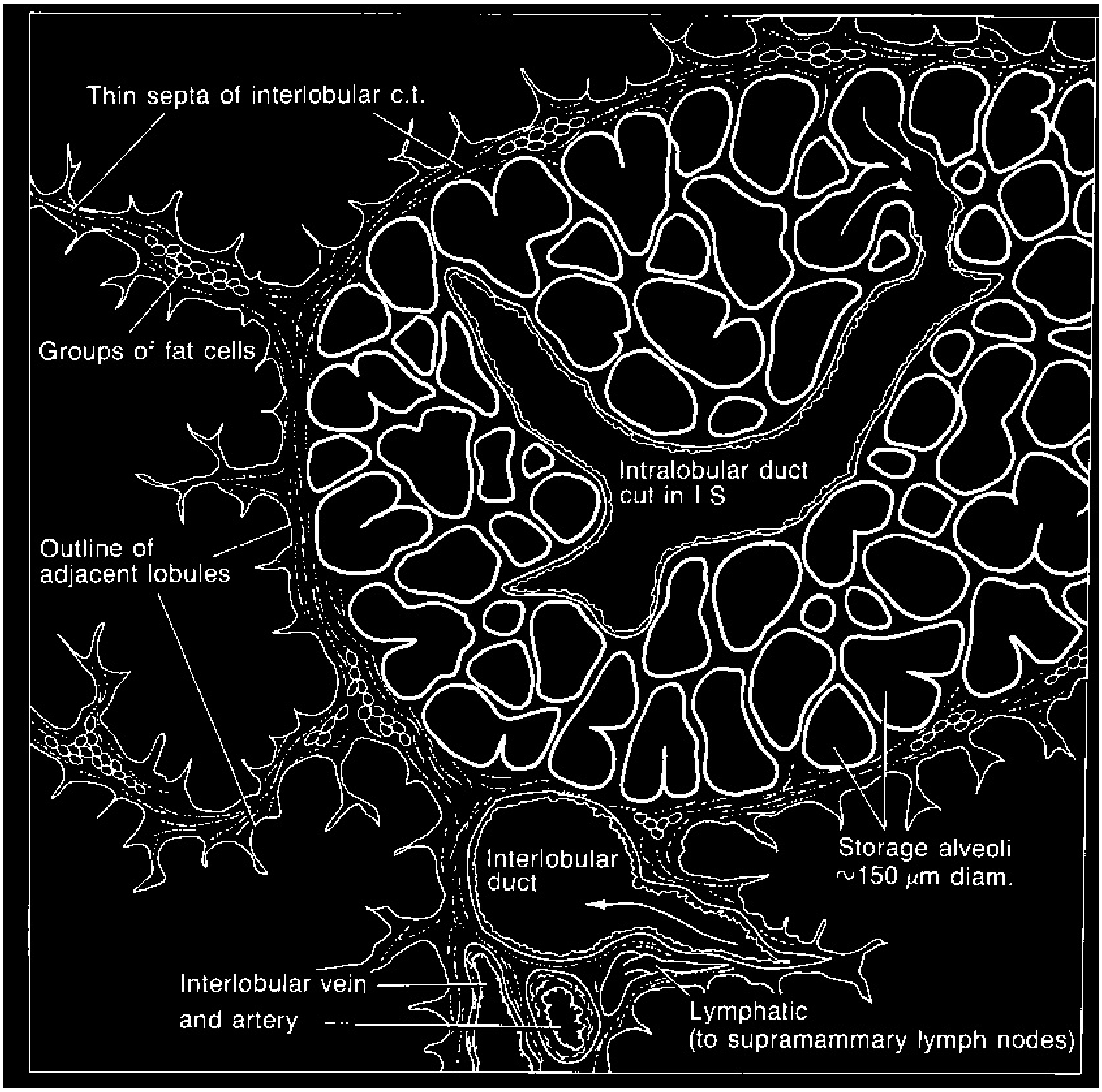
Most of this rich supply arrives through the inguinal tissue. This also carries distributing arteries and veins, canal in the external pudendal arteries derived from lymphatics and the larger interlobular ducts, which con- the external iliac trunks. The udder also receives a sub- verge and unite into major ducts opening into the gland sidiary supply, cranially through the subcutaneous cistern.

abdominal artery and caudally via the perineal artery. Numerous small veins leaving the parenchyma anasto- mose and converge around the base of the udder into

The teat

a circular vessel that is drained by three trunks: the large subcutaneous abdominal vein, which passes cra- Each teat has a single narrow teat canal, which dorsally nially and penetrates the abdominal wall near the opens into a wider teat cistern lined by bilayered xiphoid cartilage; the external pudendal vein, which epithelium. Normally, the teat canal is kept closed by departs through the inguinal canal; and the perineal sphincter action of the surrounding smooth muscle and *vein.*

elastic tissues. Thus in section the lumen is a narrow



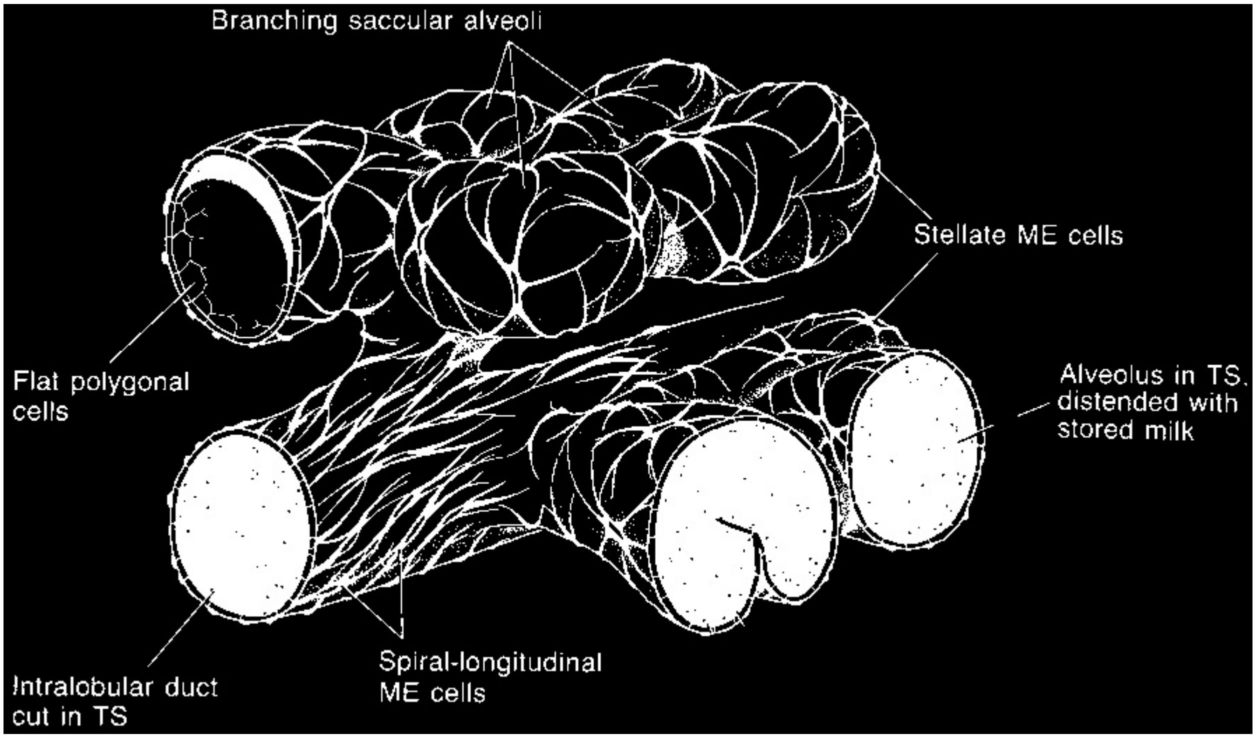


Fig. 22.3

Histological features of the lactating udder, showing large polyhedral lobules supported by thin septa of connective tissue carrying the distributing service vessels: interlobular ducts emerging (at lower right) from lobules, arteries supplying and veins draining the dense networks of perialveolar capillaries. Nearby collecting lymphatics carry a considerable flow of afferent lymph rich in lymphoeytes, neutrophils and macrophages and during infections, e.g.

mastitis, carrying antigens that induce immune responses in the supramammary lymph nodes. In each lobule the alveoli tend to be similar in size, but are generally smaller, averaging 60 mm across, with a tall cobbled epithelium in lobules that released milk at the previous lactation. When fully distended with milk, as shown, alveoli approach 150 mm in diameter and have a thin stretched lining. Smaller profiles represent alveoli slices in oblique to tangential planes. Intralobular ducts drain milk from alveoli (curved arrows), but unless fortuitously sliced in longitudinal section are almost indistinguishable from the alveoli, being comparable in width and lined by identical secretory epithelium. c.t., connective tissue; LS, longitudinal section (diagram by E.H. Batten).

Fig. 22.4

Diagram showing several branching milk-distended alveoli of the lactating udder draining into a relatively *wide intralobular duct. In the sectioned profiles fat droplets in the milk are shown white against a black background. Contraction of the network of stellate myoepithelial cells (cytoplasm black, nuclei white) expels milk from the alveoli into the intralobular ducts. In turn these become shortened and compressed by the contraction of the spirally aligned myoepithelial cells, which propel milk towards the larger interlobular ducts. ME, myoepithelial cells; TS, transverse section (after Linzell, 1961).*

stellate crevice, with the lining of thick, keratinizing,

lium of the teat canal. The teat is covered by thick, strat-

stratified squamous epithelium thrown into several

ified squamous, keratinizing epidermis with neither hair

longitudinal folds that almost meet centrally (Fig. 22.5).

follicles nor sweat and sebaceous glands. Whereas the

The teat is robustly constructed and well adapted to

thinner skin over the udder is relatively loosely *tolerate the shear stresses generated by a suckling calf*

attached and can freely be moved over the underlying

or milking machine.

glandular lobules, the teat skin is immobile and tightly

Structurally the teat wall comprises five distinct tissue

anchored to the deeper fibromuscular core. This firm

layers: superficial epidermis, then dermis, intermediate

surface is well suited to withstand mechanical shear

layer, fibrous lamina propria and internally the epithe-

forces set up by suckling, hand or machine milking. In

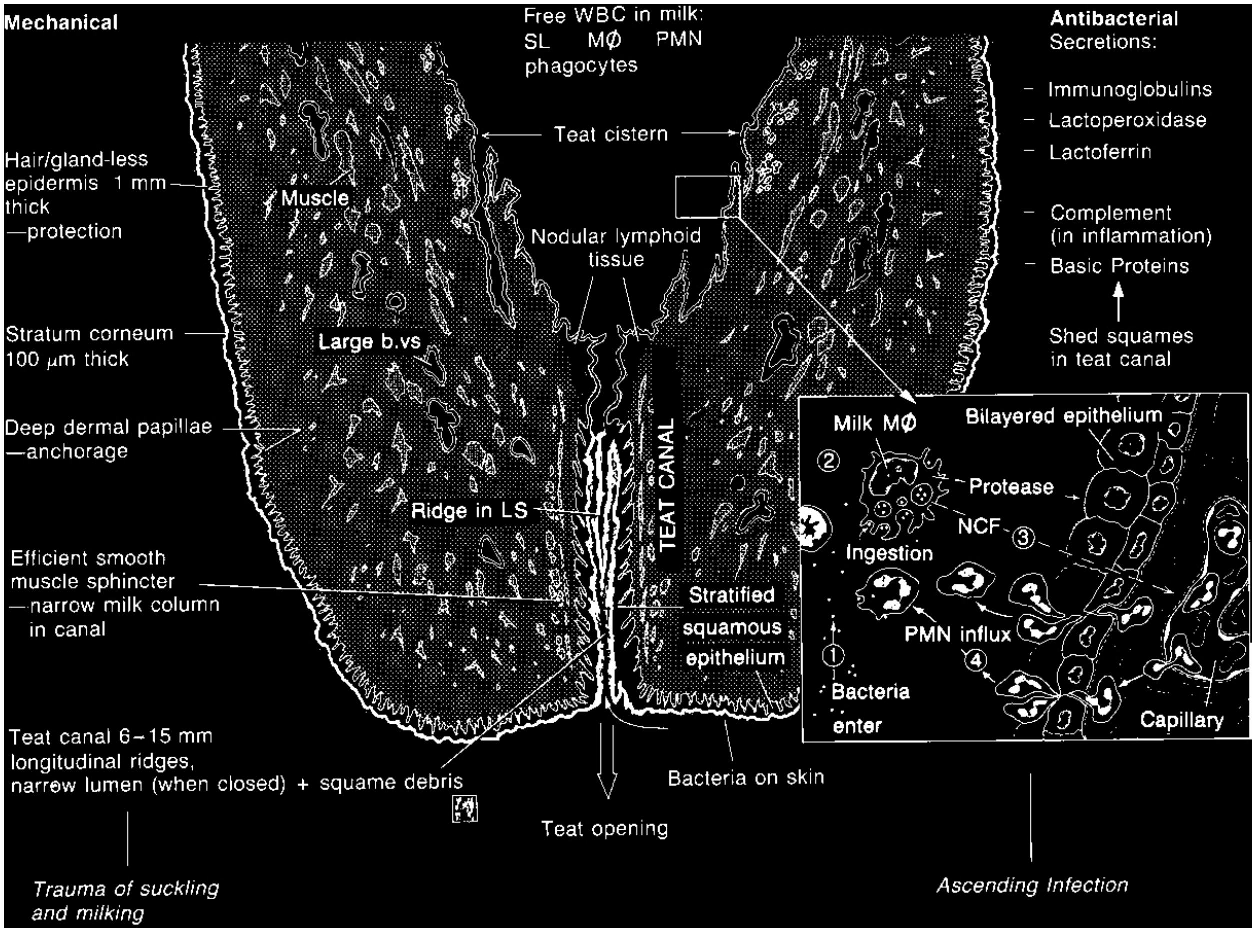


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Fig. 22.5

Diagram of a vertical section of a cow's teat, showing on the left factors that protect against mechanical trauma during suckling or milking, and on the right defences against ascending infection by bacteria from the skin surface (curved arrow) entering the teat canal.

Milk normally contains shed epithelial cells, from both alveoli and ducts, squames from the teat canal, small lymphocytes (SL), macrophages (MØ) and neutrophils (PMN). As phagocytes the last two cell types often contain small droplets of fat ingested from the milk. Subepithelial plasma cells occur near the ring of nodular lymphoid tissue that surrounds the rosette or inner end of the teat canal, where the stratified, keratinizing lining gives way to a bilayered cuboidal epithelium of the teat cistern. Insert right summarizes the early response to mastitis-forming bacteria experimentally introduced into the teat *canal. Bacteria (1) are ingested by milk macrophages (2), which release enzymes that damage and loosen the inner layer of the epithelium and neutrophil chemotactic factor (NCF), which induces (3) within 4 hours the emigration of large numbers of PMN from the subepithelial capillaries and venules. After insinuating through the cisternal epithelium the PMN (4) join with the macrophages in the ingestion and killing of bacteria. WBC, white blood cells; b.vs, blood vessels; LS, longitudinal section (diagram by E.H. Batten).*

the lactating cow the teat epidermis is remarkable for

Over this interface the area of adhesive basement

three features.

membrane is fivefold greater than in the flat underside

of hairy epidermis. This interlocking pattern binds epi-

(1)

In thickness about 1 mm, it is comparable with

dermis securely and inseparably into the dermis and

muzzle epidermis and some 12 times deeper than

dissipates shear stresses from the surface through the

epidermis of hair skin (75 mm in frozen sections,

deeper tissues. The dermal fibrous mat continues into

which preserve the 30 layers of horny squames

the dense fibromuscular layer, without the intervening

only 1 mm thick).

loose superficial fascia typical of thin skin.

(2)

The protective stratum corneum is a compact

Beneath the epidermis the dermis carries a rich cap-

layer, 100 mm deep and comprising as many over-

illary network and numerous fine bundles of sensory

lapping layers of dead horny squames.

fibres derived from lumbar nerves 2–4. Despite its

(3)

The underside is deeply papillated: epidermal

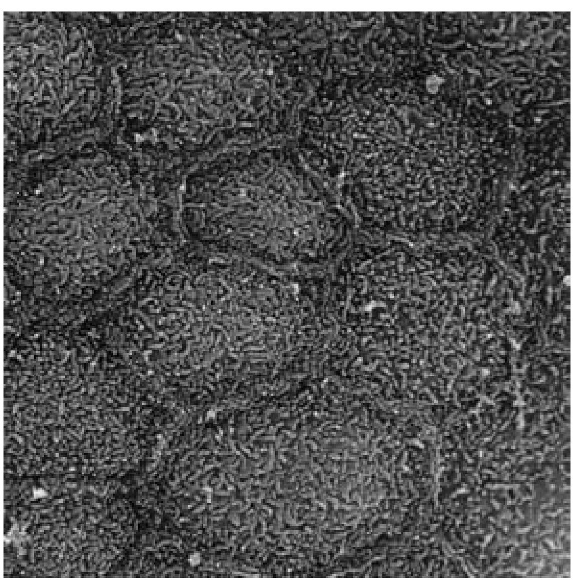
thickness as a protection against wear, teat epidermis

pegs interdigitate with narrow, deep intrusions of

is highly sensitive, since the penetrating dermal papil-

dermal connective tissue.

lae carry sensory nerves and endings to within 200 mm



or less of the surface. This rich innervation receives

around the inner opening of the teat canal (earlier

tactile stimuli and relays to the central nervous system

termed Furstenberg's rosette from the mucosal creases)

impulses that lead to the release of oxytocin from the

the surface cells are more rounded and protruding, with

pars nervosa into the blood. In turn, circulating oxy-

sparser microvilli. In this region just beyond the barrier

tocin induces contraction of myoepithelial cells, pro-

epithelium of the teat canal the lining may be a lym-

moting flow from the terminal alveoli and along the

phoepithelium important in the uptake or penetration

ducts during milk let-down. The deeper regions of

of invading antigens. Intraepithelial lymphocytes are

the dermis contain dense collagenous tissue sur-

profuse and both diffuse and nodular lymphoid tissue

rounding bundles of smooth muscle arranged mainly

are present in the lamina propria. The accumulations

longitudinally.

of plasma cells and germinal centres (Fig. 22.7) often

The third or intermediate layer contributes much of *present there provide evidence of local humoral*

the strength of the teat wall, as it contains numerous

immune responses.

bundles of smooth muscle set in coarse fibroelastic

tissue. These muscle bundles are aligned in longitudi-

nal, circular and oblique planes. Major blood vessels

are present, including distributing arteries, a complex

The physiology of lactation

plexus of anastomosing veins and numerous collecting

lymphatics, which drain to the supramammary nodes.

Introduction

The lamina propria resembles the dermis in its fib-

The secretion of milk by specialized mammary glands

roelastic components, but carries more microvessels

in the female for the nourishment of the newborn is

catering for the nutrition of the adjoining epithelium of

the essential characteristic that distinguishes mammals

the teat canal. During ascending infections with patho-

from other animals. This feature is epitomized in the

genic bacteria, increased emigration from the local

dairy cow which, as a result of intensive selection, has *venules creates leucocytic infiltrations beneath regions*

a disproportionately high output of energy in milk in

where epithelial cells have been damaged, as explained

relation to body size. Continuing improvements in milk

in Fig. 22.5.

yield and feed efficiency are the result of refinement of

Both the teat cistern and the gland cistern dorsal to

the genetic make-up of stock and improvements in

it are lined by a common bilayered cuboidal epithelium.

management and nutritional practices. This focusing of

Under scanning electron microscopy the superficial

effort on increasing milk production has prompted the

cells fit closely in hexagonal profiles densely covered

facetious comment that the modern dairy cow should

with microvilli (Fig. 22.6). In the junctional region

perhaps be regarded as an appendage of the udder

rather than vice versa! Indeed, the readjustment of

physiological processes that occurs in order to meet the

extra metabolic demands of lactation involves not just

differentiation and activation of mammary tissue but

extends to changes throughout the body. Not the least *of these is the hormonal regulation of nutrient utilization and partitioning between the mammary gland and other organs.*

Milk is a complex secretion and its production is under complex control. By understanding the underlying physiology, the relevance of correct nutritional and husbandry practices in maintaining health and optimizing performance may be better appreciated.

Mammogenesis

Mammogenesis may be defined as the growth and differentiation of the mammary gland to the stage prior to active secretion. Since milk yield is ultimately dependent on the number of secretory cells and their activity, factors that influence the former during mammogene-

Fig. 22.6

Characteristic outline of teat epithelial cells covered

sis can have lasting implications for subsequent milk

with irregular microvilli (¥9000). From Collins et al. (1986).

production.

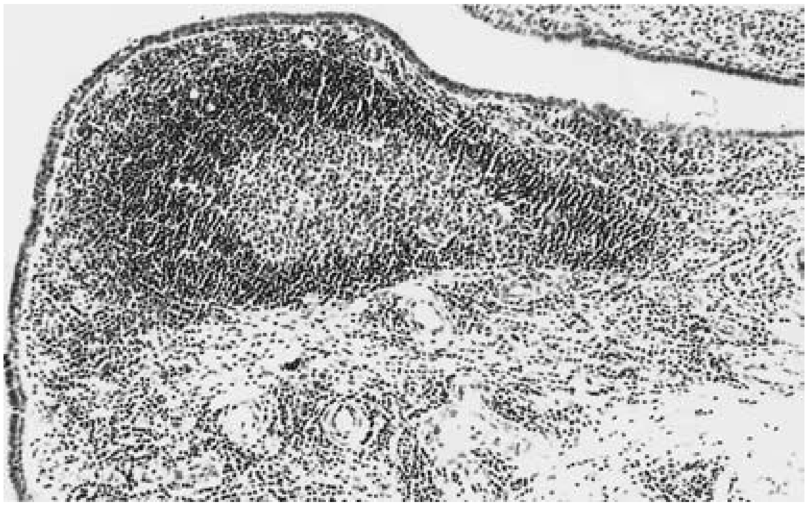


Fig. 22.7

A lymphoid nodule with germinal centre beneath the double cuboidal epithelium lining Furstenberg's rosette (HE ¥ 32). From Collins et al., 1986.

From birth to puberty mammary growth is isometric, during this critical phase of mammary development i.e. in balance with the growth rate of the whole body, may in fact be caused by a decrease in endogenous but just prior to the onset of ovarian activity mammary levels of somatotropin, as has been observed during growth becomes allometric (i.e. exceeds that of the high plane feeding. Thus the interplay between nutri-

body surface). Only during the first pregnancy does

tional management and hormonal balance during

marked branching of the duct system and lobulo-

mammogenesis may have important consequences for

alveolar development occur,

with expanding

subsequent production.

parenchyma displacing adipose tissue within the

Mammary development is partly reversed during

mammary fat pad. Lobulo-alveolar proliferation accel-

advancing lactation when gradual involution occurs.

erates as pregnancy advances with division of secretory

These effects become more pronounced during the dry

cells continuing at least until the onset of lactation. Bal-

period. A period of non-lactation between successive

anced mammary development exhibits a crucial

lactations is an essential prerequisite for maximal milk

dependence on hormonal stimulation. The hormones

production. Milk yields in the next lactation are defi-

principally implicated include steroids (oestrogens,

nitely impaired if cows are dry for less than six weeks.

progesterone and adrenal corticoids) and protein hor-

On the other hand there is little or no advantage to be

mones (prolactin, somatotropin and placental lacto-

gained in terms of an increase in subsequent lactation

gen). Thyroid hormones are possibly also involved.

yield by extending the dry period to more than eight

Many of these hormones interact synergistically to

weeks.

promote the different stages of mammogenesis. Oestro-

gens and somatotropin are responsible for ductal devel-

Lactogenesis

opment whereas progesterone and prolactin appear to

regulate lobulo-alveolar proliferation. The additional

The initiation of milk secretion (lactogenesis) in all

presence of adrenal corticoids maximizes this growth.

mammals is closely coordinated with parturition. Par-

Placental lactogen may, in some species, also stimulate

turition itself involves a complex interplay of endocrine

alveolar formation but in the cow relatively little enters

controls with marked differences between species.

the maternal circulation.

There are two general concepts as to what constitutes

During the period of allometric growth just prior

the main lactogenic trigger, the positive stimulus of

to puberty the administration of exogenous soma-

lactation-promoting hormones and the release from the

totropin to heifers appears to promote an increase in

inhibitory effects of progesterone. A peak in blood

mammary parenchyma. It is known that excess energy

prolactin levels coincides with, but is not essential for,

consumption during the period of allometric growth in

parturition. Suppression of prolactin release in cows

heifers offered a high plane of nutrition results in lower

inhibits the final stages of secretory cell differentiation

mammary secretory tissue weight and is also associated

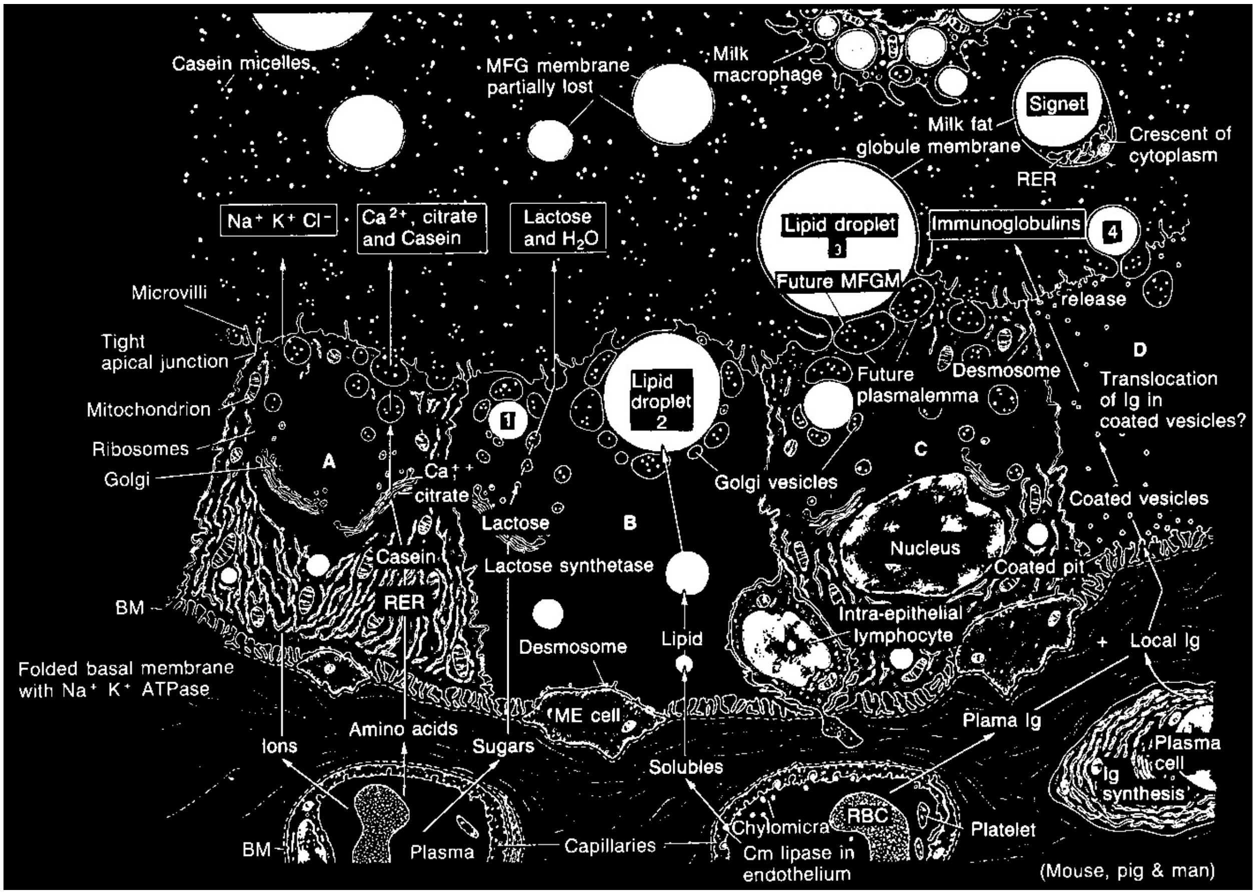
and results in reduced milk yield. Thus elevation of

with low milk production during subsequent lactation.

prolactin (together with adequate amounts of adrenal

It has been suggested that these effects of overfeeding

corticoids) and the permissive effect of progesterone



withdrawal, appear to provide the main lactogenic

milk its concentration, at about 4.8 per cent, is the most

stimulus in the cow. An additional feature may be the

consistent of any constituent due largely to its influence

removal near term of a locally produced inhibitory

in maintaining the osmolality of milk. Blood glucose is

factor (possibly prostaglandin F2a).

the main precursor of lactose but small amounts may

Lactogenesis requires the preferential supply and *also be formed from amino acids, glycerol and acetate.*

uptake of nutrients by mammary tissue. Nutrient avail-

The final enzyme-catalysed step in lactose synthesis

ability is enhanced by the disconnection of the fetal

from glucose involves an enzyme, ‘lactose synthetase’,

supply at parturition and increases in mammary blood

which is unique to mammary tissue. This is composed

flow and local selective nutrient uptake become

of two protein components and the availability of the

evident.

second component, a-lactalbumin (a milk protein),

determines the rate of synthesis of lactose, which occurs

in the Golgi membranes of secretory cells.

Milk synthesis and secretion

Milk protein synthesis involves the assembly of dif-

The constituents of milk are synthesized mainly from

ferent amino acids in a specific order along a chain. It

small molecules absorbed from the blood, specific

takes place in the ribosomes of the rough endoplasmic

carrier systems probably assisting their entry into se-

reticulum (RER in Fig. 22.8) of secretory cells, proteins *cretory cells. The blood supply provides not only*

destined for secretion being released into the lumina of

precursors for milk synthesis but also adequate

the endoplasmic reticulum. Total amino acid nitrogen

energy-yielding substrates to drive the synthetic

uptake by mammary tissue entirely accounts for the

processes.

output of nitrogen in milk protein. However, the pro-

Lactose (milk sugar) is a disaccharide composed of

portions of different amino acids absorbed by the

one molecule of glucose and one of galactose. In bovine

glands are at variance with their appearance in milk

Fig. 22.8

Mammary alveolus secretory pathways. RBC, red blood cell; Ig, immunoglobulin; RER, rough endoplasmic reticulum; BM, basement membrane; MFG, milk fat globule; MFGM, milk fat globule membrane (diagram by E.H. Batten).

protein, indicating that some are metabolized while

apocrine, since it does involve some loss of cell compo-

others are synthesized by mammary tissue. The major-

nents – the membrane investing the lipid and beneath *ity of milk proteins are synthesized locally and are*

it usually a thin veil of cytoplasm, as illustrated in Fig.

unique to milk (e.g. caseins). However, certain blood

22.8. About 5 per cent of droplets are signet-shaped,

proteins and similar proteins synthesized by plasma

with a crescentic fragment of cytoplasm containing

cells adjacent to secretory epithelia are also transferred

a few mitochondria or short profiles of rough ER.

into lacteal secretions – in large amounts in colostrum

Immune proteins, such as various immunoglobulins

(see below).

arriving via the blood or derived from local plasma

The fat content of bovine milk varies widely between

cells, are taken into the cell base by receptor-

and within breeds and is influenced by diet and envi-

mediated endocytosis into coated vesicles, translocated

ronmental factors. The majority of milk fat is in the

through the cytoplasm and released at the apical

form of triglycerides, which are assembled in or near

membrane.

the endoplasmic reticulum of secretory cells using fatty

Mature milk is characterized by a high concentration

acids and glycerol synthesized in the cytosol. Approxi-

of potassium and a relatively low sodium concentration

mately half of the fatty acids in milk are derived directly

similar to the situation within the secretory cells. Milk

from the blood – chiefly those greater than 14 carbons

is 86 per cent water. The amount of water (and hence

in length. De novo synthesis of fatty acids utilizes

milk volume) is determined largely by the rate of

volatile fatty acids arising from rumen fermentation,

lactose secretion since lactose is not reabsorbed across

fatty acid synthesis from glucose being negligible in

epithelial cell membranes and it exerts an important

ruminants. Acetate and b-hydroxybutyrate are impor-

osmotic 'draw' within the milk duct system.

tant precursors and contribute mainly to the synthesis

of shorter-chain fatty acids. The glycerol required for

Milk ejection

milk triglycerides is partly derived from hydrolysis of

blood lipids and partly by synthesis from glucose.

In the interval between milkings, milk continues to be

Esterification of fatty acids with glycerol is followed by

synthesized and secreted at a more or less constant rate

aggregation of triglycerides to form the characteristic

into the alveolar lumina and thence to the large col-

fat droplets of secretory cells.

lecting ducts and sinuses. The resistance of the teat

The mechanisms for cellular release of secretion

sphincter retains the milk in the sinuses but much of the

differ for the various components of milk. Instead of

milk remains within alveoli and will not flow out pas-

combining into a large exocrine granule typical of

sively even when the teat sphincter is patent. Forcible

zymogenic and serous cells, milk protein remains sepa-

expulsion is, therefore, required to remove this alveolar

rate as multiple small granules. These are visible only

milk from the gland. Milk ejection is under neuroen-

ultrastructurally and present a large surface area,

docrine control.

which facilitates rapid digestion. Non-immune protein,

The milk ejection reflex involves stimulation of nerve

such as casein, is delivered from the rough endoplasmic *receptors in the skin of the teat. Mechanical stimulation*

reticulum to the Golgi complex, where through the

triggers an impulse in afferent mammary nerves. This

agency of lactose synthetase, lactose is added. This

impulse is transmitted via the spinal cord and ultimately

causes the vesicles leaving the Golgi to swell osmoti-

arrives in the posterior hypothalamus. Specialized neu-

cally. As they rise through the supranuclear cytoplasm

rones in this region synthesize oxytocin (a peptide

the vesicles become tightly clustered around the sides

hormone) and a carrier protein. In addition to receiv-

of the lipid droplets, which lie free in the cytoplasm and

ing the afferent excitatory stimulus originating from

may be up to 5 mm in diameter. Subsequently, mem-

the teat, the neurones also receive facilitatory and

branes of the more superficial vesicles fuse with the

inhibitory impulses that arise in other parts of the brain.

apical plasma membrane and their content of protein,

If the net result of these impulses is stimulatory, neuro-

lactose, calcium and fluid is emptied into the alveolar

secretory granules are released into blood capillaries *lumen by conventional exocytosis. As the vesicles suc-*

from axons that terminate in the posterior pituitary.

cessively discharge, their inner walls remain over the

Thus following mechanical stimulation of the teats of

surface of the protruding lipid as the milk fat droplet

cows, oxytocin increases rapidly in the blood, reaching

membrane. Ultimately undercut by the fusion of mem-

a peak within 2 minutes.

branes between the lowest vesicles, the milk fat droplet

In mammary tissue, contractile myoepithelial cells

is liberated into the lumen without damage to the

form a basketwork surrounding the alveoli. Oxytocin in

cell and in a manner reminiscent of the shedding from

mammary blood binds with high affinity to receptor

an erythroblast of a pyknotic nucleus of comparable

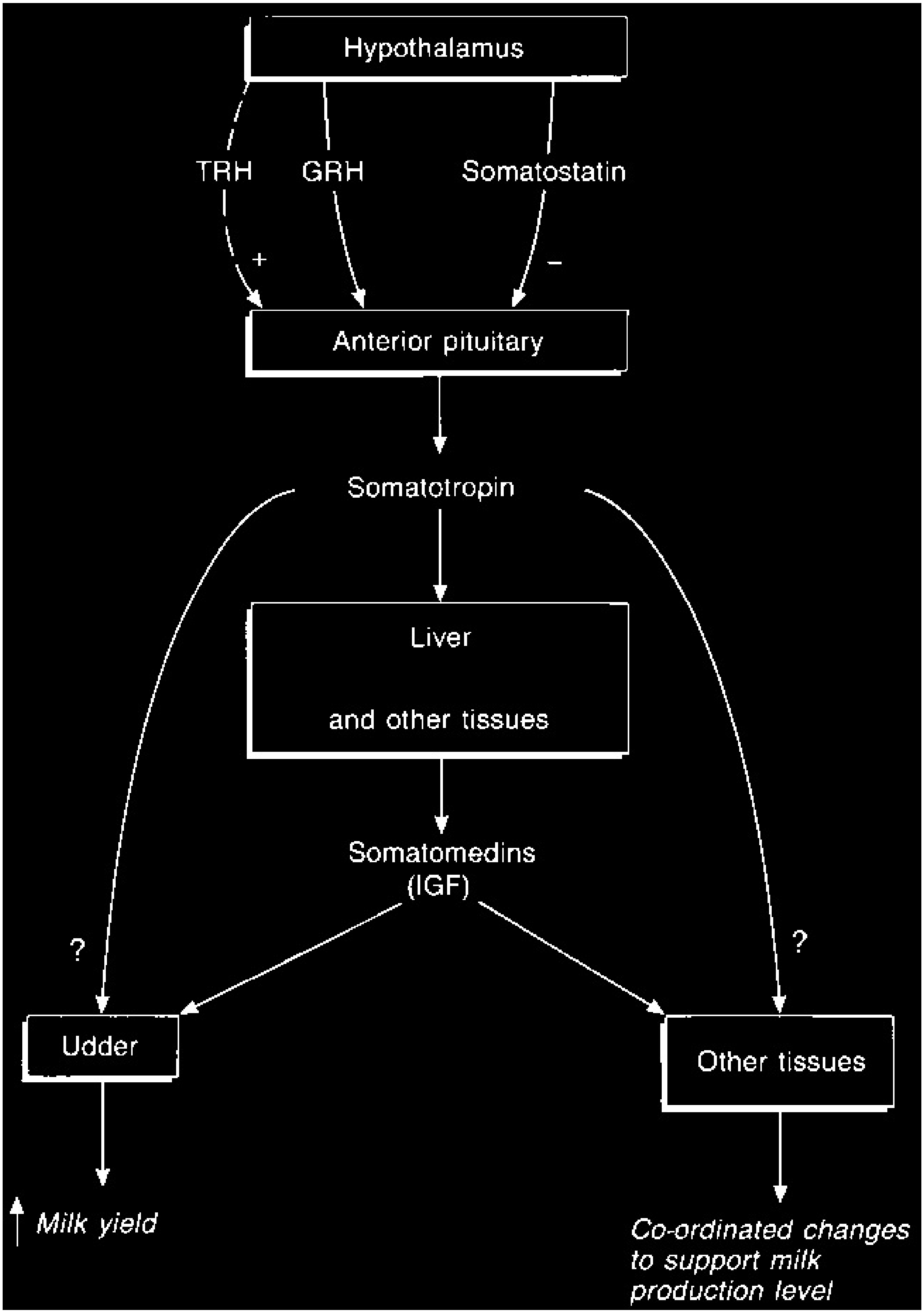
sites on myoepithelial cells (Fig. 22.4), resulting in con-

size.

traction of the cells and expulsion of the milk from the

The process of milk fat release is best termed micro-

alveoli.


Hypothalamus
TRH
GRH
Somatostatin
+
−
Anterior pituitary
Somatotropin
Liver
and other tissues
Somatomedins
(IGF)
?
?
Udder
Other tissues
↑ Milk yield
Co-ordinated changes
to support milk
production level

Although sucking and milking are the most potent and natural stimuli to elicit the milk ejection reflex, udder washing and even visual and auditory cues associated with milking routines can substitute, as the reflex becomes conditioned by experience. Stressful stimuli which involve the release of catecholamines and activity of the sympathetic nervous system can have negative influences on oxytocin release, mammary blood flow and oxytocin binding to myoepithelial cells, thereby inhibiting milk ejection. Myoepithelial cells also contract to an extent in response to direct mechanical stimuli, independently of oxytocin release. Palpation of the udder (or butting by calves) may trigger this local so-called 'tap reflex'.

Galactopoiesis

Frequent milk let-down and its removal from alveolar lumina assists in the maintenance of milk production (galactopoiesis) by preventing 'end product inhibition'. Nevertheless, the continued secretion of milk also *depends on a continued hormonal drive, which induces*

and maintains the synthetic enzyme complement of

secretory cells and also ensures an adequate supply of

substrates. The chief hormones implicated in the main-

tenance of lactation are different from those responsi-

ble for lactogenesis.

The essential role of the pituitary gland in the main-

tenance of lactation in all mammals has long been rec-

Fig. 22.9

Regulation of somatotropin release and its effects on

ognized. The roles of the various pituitary hormones

milk production. TRH, thyroid hormone releasing hormone; GRH,

have been revealed by studies on hypophysectomized

growth hormone releasing hormone; lGF = insulin-like growth

animals with hormonal supplementation or by the use

factor.

of specific antagonists. In most species (i.e. rabbits, pigs,

dogs, humans) prolactin has been identified as the key

galactopoietic hormone and suppression of prolactin

action of the specific releasing hormone. A direct effect

secretion by bromocriptine has a rapid effect in inhibit-

of increased levels of somatotropin is the induction in

ing milk secretion. In ruminants, however, suppression

the liver and other organs of the synthesis of other pep-

of prolactin secretion has only a partial (sheep) or no

tides known as somatomedins or insulin-like growth

inhibitory effect (cows, goats) on lactation. In these

factors (IGFs). IGFs in turn appear responsible for

species, somatotropin (pituitary growth hormone) pro-

mediating many of the effects attributed to soma-

vides the main galactopoietic stimulus. The dose-

totropin (Fig. 22.9).

dependent stimulation of milk yield in dairy cows that

It seems likely that somatotropin does not exert its

follows administration of somatotropin has been known

galactopoietic effect by direct stimulation of the udder.

for many years. With the advent of recombinant DNA

Rather it acts by partitioning available energy away

technology, commercial exploitation of this effect is

from body tissues and towards milk production but the

now practicable and our knowledge of the role of soma-

increased yield is not merely a passive response to an

totropin has increased as a result of the considerable
increased nutrient supply. There is also an increased
recent research on this topic.
synthetic activity per secretory cell. Administration
The release of somatotropin into circulation from the
of somatotropin also elevates cardiac output and
anterior pituitary is under the influence of various
mammary blood flow. It is considered that this increase
hypothalamic peptides that arrive in the hypophyseal
in blood flow is, at least in part, a consequence rather
portal blood supply; these include a specific soma-
than a cause of the increased activity of mammary
totropin releasing hormone and an inhibitory peptide,
tissue.
somatostatin. Thyroid hormone releasing hormone also
The metabolic effects of administering supplemen-
enhances somatotropin release and synergizes with the
tary somatotropin to dairy cows are well documented.

In early short-term studies, acute responses of hyper-
management during this period is clearly of practical

glycaemia ('diabetogenesis') and elevation of cir-
relevance in influencing mammogenesis and sub-
culating free fatty acids ('lipolysis') were reported. In
sequent yield.
contrast, there is now substantial evidence from studies
The hormonal manipulation of galactopoiesis has
where somatotropin has been administered for long
considerable commercial potential, both in a free
periods which indicates that the significant increases in
market for milk products and for efficient quota
milk yield are perfectly balanced by increased volun-
management under a milk quota system. Biotechnol-
tary feed intakes and alterations in metabolism of body
ogy-derived somatotropin in prolonged-release formu-
tissues such that steady-state concentrations of blood
lations is already available for commercial use in some
metabolites are maintained. These coordinated changes
countries (see p. 1073). Endogenous somatotropin pro-
are consistent with the role of somatotropin as a home-
duction may also be enhanced by administering releas-
orhetic control, allowing a substantial shift in the parti-

ing factors or by immunization of animals against their

tioning of nutrients to the mammary gland.

natural inhibitory peptide, somatostatin. Research into

The key role of somatotropin in milk production is

such approaches is under way.

underscored by the evidence that cows selected for high

Developments in direct genetic transfers between

genetic merit for yield show higher endogenous levels

mammalian cells make possible the insertion of extra

(basal and after stimulation) of somatotropin than

somatotropin genes which, if expressed, will enable

low yielders. Furthermore, somatotropin levels decline

cows to produce high endogenous levels of soma-

with advancing lactation in line with milk production.

totropin. The genes might be triggered by an external

Somatotropin levels are also influenced by nutritional

stimulus such as a dietary factor. Such transgenic ‘super

status independently of these genetic effects. Underfed

cows’ could be propagated rapidly using modern repro-

cows have generally higher somatotropin levels than

ductive techniques. Transgenic techniques might also be *those that are well fed, although this may be offset by*

employed to modify the characteristics of the milk con-

a lower somatotropin responsiveness of the underfed

stituents produced.

animals.

There are also opportunities for optimizing milking

Other hormones with a suggested role in galac-

procedures to exploit physiological controls of lactation

topoiesis include adrenal corticoids and thyroid

more fully. Further automation of the milking process

hormones. In most species adrenal corticoids are es-

culminating in robotic milking may permit milking

sential for lactation but there is little evidence that

several times a day and, with some sophistication,

plasma levels are a limiting factor. Thyroxine and tri-

optimal prestimulation, stripping and individual quarter

iodothyronine may have a stimulatory effect on milk

milking.

yield via effects on metabolic rate.

Immediate increases in milk yield can be obtained by

commencing three times a day milking, which indicates

Immunology of the udder and teat

that the secretory capacity of mammary cells can be

increased. Frequency of milking does not appear to

Immunity in the mammary gland may be divided into

affect endogenous somatotropin levels. The mecha-

two systems (see Chapter 29). Firstly, a non-specific

nisms are not fully understood but may involve the

system that offers a first line of defence when a

removal of inhibitors.

pathogen invades, and frequently is able to resist the

invasion of a number of potentially infectious agents.

Secondly, if the non-specific system fails, the tissues of

Manipulation of lactation

the mammary gland can adapt and produce a specific

The continuing steady increase in annual average milk

defence against each infectious agent. Frequently this

yields of dairy cows is the result of judicious genetic

system, once developed, remembers the invading

selection and improvements in management, especially

pathogen, which can be resisted by the specific defence

nutritional management. Experts expect these trends to *system on a later occasion.*

continue for some years to come. However, a growing

understanding of the physiological processes of lacta-

Non-specific immunity

tion, together with advances in biotechnology, now

make possible a variety of new ways to control and

Most infections of the mammary gland of the dairy cow

manipulate lactation.

enter through the teat canal so the teat provides a very

Administration of somatotropin to prepubertal

important barrier to infection, particularly since its ex-

heifers has been shown to increase mammary paren-

terior surface is frequently exposed to a most con-

chyma but whether this translates into increased milk

taminated environment. The defences of the mammary

yields is not yet clear. Nevertheless, optimal nutritional

gland may be considered under several headings.

The teat canal as a mechanical barrier

bind electrostatically to the mastitis pathogens which,

at the same pH, carry a negative charge. The inhibiting

The length of the teat canal has no effect on the sus-

effect of the various concentrations of these proteins

ceptibility of cows to mastitis but it has been reported

has been demonstrated in vitro on the growth of staphy-in the literature that teat ducts from quarters suscepti-

lococci and streptococci. This antimicrobial activity of

ble to infection had a larger diameter than those from

these proteins was not seen when micro-organisms

resistant quarters. Differences in teat duct patency

were incubated with whole keratin under in vitro con-

might be expected to correlate positively with ease of

ditions. The cationic protein under these conditions

milking but a relationship between milking characteris-

would have already bound to other negatively charged

tics and the incidence of intramammary infection is

molecules in the keratin. In the living animal continu-

not universally accepted. Teat ducts with a temporary

ous synthesis of these cationic proteins would overcome

patency, such that a continuous unbroken column of

such binding. Despite the antimicrobial environment

milk is maintained for some time after milking, may *within the teat canal, local colonization by Gram-*

offer a means of entry for micro-organisms and a way

positive cocci has been reported, but the growth is very

in which they may be transported upwards through the

feeble with a low percentage viability.

duct. In capillary columns of milk at 37°C, micro-

organisms are capable of rising rapidly in association

with ascending milk fat globules. Any mechanism,

Antimicrobial substances in

therefore, that is likely to break the fat-rich milk

mammary secretions

column and prevent an upward passage of bacteria is

Non-specific antimicrobial substances in mammary

likely to increase the mammary gland defences. Various

secretions also contribute to the defences of the

suggestions have been made on how the teat duct

mammary gland. Lactoferrin is an iron-chelating

closes, e.g. it may close in a spiral fashion 'wringing out'

protein which, in the presence of bicarbonate, inhibits

the last drops of milk, but as the streak canal has ridges

the growth of micro-organisms having a high iron *arranged longitudinally a spiral wringing would not be requirement. The activity of this protein is inhibited by effective. Teat canal keratin is a white wax-like material the presence of citrate. Lactoferrin is thought to exert derived from the surface cells of the stratified squamous its most protective effects in the mammary secretions epithelium and which forms a network in the lumen of during the dry period when its levels are high compared the canal, thereby trapping invading bacteria and dis- with those in full lactation. These higher concentrations rupting the milk column. Another simple mechanical of lactoferrin may also influence the defences of the dry method of preventing organisms from penetrating the gland through the modulation of leucocyte functions. teat canal is the flushing action during milking. Organ- Another antibacterial system present in milk in- isms not adhering to the teat canal wall or the keratin volves the enzyme lactoperoxidase. This enzyme, in mesh at the beginning of milking are soon flushed out. the presence of thiocyanate and hydrogen peroxide, can The higher infection rate of quarters at drying off has* *produce a short-lived highly oxidative system that is*

been attributed to the cessation of milking and the con-

bacteriostatic for Gram-positive and bacteriocidal for

sequent failure to flush out pathogens. Later in the

Gram-negative organisms. Thiocyanate is present in

dry period, there is an increase in the antimicrobial

milk, particularly in animals fed on diets containing

properties of the canal, which may restrict bacterial

legumes or brassicas. Doubt has been expressed in the

multiplication.

past over the source of hydrogen peroxide (H2O2).

Phagocytosing neutrophils are likely to be one source

of H

Antimicrobial substances

2O2 and some can be produced by the metabolism

of catalase-negative organisms such as streptococci.

within the teat canal

Another enzyme present in milk, xanthine oxidase, may

Antimicrobial substances in the teat canal may con-

also contribute by generating H2O2. Recent research

tribute to the defence of the mammary gland. The

has demonstrated that xanthine oxidase is present in
antimicrobial role of esterified and non-esterified fatty
the teat duct and secretory tissue of the bovine
acids, particularly myristic acid, palmitoleic acid and
mammary gland. The action of xanthine oxidase on its
linoleic acid has been described. These fatty acids are
substrate leads to a release of hydrogen peroxide, which
present in the teat canal keratin and it was suggested
is then available to the lactoperoxidase system.
that the unsaturated fatty acids were the most
In addition to the above, antimicrobial systems that
inhibitory.
operate locally within the teat canal are likely also to
Some proteins isolated from the teat canal also play
be operative in the milk itself and in deeper parts of the
an important role in the defence of the mammary gland.
mammary gland. The role of lysozyme in bovine body
At physiological pH they carry a positive charge and
fluids, including milk, is equivocal. Some authors doubt

its existence and, if present, the concentration would be

Differences in the functional activity of T lympho-

extremely low, but possibly increasing in mastitis. As yet

cytes in blood and those in mammary secretions are

no defensive role has been ascribed to lysozyme in

evident as differing responses to specific antigens.

bovine tissues.

Much of this work has been carried out using human

Antimicrobial cationic proteins, as found in the teat

mammary secretions and supports the view that lym-

canal, may also be present in milk during mild in-

phocytes in the mammary secretion form a distinct sub-

flammation. These proteins possess similar properties to

population. They belong to a mucosal immune system

the cationic proteins in the milk cells and are thought to

in which lymphocytes migrate from secretory surfaces

have left the cells by a process of reverse pinocytosis.

of the body, e.g. the gut, to the mammary gland, but this

Earlier methods used by many workers attempting to

is not the case in ruminants.

demonstrate haemolytic complement were too insensi-

A similar migration occurs with B cells, but in the cow *tive, but more recently a sensitive microassay revealed it has been suggested that following intestinal immu- that low levels of haemolytic complement are present nization there is a migration of antigen-stimulated IgG in milk throughout lactation, albeit usually masked by lymphoblasts and perhaps of antigen to the spleen and the anticomplement activity of the milk. Complement peripheral lymph nodes. This would be consistent with levels are highest in colostrum, in inflamed glands and the appearance of serum-derived IgG antibodies in the in late lactation. A high correlation between the levels colostrum and milk. When antigen is infused directly of serum albumin and the third component of comple- into the udder all classes of antibody, but particularly ment during an inflammatory response suggests that IgA and IgG1, are produced locally from antibody- complement components are passively transferred into forming cells in the glandular stroma and in the regional the milk but this relationship is not seen in normal milk. supramammary lymph nodes.*

Although the defensive role of the classical comple-

Tissues in the terminal inner portion of the teat

ment pathway remains in doubt it has been established

contain a high proportion of plasma cells, lymphocytes

that complement-sensitive organisms, such as some

and macrophages, which may be involved in local

strains of Escherichia coli, are killed by the alternative immunity, and antibody-containing cells have been

complement pathway. In vitro tests, however, do not

demonstrated in germinal centres in the distal

support this since serum-sensitive strains of E. coli

Furstenberg's rosettes of the teat cistern (Fig. 22.7). Of

can be grown in milk drawn from the udder. It is possi-

the plasma cells in this region 88 per cent synthesize

ble, however, that in vivo a very mild inflammatory

IgG1, 10 per cent IgM while only a few synthesize IgA.

response is needed to elevate slightly the serum-derived

The distribution of these cells does not change in rela-

complement in milk.

tion to the mammary secretory activity.

Although the homing of lymphocytes to the mam-

mary gland appears to be well established in some

Specific immunity: lymphocytes *(see*

species, not all migrate into the secretions; in the rat

Chapter 29)

mammary gland some remain in the alveolar and ductal

Lymphocytes are present in cows' milk at all stages of

epithelium. These intraepithelial lymphocytes are likely

lactation and constitute 1–2 per cent of the milk cell

to be the predominating cell types infiltrating bovine

population, which is low compared with that of human

mammary tissues and remain in association with the

milk. Lymphocytes consist of T and B cells together

epithelia after a Staphylococcus aureus infection. Infor-with a population of lymphoid cells, which do not con-

mation from other species may reveal the precise iden-

sistently carry markers of either T or B cells, the so-

tity and function of these cells. In humans a substantial

called null cells. The ratio of these cells (T : B : null) is

proportion are T cells. Intraepithelial lymphocytes may

similar to that in peripheral blood, but the percentage

form an important defence against infection at mucosal

of B cells is slightly increased in dry gland secretions.

surfaces. Currently, there is a paucity of information on

Lymphocytes in mammary secretions are functionally

the role or even existence of natural killer (NK) and

competent, responding to mitogens and antigens.

killer (K) cells in the bovine mammary gland; never-

However, some responses of the T cells from mammary

theless, there is some evidence to suggest that lympho-

secretions to mitogens are lower than those of T cells

cyte activity in bovine mammary tissues may differ from

from the systemic circulation. The precise reason for

that of other species.

this difference in responsiveness is not clear, although

it is known that mammary secretions contain soluble

Immunoglobulins in mammary secretions

immunosuppressive factors that may be responsible. In

(see p. 380)

addition, the T cell population in the mammary secre-

tion may contain a greater proportion of suppressor

Milk contains most immunoglobulin classes in differing

cells which would inhibit responses.

amounts that vary during lactation. IgG1 is present in

Table 22.1

Immunoglobulin (mg/100 ml) to the blood and

plement in milk. There have been some reports that

mammary secretions of the cow (from Lascelles, 1979).

IgA antibodies assist the binding of bacteria to fat-

globule membranes. This would hinder the mammary

IgG1

IgG2

IgA

IgM

defence system by making the bacteria more difficult to

phagocytose.

Blood serum

1400

1300

39

380

Colostral whey

1000–9000

250

470

540

Milk whey

40

6

11

9

Phagocytic cell mobilization in the

mammary gland and phagocytosis

The most effective system of udder defence against

the largest concentrations and it passes from the blood

invading pathogens is the phagocytic activity of neu-

to the milk by a process of selective transfer. During

trophils. Normally, these cells are present in milk in very

inflammation of the udder, IgG2 and other proteins are

low numbers, the predominating leucocytes in the milk

transferred from the blood. Some immunoglobulins

of healthy cows being macrophages and lymphocytes.

such as IgM and IgA are locally produced and they

Neutrophil numbers, however, rapidly increase in the

arise from cells of the lymphoblast-plasma cell series

very earliest stages of infection. The value of neu-
that are located close to glandular epithelium in various
trophils in early infection was seen when unrestricted
parts of the mammary gland. The distribution of im-
growth of bacteria occurred in the mammary gland of
munoglobulin classes in blood, colostrum and milk is
cows rendered neutropenic by the administration of
shown in Table 22.1.
anti-bovine leucocyte serum.
It will be noted from Table 22.1 that colostrum has a
Neutrophil recruitment within the mammary gland is
markedly higher concentration of IgG1 than serum. This
likely to be triggered by the presence of bacteria and
concentration is associated with the presence of specific
bacterial products, which stimulate the formation of
receptor sites for this immunoglobulin on the mem-
endogenous inflammatory mediators. These mediators
branes of bovine mammary epithelial cells. There are
lead to a margination of neutrophils in capillary vessels,
suggestions in the literature that the levels of IgA in
cause a relaxation of endothelial cell junctions and

milk and colostrum have probably been underesti-

allow a diapedesis of the neutrophils into the sur-

mated because much of the IgA is associated with milk

rounding subepithelial connective tissues. The neu-

fat globule membranes, and some IgM may also be

trophils in turn may release other inflammatory agents,

globule bound. The precise origin of IgG2 and IgA in

further accelerating the process of neutrophil mobi-

the mammary gland of the cow remains in doubt. A

lization. The identity of the inflammatory mediators,

local synthesis of IgG2 has been reported in the cow but

which has been studied by a number of workers, in-

this was not confirmed in the ewe. There appears to be

cludes prostaglandins produced by the cyclo-oxygenase

less disagreement concerning the origin of IgM and

pathway, and leukotrienes produced by lipo-oxygena-

IgA, which are thought to be largely derived from local

tion and interleukins. Prostaglandins have been meas-

synthesis in the mammary gland of the cow, but in the

ured in bovine milk and shown to increase in

ewe the synthesis of these immunoglobulins appears *concentration from 4 hours after the administration of*

to be confined to the period of mammary involution

intramammary endotoxin. Prostaglandins are synthe-

whereas in early and mid-lactation large amounts are

sized in bovine mammary tissue and may also be gen-

transferred from the blood.

erated by neutrophils.

Inflammation of the mammary gland leads to a rapid

Pathogens entering the mammary gland and causing

increase in levels of immunoglobulin and other serum

mastitis are rarely invasive. Therefore, if an antimicro-

proteins, including complement, within the first few

bial environment is to be produced in the mammary

hours. In this situation IgM and IgG1, together with

gland neutrophils must be present in the teat and lac-

serum-derived complement, control the growth of

tiferous sinus regions, the ducts and in the alveolar

serum-sensitive coliform organisms. Phagocytosis by

lumen. Milk collects in the teat and lactiferous sinus

neutrophils is more efficient if they are coated with

regions and it is thought that neutrophils are attracted *specific IgG2 antibodies.*

as far as the luminal surface of the two-cell-thick epithe-

The precise role of IgA in the mammary gland of the

lium by a concentration gradient of chemotactic factors

cow remains in doubt. Some workers believe that it may

originating from the lumen of the gland. Under these

block IgG- or IgM-mediated complement fixation, in

conditions, the neutrophils pass through the basement

which case it would have detrimental effects on the pro-

membrane and between the epithelial cells (Fig. 22.5).

tection of the mammary gland in early infection. On the

In severe staphylococcal infections the surface cells

other hand, it may activate complement, but this may

suffer toxic damage and in some cases this leads to large

not be of great importance due to the low levels of com-

areas of epithelial erosion. Infections with E. coli

frequently lead to more localized toxin-induced epithe-

opsonin for neutrophil phagocytosis of mammary gland

lial lesions and it is from these regions that the neu-

pathogens using decomplemented non-immune bovine *trophils migrate into the lumen.*

serum is IgM.

A rapid neutrophil migration is essential for the effi-

cient defence of the mammary gland following E. coli

References

invasion, but particularly if the response occurs before

the bacterial count in the milk exceeds 104/ml. Some

Collins, R.A., Parsons, K.R. & Bland, A.P. (1986) Antibody cows, however, particularly if recently calved, fail to

containing cells and specialised epithelial cells in the bovine recruit neutrophils into their milk, and this leads to an

*teat. Research in Veterinary Science, **41**, 50–5.*

unrestricted bacterial growth and severe damage within

Lascelles, A.K. (1979) The immune system of the ruminant

the mammary gland tissues. This situation may not be

mammary gland and its role in the control of mastitis.

observed clinically since there may be a complete lack

*Journal of Dairy Science, **62**, 156–60.*

of inflammatory reaction. Nevertheless, these animals

Linzell, J.L. (1961) Recent advances in the physiology of the

soon become severely ill and death may follow. Fre-

udder. In Veterinary Annual (ed. W.A. Pool). John Wright quently, cows respond *with a neutrophil recruitment*

and Sons, Bristol, 44–53.

but there is often a delay such that bacterial numbers

Turner, C.W. (1952) The Mammary Gland. In The Anatomy of

may increase to a high level. Bacteria and neutrophils

the Udder of Cattle and Domestic Animals. Lucas Brothers may then coexist in the mammary gland resulting in a

Publishers, Columbia, 176–83, 203–7.

protracted mastitis.

A rapid neutrophil response is also beneficial for

Further reading

controlling the growth of Staphylococcus aureus in

mammary tissues, thereby preventing severe disease. A

Butler, J.E. (1974) Immunoglobulins of the mammary secre-

complete elimination of these organisms, however,

tions. In Lactation: a Comprehensive Treatise, Vol. III (ed.

rarely occurs and frequently a chronic subclinical

by B.L. Larson & V.R. Smith), p. 217. Academic Press, New

disease remains in which small numbers of organisms

York.

are present in the milk, which has a permanently ele-

Cowie, A.T. (1977) Anatomy and physiology of the udder. In

vated cell count. These chronic infections may not be

Milking Machine (ed. by C.C. Thiel & F.H. Dodd), pp.

immediately obvious to the herdsman due to the very

156–78. National Institute for Research in Dairying,

low grade inflammatory response in the tissues.

Reading.

Craven, N. & Williams, M.R. (1985) Defences of the bovine

In any consideration of the immunology of the

mammary gland against infection and prospects for their

bovine mammary gland, availability of opsonins to per-

enhancement. Veterinary Immunology and Immunopathol-

mit the efficient phagocytosis of invading pathogens

*ogy, **10**, 71–127.*

must be considered. The effector mechanisms of the

Hibbitt, K.G., Cole, C.B. & Reiter, B. (1969) Antimicrobial phagocytes in the mammary gland may be activated by

*proteins isolated from the teat canal of the cow. Journal of the Fc region of one or more classes of immune globu-General Microbiology, **56**, 365–71.*

lin and/or by fragments of the complement system

Larson, B.L. (ed.) (1985) Lactation. Iowa State University bound to particles. Phagocytic cells have receptors for

Press, Ames, Iowa.

opsonins, where the opsonin is recognized and binds.

Mepham,T.B. (ed.) (1983) Biochemistry of Lactation. Elsevier, This is linked with an effector unit that triggers the cell

Amsterdam, New York.

function. Different species of animals have different

Peel, C.J. & Bauman, D.E. (1987) Somatotropin and lactation.

*Journal of Dairy Science, **70**, 474–86.*

specificities for their receptors for different classes

Poutrel, B. (1982) Susceptibility to mastitis: a review of factors of immune globulin. Non-ruminant neutrophils have

*related to the cow. Annales de Recherches Veterinaires, **13**, not been shown to bind to cytophilic antibody but*

85–99.

cytophilic IgG2 is active for ovine neutrophils and

Weber, A.F., Kitchell, R.L. & Sautter, J.H. (1955) Mammary increases the bacteriocidal activity against Staphylo-gland studies. 1. The identity and characterisation of

coccus aureus. IgG2 from immune bovine serum or milk

the smallest lobule unit in the udder of the dairy cow.

whey will opsonize E. coli. Furthermore, the major

*American Journal of Veterinary Science, **16**, 255–63.*

Chapter 23

Mastitis

P.W. Edmondson and A.J. Bramley

Introduction

326

cell counts in affected animals. This can result in a

Dynamics of herd infection

326

raised somatic herd cell count. It is essential to main-

Effects of lactation age and stage

327

tain a low cell count in order to comply with statutory

Teat canal

327

milk quality requirements, e.g. the EU requires all milk

Transmission, sources and control of udder pathogens

328

to be under 400 000 cells/ml, and to ensure that there is

Diagnosis of clinical mastitis

328

no penalty to milk price. In the UK, many farmers with

Diagnosis of subclinical mastitis

329

cell counts over 150 000/ml are penalized.

Cytological examination

329

Bacteriological examination

329

The subclinical stage may be prolonged or proceed

Biochemical and other tests

330

rapidly to clinical mastitis in which external signs of

Use of individual cow or quarter sampling in herd

disease such as swelling and hardness of the affected

investigations

330

gland(s) or clots or discoloration of the secretion are

Cattle housing and mastitis

331

present. Nevertheless, the subclinically infected quarter

Machine milking and mastitis

331

has a lowered milk yield, altered milk composition

Milking hygiene

332

and excretes the infecting organism. Subclinical masti-

Aetiology of mastitis

332

tis is a major element in the worldwide economic

Staphylococcus aureus

332

loss associated with mastitis, which exceeds £1/2 billion

Streptococcus agalactiae

333

annually.

Streptococcus dysgalactiae

333

Streptococcus uberis and other aesculin-hydrolysing

streptococci

333

Coliforms

334

Arcanobacterium (Actinomyces, Corynebacterium)

Dynamics of herd infection

pyogenes

334

Mycoplasmas

334

Figure 23.1 illustrates the dynamics of udder disease

Leptospira infection

335

within the herd. The mammary glands can be placed

Coagulase-negative staphylococci and

in one of three categories: uninfected, subclinically

Corynebacterium bovis

335

infected or clinically infected. The relative proportions

Recommendations for control of mastitis

335

of animals in these categories vary between herds.

Pathogen type also influences the dynamics. For

example, coliform infections tend to become rapidly

Introduction

clinical while Staphylococcus aureus infections often persist as subclinical infections for weeks or months.

Mastitis is the most prevalent infectious disease of

Clinical mastitis will usually be treated with antibiotic

adult dairy cattle. Several species of bacteria, fungi,

therapy and the clinical cure rates are variable and will

mycoplasmas and algae have been isolated from the

depend on the pathogen. Bacteriological cure rates vary

natural disease or have been shown to reproduce it

from 90 per cent for most coliform infections to as low

experimentally. The predominant species are listed in

as 25 per cent with Staphylococcus aureus in older cows.

Table 23.1. Furthermore, many clinical cases of mastitis

The mammary gland has a range of defence mecha-

that are due to infection are negative on bacteriologi-

nisms of which phagocytosis of invading organisms by

cal culture of the mammary gland secretion (Dairy

polymorphonuclear leucocytes is probably the most

Federation 1987a).

important. Spontaneous elimination of infection by

The inflammation, characteristic of mastitis, may be

these mechanisms will occur. The rates of spontaneous

undetectable without the use of diagnostic tests applied *elimination are low for staphylococcal infections (<20*

to the milk or secretion. This is termed subclinical

per cent), high for Escherichia coli (>70 per cent) and mastitis. Subclinical mastitis results in raised somatic

intermediate for streptococcal infections.

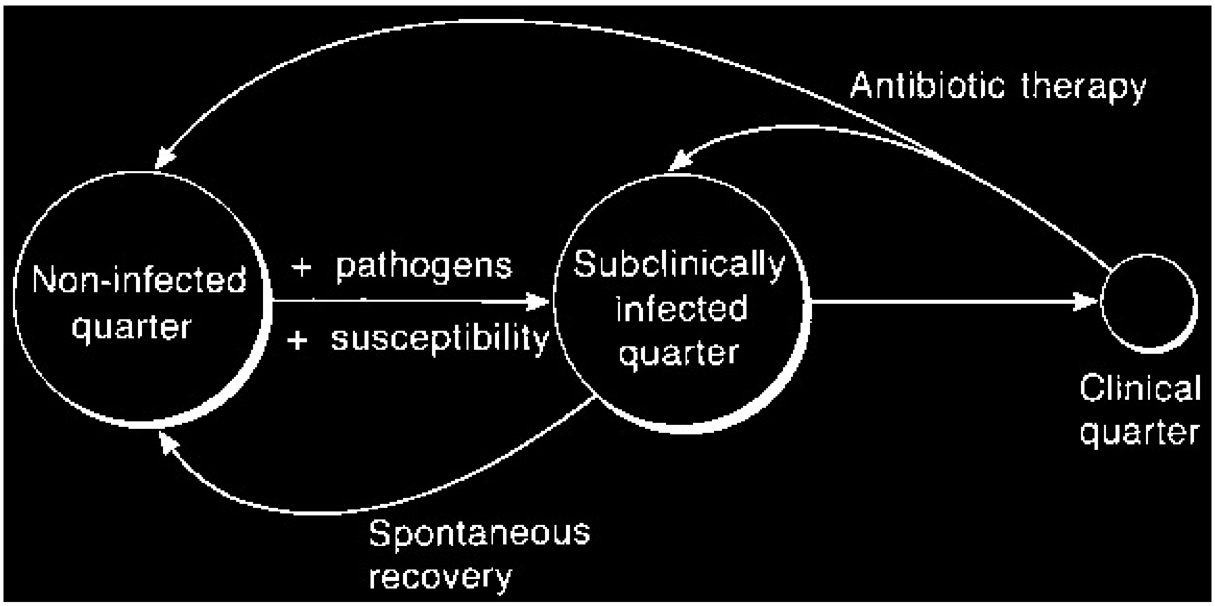


Table 23.1

Species of micro-organism frequently isolated from

Table 23.2

Distribution of clinical coliform mastitis cases with

clinical bovine mastitis.

stage of lactation when first found.

Staphylococcus aureus

Escherichia coli

Lactation stage

Number of

Percentage

Streptococcus agalactiae

Klebsiella pneumoniae

when found (weeks)

coliform cases

Streptococcus dysgalactiae

Enterobacter sp.

Streptococcus uberis

Proteus sp.

0–1a

86

20.8

Arcanobacterium

Pseudomonas aeruginosa

2–5b

94

22.9

(Actinomyces; Citrobacter

sp.

6–10

48

11.6

Corynebacterium)

11–20

58

14.1

pyogenes

21–30

51

12.4

Bacillus cereus

31–40

33

8.0

Mycoplasma bovis

Prototheca

>40

41

10.0

Mycoplasma californicum

Aspergillus sp.

Mycoplasma canadense

Fungi

a Uninfected at drying-off.

b Uninfected at calving.

ronment. The bovine teat canal varies in length from 4 to 18 mm, with a median of 12 mm. It has a heavily keratinized surface and the keratin lining is crucial to the maintenance of its barrier function (Plate 23.1). Keratin traps bacteria as they try to penetrate the teat canal. Excess keratin is removed by shear forces during the milking process and this is a normal event. If there are poor shear forces, excess keratin and bacteria are not

Fig. 23.1

Pattern of intramammary infection and clinical mas-

removed and may grow up and invade the udder. The

titis in a dairy herd.

barrier function has both physical and chemical elements. Antibacterial lipids and basic proteins have been identified within the keratin lining of the teat duct

Effects of lactation age and stage

(Williams & Mein, 1985).

The diameter of the canal and the depth of the

Udder infection may develop when the cow is lactating

keratin layer have been shown to be positively and neg-

or dry. Infection rates are highest in the early dry period

atively correlated with infection respectively. Certain

although these infections may not persist or develop

defects in machine milking operation can adversely

into clinical mastitis until the next lactation. Clinical

affect the defensive properties of the teat duct, increas-

mastitis is most common at calving and in the first three

ing mastitis incidence (see section on machine milking,

months of lactation. The incidence of clinical disease

p. 331 and Chapter 26). Any damage to the teat end or

and new infection may increase with lactation number.

teat canal is likely to increase the likelihood of new

An example for coliform mastitis incidence by stage of

infections. This will occur due to a weakened physical

lactation is shown in Table 23.2.

barrier and also the increased bacterial colonization on

The precise reasons for these effects of age and stage

the damaged teat canal.

are not known. The high incidence of mastitis around

Colonization or infection of the streak canal, partic-

calving is largely a consequence of high new infection

ularly adjacent to the teat orifice, is common with

rate in the dry period and a periparturient suppression

pathogens such as Staph. aureus or Streptococcus dys-of host defences. Increasing disease with age is proba-

galactiae. Such colonizations may persist for long

bly not due to increased intramammary susceptibility

periods in the absence of intramammary infection but

but to increasing ease of penetration of the teat duct by

are largely prevented or eliminated by postmilking teat

pathogens and accumulated previous infections.

disinfection. Other organisms are often present within

the teat duct including Corynebacterium bovis and

coagulase-negative staphylococci and there are reports

Teat canal

of the isolation of anaerobes. The environmental organ-

isms, such as coliforms and Strep. uberis rarely colonize The teat canal is the primary defence mechanism *the teat duct and this difference is important in the*

between the semisterile udder and the outside envi-

pathogenesis of infection.

Transmission, sources and control

cial effects on coliform mastitis prevention but does

of udder pathogens

reduce the rate of new dry-period infection with Strep.

uberis.

Environmental mastitis is controlled through good

Broadly, the micro-organisms causing bovine mastitis

environmental management, a good milking routine,

can be partly classified into two groups: contagious and

an efficient milking machine, vaccination against col-

environmental.

iform mastitis and premilking teat disinfection.

Contagious mastitis: The udder and teats are the reservoir of infection. Transmission occurs during the

Diagnosis of clinical mastitis

milking process or udder preparation by contaminated

hands, udder cloths and liners. Infection establishes on

The detection of clinical mastitis depends upon the

the surface of the teat and teat canal. Bacteria may then

examination of the mammary gland and its secretion.

penetrate the mammary gland. Most infections are

The affected gland may show swelling, heat, pain and/or

subclinical and result in raised cell counts. Control

hardness. The secretion may be clotted, serous or, occa-

measures include postmilking teat disinfection, dry

sionally, bloodstained (Plate 23.2a,b). In acute cases sys-

cow therapy and culling. Contagious bacteria include

temic signs of disease may also be present including

Staphylococcus aureus, coagulase negative Staphs, pyrexia, anorexia and occasionally recumbency in toxic

Streptococcus agalactiae and Strep. dysgalactiae. If a E. coli and Staph. aureus infections. Examples are herd somatic cell count is over 200 000/ml then this indi-shown of the clinical changes in Plate 23.2 (c,d).

cates that there is a problem with contagious mastitis.

Clinical disease is most commonly seen in lactating

Careful application of control measures based upon

animals, particularly in early lactation, but may develop

teat disinfection and dry-cow antibiotic therapy will

in the non-lactating gland also. Because the dry animal *eradicate Strep. agalactiae over the course of one to is rarely closely scrutinized some of these cases remain*

two years provided infected animals are not introduced

undetected until calving. 'Summer mastitis' is an acute

into the herd. Strep. agalactiae can also be eliminated disease of the non-lactating mammary gland and may

through the use of 'blitz' intramammary treatment

affect cows, heifers or young calves. Characteristically,

during lactation and these bacteria are very sensitive to

it is caused by mixed infection with Arcanobacterium

any of the penicillin antibiotics. Levels of Staph. aureus pyogenes and anaerobic bacteria, commonly Peptococ-and Strep. dysgalactiae will also fall to low levels. In cus indolicus.

some herds, poor elimination rates of staphylococcal

It is important (and in many countries statutory) that

infection by therapy will require the heavy culling

dairy cows are examined before each milking for signs

of chronically infected animals to achieve rapid

of clinical mastitis. This allows abnormal milk to be dis-

progress.

carded and the affected animal to be given therapy as

rapidly as possible, thereby reducing tissue damage and

Environmental mastitis: The environment is a reservoir giving higher cure rates,

and minimizing the risks of
of infection. Infections are transmitted onto teats
infection transfer. Discarding mastitic milk also helps to
between milkings or during udder preparation. Organ-
protect the herd somatic cell count and bactoscan
isms are forced up through the teat canal during the
or TBC. An alternative to examination of the foremilk
milking process or after milking if cows are allowed to
for abnormalities during preparation for milking is to
lie down immediately following milking. Most infec-
use in-line filters, installed in the long milk tube to
tions cause clinical mastitis. Sub-clinical infections are
screen the total milk produced. Disadvantages of this
less common with E coli, but frequently occur with
approach are that (i) not all cases of clinical mastitis
Strep uberis. Environmental mastitis is controlled by
result in the formation of clots that are trapped in the
provision of a clean environment, adequate accommo-
filters; (ii) the affected quarter(s) have to be identified
dation for cows, milking through correctly functioning
by an additional examination of the strippings milk; (iii)

machine, good udder preparation and pre-milking teat
the abnormal milk may have passed to the bulk supply
disinfection. Environmental organisms include E coli,
prior to detection, particularly in direct-to-pipeline
Streptococcus uberis (straw bedding), Klebsiella spp.
milking systems and (iv) many milkers fail to check the
(sawdust and shavings) and Bacillus spp. Although
filters. Palpation of the udder after milking also aids
there is potential for interquarter transfer at milking
clinical mastitis detection but the increase in cows
time it appears not to be the predominant infection
milked per person hour and the provision of automatic
mechanism. Postmilking teat disinfection does not
cluster removers have precluded this process in many
prevent infection. Antibiotic therapy has some benefi-
parlour operations. Some milking equipment contains

sensors to aid the detection of abnormal milk and this
using a variety of tests such as the CMT or Whiteside
is likely to become more common.
test. These tests are based upon a gelling reaction

between the nucleic acid of the cells and a reagent,
either a detergent (CMT) or sodium hydroxide (White-

Diagnosis of subclinical mastitis

side). The reactions are categorized from 0 to 4. Reac-
tions of 3 and 4 have a high probability of infection
A range of tests can be applied to milk to detect sub-
being present. The advantage of the count is that the
clinical mastitis (Schultze, 1985). These tests generally
results are available immediately, are repeatable, cheap
measure the somatic cell count or detect the presence
and give an individual quarter result. Many countries
of infecting organisms. These changes are both cytolog-
employ cell counting of herd bulk milk as an estimate
ical and biochemical. Most tests are laboratory based
of herd mastitis levels. Individual cow milk cell count
although the California Mastitis Test (CMT) and elec-
services are available in many countries as an intermit-
trical conductivity measurements can be used at the
tent or regular service (e.g. National Milk Records in
cow side. Tests can be placed in three categories and
England and Wales and the Dairy Herd Improvement

applied either alone or in combination.

Association in the USA). A consistently high bulk milk

cell count is characteristic of a high level of subclinical

infection in the herd. Herds with counts <200 000

***Cytological examination** (see p. 323;*

cells/ml generally have little economic loss associated

Chapter 25)

with subclinical disease. Such herds may however still

Milk from a healthy, uninfected bovine mammary

suffer significant costs due to a high incidence of clini-

gland contains somatic cells comprising macrophages,

cal mastitis, associated with short-duration infections

neutrophils and lymphocytes. The number of these is

such as coliforms.

usually <50 000 cells/ml milk. When mastitis is present

the cell count increases, primarily as a consequence of

Bacteriological examination

neutrophil infiltration. Subclinically infected quarters

have cell counts in excess of 200 00 cells/ml but, because

The secretion from a normal mammary gland is sterile

of the dynamic nature of the disease, this value can vary *although it may acquire bacteria from a colonized teat*

considerably and will sometimes fall below this thresh-

duct during collection. Therefore, the detection of a

old (Table 23.3).

pathogen in an aseptically collected milk sample is

During clinical episodes the cell count will be ele-

indicative of infection. The number of organisms

vated, counts in excess of 5 000 000 cells/ml being com-

excreted per millilitre of milk from an infected gland

monplace. The cell count is detectable by a microscopic

fluctuates widely; hence the recovery of even low

count or by electronic means. Detailed descriptions of

numbers of bacteria can be regarded as meaningful if

the methods employed are available (Dairy Federation,

the sample has been taken with adequate care and is

1984). An indirect estimate of cell counts can be made

not contaminated. Bacteriological examinations have

the advantage of being positive or negative, whereas

most other tests require the imposition of a threshold

Table 23.3

Variation in the cell count of a quarter infected with *value which varies between animals and herds (Dairy*

Staph. aureus compared to an uninfected quarter in a Friesian Federation, 1987a).

heifer.

A suitable sample is required for bacteriological

examination obtained by an aseptic technique. Samples

Milking No.

Somatic cell count C ¥ 1000 cells/ml

can be frozen (-20°C) prior to examination although

this reduces pathogen numbers (particularly Gram-

Control quarter

Infected quarter

negatives) and precludes cytological and some bio-

1

13

424

chemical examinations. The bacteria most commonly

2

80

3943

causing bovine mastitis will grow aerobically on blood

3

64

528

agar. The more unusual causes of mastitis such as anaer-

4

84

4046

obes, Mycoplasma spp. and Leptospira spp. require 5

44

797

more specialized techniques not appropriate to the

6

91

4540

practice laboratory. The inclusion of 0.1 per cent aes-

7

107

1471

culin in the blood agar is useful in the differentiation of

8

61

1446

Strep. uberis from other streptococci. A volume of milk 9

64

528

is spread over the surface of the agar plate, which

10

84

4046

should be incubated for 24–48 hours at 37°C. An

330 • Chapter 23

advantage of a bacteriological examination is that the

Table 23.4

Changes in milk composition associated with mas-

causative organism can be identified and provides a

titis (examples of ‘typical values’).

possibility for antimicrobial sensitivity testing. Some

organisms such as Staph. aureus may be shed intermit-

Somatic cells (1000)

tently and in small numbers in milk. With these infec-

Normal

Mastitic

tions, a negative result may indicate that the bacteria

*< **20 to 75***

100 to** > **10 000

have not been isolated due to a dilution effect. Repeat

sampling may be necessary in order to confirm a nega-

Sodium (mg/100 ml)

57

104

tive result. Disadvantages include cost, complexity and

Chloride (mg/100 ml)

100

200

time delay. Detailed methods for the collection and bac-

Potassium (mg/100 ml)

170

150

teriological examination of milk samples for infection

Conductivity (mM NaCl)

<50

>56

are available (Dairy Federation, 1981).

Lactose (mg/ml)

48

44

Catalase

increased 20-fold

NAG

increased 6-fold

Biochemical and other tests

BSA (mg/ml)

0.25

>0.6

Inflammation of the mammary gland leads to a variety

NAG, N-acetyl glucosaminidase; BSA, bovine serum albumin.

of compositional changes in milk either because of local

effects or because of an increase of serum components

entering the milk. Some of these changes can be used

to screen for subclinical mastitis.

tests and their application the reader is referred to

Significant changes in ionic composition occur with

Schultze (1985).

both Na+ and Cl- levels increasing, K+ decreasing. The *individual ions can be directly determined but more*

commonly the net change in ionic composition is used,

Use of individual cow or quarter

measured as an increase in electrical conductivity. Both

sampling in herd investigations

laboratory and farm-based meters exist and milking

equipment incorporating electrodes to measure milk

Mastitis control relies upon the application of effective

conductivity during milking is marketed in some coun-

control measures to the herd rather than identification

tries. There are a variety of other factors which may

or special treatment of individual animals. It is essen-

affect electrical conductivity such as oestrus. The major-

tial to identify the organisms responsible for the

ity of electrical conductivity meters work on pooled

problem and in high cell count herds, the proportion of

milk from all quarters and are unlikely to be very accu-

cows infected. This requires bacteriology and individual

rate due to a dilution effect. However, as for the major-

cow cell count data which will help to identify the

ity of the milk parameters, the conductivity values of *nature of a herd problem or individual animals for seg-*

normal and infected quarters overlap and conductivity

regation or culling. As payment of milk on the basis of

values vary between herds. These facts make the appli-

cell count becomes more common then the emphasis

cation of threshold values for diagnosis inaccurate. A

placed on these systems tends to increase.

fall in lactose concentration is also usual and has been

If the aetiology of clinical mastitis is to be determined

employed diagnostically but has poor discrimination.

then a microbiological analysis is needed. Such

Enzymatic changes also occur. Some of the enzyme

analyses provide information on the patterns of the

changes are associated with the increase in cell count

disease within a herd since there will be delay between

(e.g. catalase), others with secretory cell damage (e.g.

sampling and diagnosis during which therapy will

part of N-acetylglucosaminidase (NAG) increase) or

usually have begun. Often a broad-spectrum antibiotic

with increased permeability (plasmin). The use of NAG

is employed to cover the range of possibilities.

has been widely tested and found to correlate well with

However, the pattern of disease may be helpful in

cell count and infection and offers promise as a cow-

determining the attention needed to remedy the herd

side test.

problem. The isolation of Strep. agalactiae indicates As serum components leak into the mastitic gland

either that teat disinfection and dry-cow therapy are

they can be employed as indicators of inflammation.

not being employed effectively or infected animals have

The most studied have been antitrypsin and bovine

been introduced. A pattern of high herd cell count,

serum albumin (BSA). Automated methods for the

repeated clinical cases and the frequent isolation of

detection of antitrypsin have been developed and the

Staph. aureus would be typical of poor elimination of test is more sensitive than BSA. Table 23.4 summarizes

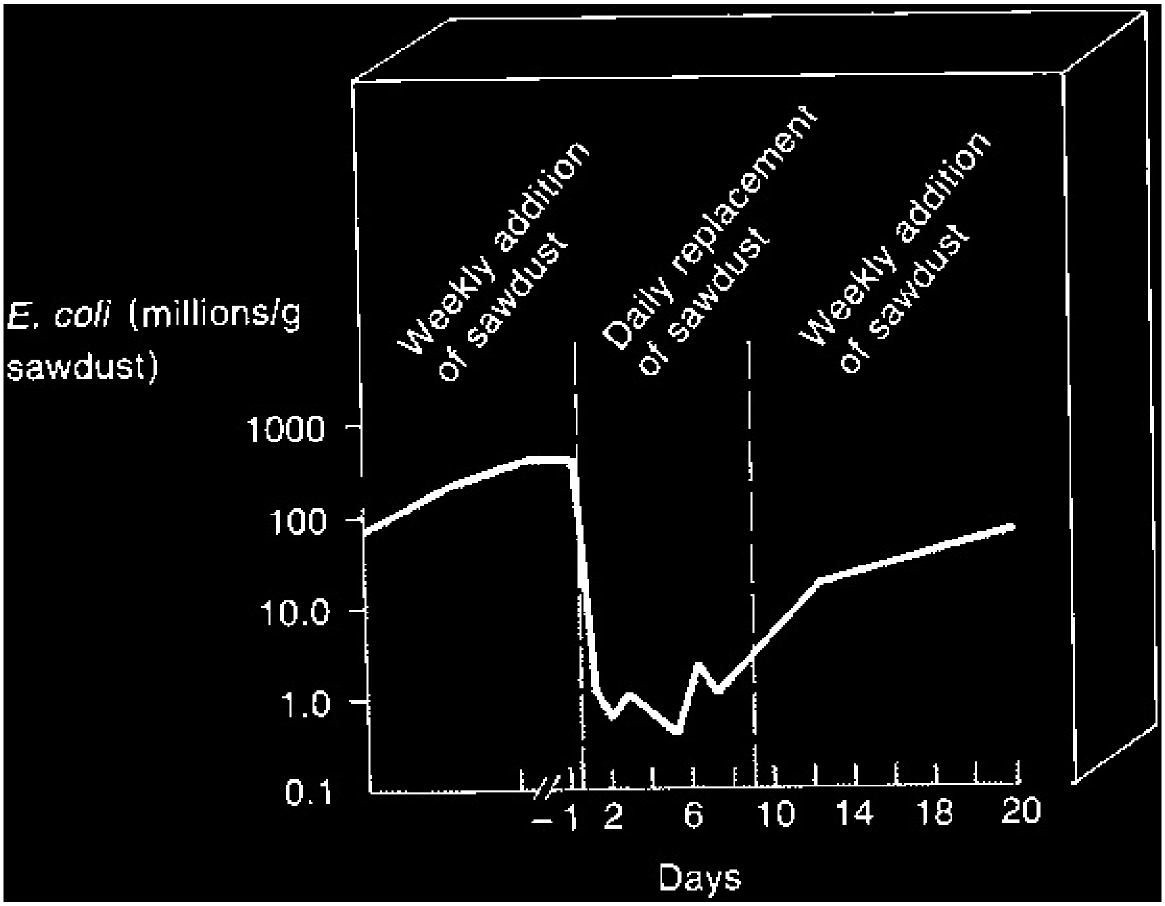
infection by lactation or dry-period therapy. This might

the major compositional changes in milk due to udder

prompt the use of bacteriological analysis of samples

infection and inflammation. For more detail of these

taken after treatment or at drying-off and calving.



Individual cow cell count or other diagnostic tests can be used to identify chronically infected animals for culling, treatment during lactation and other options, although such animals might be identifiable via an examination of clinical records. In the majority of herds the records are unfortunately inadequate for such a purpose. When using individual cow cell counts or other indirect tests the variation in inflammation should be remembered. Confident diagnosis on a single sample *is not possible. The changes in these measures due to lactation stage and yield are also relevant. Cell counts in colostrum and in dry-cow secretion are naturally elevated and diagnostically unreliable. As lactation declines and yield falls cell count and electrical conductivity increase slightly. Milk composition and cell count may remain permanently altered or elevated in*

Fig. 23.2

Controlling coliform contamination of sawdust in

glands that have suffered severe secretory tissue

cubicles by daily removal and replacement.

damage, even if the causative organism has been successfully eliminated (see Chapter 25).

and replacement of bedding offers the soundest basis for reducing it (Fig. 23.2; Dodd et al., 1984). Herds which house cattle in straw yards should clean these out

Cattle housing and mastitis

every 4 to 6 weeks. In mild weather, this may need to be reduced to every 3 to 4 weeks.

In many countries climatic conditions require that

The climate within cattle housing is also important *cattle are housed for at least part of the year with con-*

since high humidity favours the survival and multipli-

sequences for mastitis. In some countries cows are

cation of micro-organisms. It has been found that cattle

housed all year round. Housing increases the risk of

litter generally appearing to be clean and dry can

mastitis because the confinement of the animals and the

harbour high numbers of micro-organisms and this can

multiplication of micro-organisms in various litters

pose significant problems when giving advice over herd

elevate teat challenge, and consequently mastitis.

mastitis problems.

Prominent among these bacteria are the coliforms,

The design and size of yards and cubicles influence

Strep. uberis and faecal streptococci.

cow cleanliness and thus milk bacteriological quality and

The relationship between housing and mastitis is

mastitis. Cubicles that are too short will leave cows'

most clearly established for coliform mastitis. Coliform

udders lying in the alleyway while those which are too

bacteria have been shown to multiply readily in organic *long will lead to dunging on the cubicle surface itself.*

litters, particularly sawdust, reaching counts of >100

Obviously, the correct dimensions vary depending upon

million/g. These numbers often exceed those found in

breed and age. There should be 5 to 10 per cent more

bovine faeces and impose a risk of infection. Sawdust

cubicles than cows. In loose housing, a lying area of 6 m2

has been shown to act as a source of Klebsiella pneu-

for a Holstein cow should be allowed. Overcrowding in

moniae, particularly if not kiln-dried, and can lead to loose yards will lead to an increase in environmental

severe mastitis problems. Some outbreaks have been

infections, in particular Strep. uberis. Improper place-controlled by switching from sawdust to sand, which

ment of access gates and water troughs in yards will lead

tends to harbour lower numbers of coliforms and

to excessively dirty lying areas. Use of dung channels and

reduces the risk of disease.

grids can increase the incidence of damaged teats, etc.

Streptococcus uberis colonizes the bovine gut and is

These and other ways in which the environment influ-

excreted in faeces and consequently contaminates *ences mastitis are the subject of a review by the Inter-*

cattle litter. In straw, multiplication of the organism

national Dairy Federation (Dairy Federation, 1987b).

often occurs leading to high levels of teat challenge and

Detailed information on suitable dimensions and

increased infection rates (Bramley, 1982). Since Strep.

designs for cattle housing are also available (pp. 42–4).

uberis is particularly infectious for the non-lactating or parturient udder this can be a particular problem if

dry-cow or calving accommodation is not adequately

Machine milking and mastitis

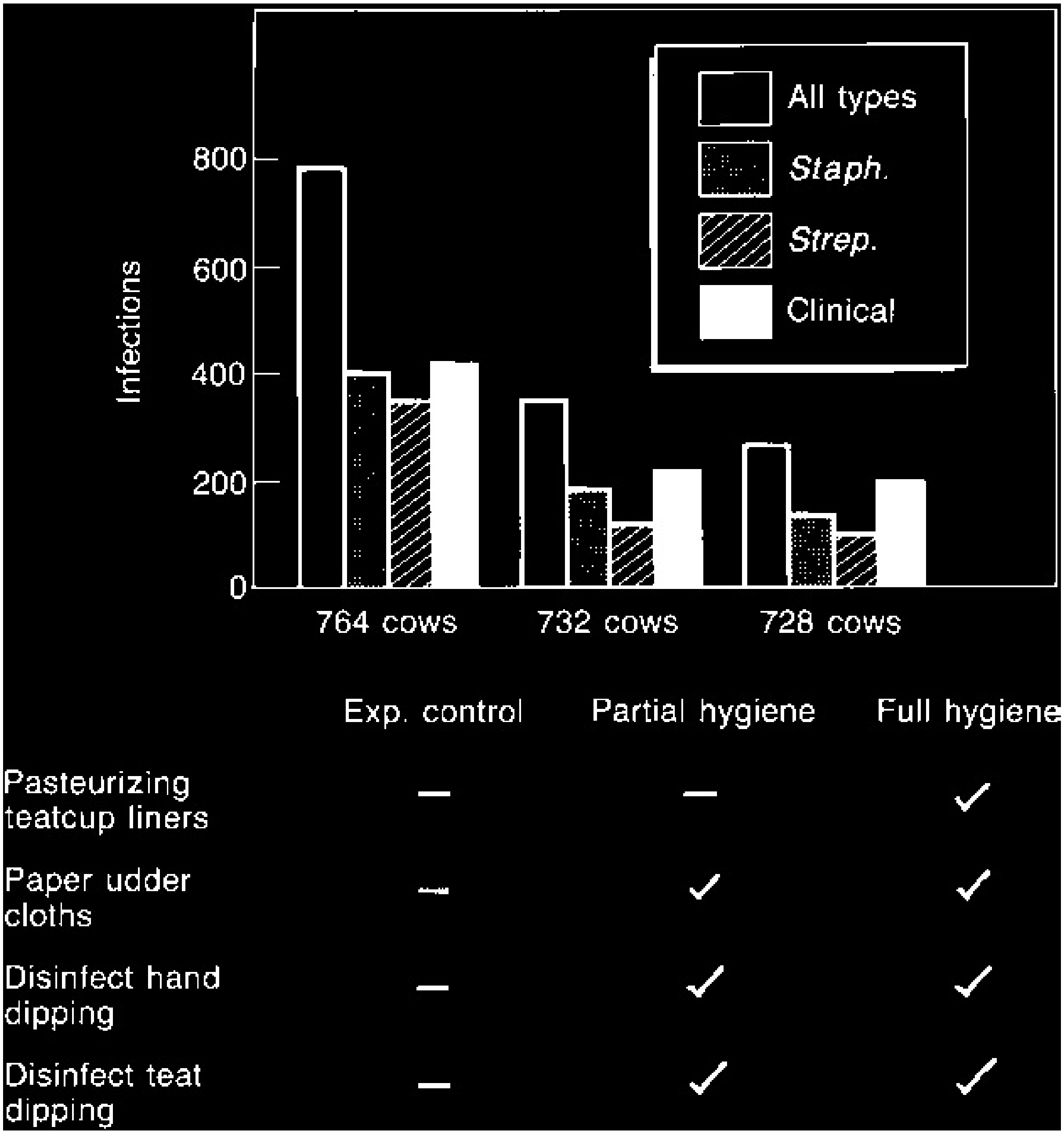
cleaned and bedded.

Since multiplication in the litter is a crucial factor in

There is unequivocal evidence that the events occurring

increasing challenge to the teat surface, regular removal

at milking time influence the incidence of mastitis.



These influences may be via the hygiene practised at

milking time or because of effects of the milking

machine per se. For details on how the milking machine can affect mastitis see Chapter 26.

Milking hygiene

The milk secreted by infected cows contains varying numbers of pathogenic micro-organisms. Herd milking provides opportunities for the transmission of these bacteria between udder quarters and cows via the milking machine itself, the milker's hands or cloths. Various techniques can be employed at milking time to reduce transmission including:

(1)

Using disinfected water for teat washing.

(2)

Employing individual paper towels or cloths for teat drying.

(3)

Wearing clean rubber gloves.

(4)

Applying a suitable disinfectant to the teat surface after milking.

(5)

Disinfecting or heat treating the cluster between

Fig. 23.3

Effect of milking time hygiene on new udder infections.

milking cows.

(6)

Premilking teat disinfection.

In addition, segregation of infected animals from the

toscan or TBC. There will be an increased risk of liner

healthy herd can be used although it is impractical in

slip and impact forces at the teat end. These factors will

most herds and requires the use of individual cow cell

increase the risk of environmental infections. Ideally,

counts or a similar test. The use of measures such as

a suitable concentration of an approved disinfectant

those described above can reduce infection rates by

(usually iodine or chlorine) should be included in the

about 50 per cent, effects being greatest against Staph.

wash water supply. There have been examples of col-

aureus, Strep. agalactiae and Strep. dysgalactiae (Fig.

iform and Pseudomonas mastitis problems associated

23.3). The measures are less effective against coliforms

with contaminated udder wash water supplies. These

and Strep. uberis infection because of their wider dis-are unlikely where mains *water is in use although*

tribution in the environment.

uncovered water storage tanks may become contami-

Of the various measures to prevent new intramam-

nated with faeces or carcasses of small animals and

mary infections among milking cows, postmilking teat

provide a source of infection. For a review of this

disinfection is the most valuable. Various disinfectants

subject see Bramley & McKinnon (1990)

are used, most commonly iodophors, chlorhexidine and

hypochlorite. Emollients are often added to promote

good skin condition and rapid healing of lesions. These

Aetiology of mastitis

disinfectants will rapidly destroy bacteria reaching the

teat surface during milking and will prevent coloniza-

It has already been stated that mastitis is a consequence

tion of the teat duct and the infection of teat lesions.

of intramammary infection with one or more microor-

The speed of kill of the postmilking teat disinfectant is

ganisms of many different genera. The following section

not important provided that it is effective. This is con-

provides information on the most common or impor-

trary to the action of premilking disinfectants which

tant of the different mammary infections.

must have a rapid speed of kill. This fast action is

required to avoid slowing down the milking procedure.

Staphylococcus aureus *(see p. 385)*

The importance of premilking hygiene in the pro-

duction of milk of high bacteriological quality should

In many countries this organism is the predominant

be emphasized. Data show that effective washing of the

cause of subclinical mastitis but is also isolated from

teat followed by drying significantly reduces the bacte-

clinical disease. The important sources of infection are

rial content of bulk milk. Washing without drying will

infected udders, teat ducts or teat lesions. Extramam-

result in bacteria being put in suspension. This solution

mary sources do exist, notably the vagina and tonsils

will be sucked in with the milk and increase the bac-

but do not appear important in the pathogenesis of

infection. It has proved possible to eradicate Staph.

tion. The duration of infection is shorter than staphylo-

aureus mastitis from individual herds by the application cocci, primarily because of the better response to

of hygiene at milking time and culling. The major limi-

therapy. More rapid elimination of Strep. agalactiae can tation to more effective control of Staph. aureus masti-be achieved by diagnosis and treatment of infected

tis remains its poor response to antibiotic therapy. Cure

animals although the economic basis for this is doubt-

rates are highest in first and second lactation animals.

ful (for therapy see p. 396).

In older cows cure rates during lactation may be as low

as 25 per cent following intramammary antibiotic

Streptococcus dysgalactiae (see p. 387)

therapy. Even following the use of dry-cow therapy,

This organism has both contagious and environmental

cure rates of 33 per cent in older cows are common.

characteristics often associated with poor teat skin con-

There are a variety of reasons for this of which antibi-

dition. Very good control of lactation infections can be

otic resistance plays only a minor role. In vitro demon-achieved by teat disinfection indicating that cow-to-cow

stration of sensitivity of Staph. aureus to an antibiotic transfer is an important *mechanism. However, infection*

is no guarantee of therapeutic success. The ability of the

in the dry period and in heifers is commonplace, par-

bacteria to survive inside polymorphonucleocytes

ticularly among animals not protected by dry-cow

(PMN), macrophages and epithelial cells, protected

therapy. Outbreaks of clinical mastitis with Strep.

from antibiotic action, may significantly contribute to

dysgalactiae frequently follow a breakdown in herd

their therapy resistance. Additionally, the pathological

hygiene practices or increases in teat lesions. The inci-

changes, notably granulomata and fibrosis, induced in

dence of teat lesions can increase rapidly following fail-

chronic Staph. aureus infections renders chronically

ures in pulsation, excessive milking vacuum or adverse

infected cows essentially incurable. Most commonly

housing or climatic conditions. In such outbreaks the

Staph. aureus udder infection is chronic, acute mastitis machine should be given a thorough examination by an

being less common than with other bacteria. However,

expert and the teats closely inspected for damage. The *acute gangrenous Staph. aureus infections can arise in inclusion of a high level of a suitable emollient in the*

which uncontrolled growth of the organism occurs elab-

teat dip can promote rapid healing of lesions and

orating large quantities of a toxin. Such infections are

prevent their colonization.

probably not due to strains of increased virulence but

Clinical Strep. dysgalactiae mastitis can be acute with rather to a failure by the host to mount an effective

anorexia and pyrexia in addition to the local signs.

defence. Workers in California showed the critical role

However, the response to therapy is usually rapid and

of the PMN in this defence since subclinically infected

elimination rates with penicillins are similarly high to

cows, made neutropenic, rapidly developed acute gan-

Strep. agalactiae. Streptococcus dysgalactiae is also grenous Staph. aureus mastitis (Schalm et al., 1976) (for encountered in mixed culture with other organisms,

therapy see p. 396)

notably A. pyogenes and P. indolicus in summer mastitis. The bacteria can be isolated from bovine tonsils and

Streptococcus agalactiae *(see p. 387)*

the bovine genital tract and these sources, allied to the *ability of the organism to infect and colonize lesions,*

The sources of Strep. agalactiae are similar to those of may be important in the pathogenesis of dry-period

Staph. aureus, namely the teats and udder. Conse-

infections.

quently, milking time hygiene is an effective means of

preventing infection during lactation. The presence of

Streptococcus uberis and other

Strep. agalactiae in a herd suggests that there are defects

***aesculin-hydrolysing streptococci** (see*

in milking hygiene, postmilking teat disinfection and/or

p. 387)

dry-cow therapy. Since Strep. agalactiae is easily eliminated by intramammary antibiotic therapy it is elimi-

These organisms are an important cause of bovine mas-

nated from herds employing teat disinfection and

titis and, in some herds, are the major cause of clinical

dry-cow therapy effectively and routinely. It is possible

disease. Several species can be involved but the pre-

to include the elimination of infection by blitz therapy

dominant one (>70 per cent) is Strep. uberis. Others during lactation. Blitz therapy is where all quarters of *include Strep. bovis, Strep. faecalis and Strep. faecium.*

infected cows are treated with intramammary anti-

Infection with these organisms is not controlled by

biotics. The whole herd may be treated or selected

postmilking teat disinfection although dry-cow antibi-

animals. The level of infection relates well to individual

otic therapy reduces infection rates by about 50 per

cow cell counts. It is important to confirm that Strep.

cent. However, Strep. uberis remains the commonest

agalactiae is the cause of the high cell count before cause of infection in the dry period and susceptibility to

embarking on blitz therapy. The disease may exist as an

infection has been shown to increase following drying-

acute clinical mastitis or persist as a subclinical infec-

off (Marshall et al., 1986). In untreated dry cows the

highest rates of infection occur in the initial two weeks

high-yielding cows, this is not effective, possibly because

following drying-off while in animals given antibiotic

the rate of neutrophil diapedesis is poor. Recent

therapy at drying-off infection tends to be peripartur-i-

research indicates that low levels of selenium may be

ent. The high infection rates in the dry period and the

implicated in the process (Erskine et al., 1989) (for

failure of post milking teat disinfection to control

therapy see p. 396)

disease emphasize the independence of milking and

transmission. The bacteria are widely disseminated on

Arcanobacterium (Actinomyces,

the cow, are present in low numbers in cattle faeces and

***Corynebacterium) pyogenes** (see Chapter 24)*

multiply in bedding materials, particularly straw, to

reach high levels. Deep straw yards for housing dry

This bacterium is often involved in suppurative condi-

cows seem to pose a particular risk factor. Not all

tions in cattle, including mastitis. It is most frequently

strains are virulent for the lactating gland and a capsu-

encountered as one of the mixture of pathogens respon-

lar layer is often elaborated conferring resistance to

sible for 'summer mastitis' in northern Europe. This

phagocytosis. Susceptibility of the lactating gland to

acute clinical disease of the non-lactating animal has *infection may be influenced by the lactoperoxidase*

been described in the section on diagnosis (see p. 328).

system, which in turn can be affected by feeding regi-

Arcanobacterium pyogenes may also infect the lactating mens altering milk thiocyanate levels. Although Strep.

cow, or infection may be carried over from the dry

uberis is sensitive in vitro to a range of antibiotics, period. Infection in the lactating cow is usually associ-intramammary therapy often is ineffective and chronic

ated with teat damage.

infections are common in some herds. Under these

The epidemiology of summer mastitis has been much

circumstances cow-to-cow transmission may become

studied because of its epidemic and destructive nature.

more important (for therapy see p. 396)

The disease has been associated with fly-borne trans-

mission and the sheep head fly Hydrotaea irritans has been shown able to carry A. pyogenes, Strep. dysgalac-

***Coliforms** (see pp. 383, 1016)*

tiae and the anaerobic peptococci responsible for the The coliform species most commonly implicated in

disease. With one exception transmission experiments

mastitis are E. coli, although other species including with infected flies have proved unsuccessful but data do

Enterobacter aerogenes, Pseudomonas aeruginosa, Ent.

reveal that the use of insecticides or barriers (surgical

oxytoca, K. pneumoniae and Citrobacter spp. are also tape, Stockholm tar, etc.) reduces the disease incidence.

encountered. Infection is more common among housed

The most effective control measure is the prophylactic

cows and occurs particularly around calving. Subclini-

use of dry-cow therapy. A review of the epidemiology,

cal infection is less common and peracute mastitis

transmission and pathogenesis has been published

occurs frequently around calving. About 50 per cent

(Thomas et al., 1987).

of these peracute infections die. Treatment involves

frequent stripping to remove endotoxin, antibiotic,

***Mycoplasmas** (see p. 385)*

supportive therapy including hypertonic saline and

oxytocin, etc. The use of anti-inflammatory drugs, par-

In recent years several species of Mycoplasma have

ticularly non-steroidal anti-inflammatories, may also be

been recognized as important causes of bovine mastitis.

helpful. Many new E. coli infections occur during the The most common cause is Mycoplasma bovis but other *dry period but do not manifest as a clinical disease until*

species implicated include M. bovigenitalium, M.

into the next lactation. The incidence of coliform mas-

canadense, M. californicum and M. alkalescens.

titis has increased despite the adoption of the National

Characteristically, infection with Mycoplasma spp.

Institute for Research in Dairying (NIRD) five-point

leads to a mastitis, often involving multiple quarters,

plan, improved milking machines and better hygiene.

which is refractory to antibiotic treatment. The secre-

Transmission between cows is unimportant in patho-

tion may remain normal at the onset although a granu-

genesis and the use of postmilking teat disinfection and

lar or flaky deposit is recognized on standing. In the

dry-cow therapy does not reduce infection rates. The

later stages a purulent or thick secretion, without offen-

primary source of infection is bovine faeces although

sive smell is often reported. Swelling and firmness is

secondary multiplication of the bacteria to high

common but after a few days the mammary gland may

numbers in cattle litter is often a factor (see section on *reduce in size. Milk secretion is severely reduced.*

cattle housing and mastitis, p. 331).

Swelling of the supramammary lymph nodes occurs and

Infection with coliform bacteria leads to a rapid

there may be pyrexia, transient malaise and arthritis.

development of inflammation and often the influx of

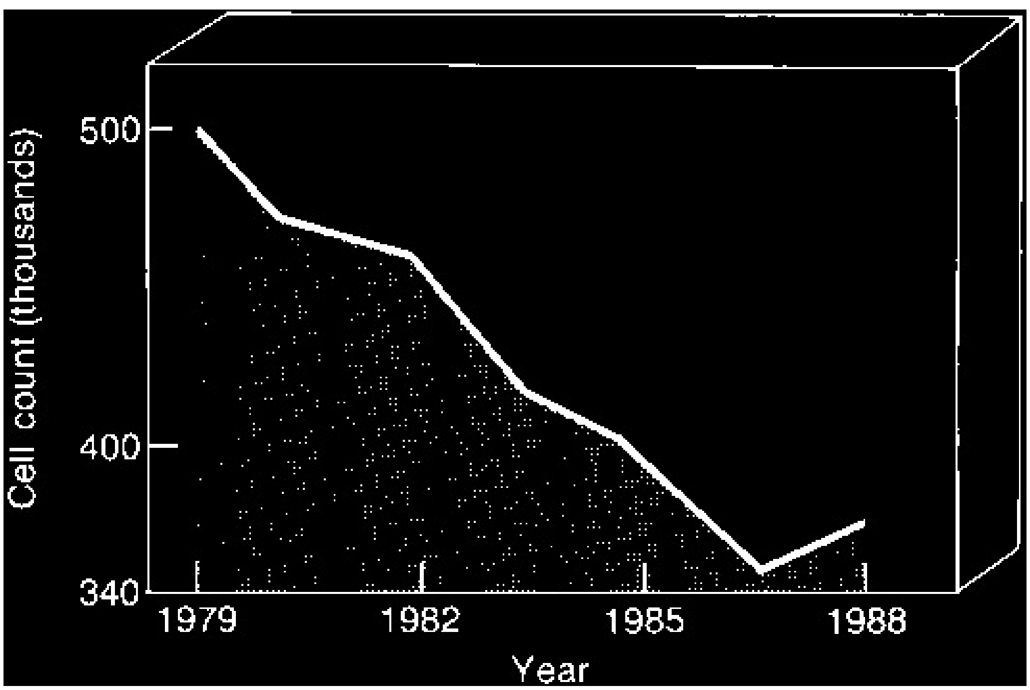
Secretion of mycoplasmas in the milk frequently lasts

neutrophils eliminates the infection (Hill et al., 1979).

for two months and often for longer. Intermittent shed-

In some animals, particularly in early lactation and in

ding is common. Clearly, such cows constitute an infec-



tion risk for the herd. Most reports relate to infection

These include Staph. epidermidis, Staph. simulans and in lactating cows but outbreaks among dry cows,

Staph. xylosus. Most of these organisms are of low vir-notably with M. californicum, do occur (Jasper, 1982).

ulence although some isolations are associated with

Diagnosis requires the application of specific micro-

clinical disease. These organisms generally produce a

biological and serological tests in specialist veterinary

slight elevation of somatic cell count, which may

diagnostic laboratories. These involve culture from milk

increase resistance to infection with major pathogens.

onto selective media and a range of serological tests,

Similarly, Corynebacterium bovis is not usually asso-

often growth inhibition, to identify the species.

ciated with clinical disease and primarily colonizes the

The most severe problems with this disease have

distal teat duct. It is associated with suboptimal teat dis-

occurred in large dairy herds in California and Florida.

infection. It is rapidly eliminated by antibiotic therapy

It should be considered as highly infectious and

and its spread is prevented by effective teat disinfec-

affected animals either removed or isolated within the

tion. In the absence of such measures it may be isolated

herd. Examination of bulk milk has proved a useful

from >70 per cent of aseptically collected milk samples.

screening method for affected herds. If a herd is sus-

Growth on blood agar may require incubation for 48

pected of having a problem with Mycoplasma mastitis

hours, preferably at 30°C, and stimulation by fatty acids

then specialist advice should be rapidly sought. For

supplied either by the milk or by additions to the media

further information the reader is referred to detailed

such as Tween 80.

reviews (Boughton, 1979; Jasper, 1982) (for therapy see

p. 396)

Recommendations for control

Leptospira infection *(see also p. 737)*

of mastitis

Increasing concern has arisen over leptospirosis for a

variety of reasons. Most importantly organisms of the

In the USA, UK and Australasia and many other parts

hebdomadis subgroup are pathogenic for man. The *of the world there is a recommended mastitis control*

organism most involved is Leptospira hardjo and this is scheme based upon the '5-point plan'. The elements in

responsible for the so-called 'milk drop syndrome' and

the scheme are as follows:

is also associated with abortion in affected herds. The

(1)

Apply an approved teat disinfectant after every

characteristic milk drop appears initially as a mastitis,

milking.

usually with the milk yield of all four quarters falling to

(2)

Treat clinical cases of mastitis.

zero within 24 hours. Pyrexia is common and the udder

(3)

Infuse long-acting antibiotic into all quarters at

secretion is thickened or clotted and occasionally

drying-off.

bloody. The udder remains flaccid and the condition

(4)

An annual milking machine test and appropriate *usually resolves within seven to fourteen days. Cases*

maintenance.

may be restricted to a few animals or up to 50 per cent

(5)

Cull cows showing repeated cases of clinical

of animals may become affected over a period of two

mastitis.

to three months (Jackson & Bramley, 1983). Antibiotic

therapy with tetracyclines or streptomycin may aid the

These measures were the basis of controlled experi-

resolution of the clinical phase and reduce carriers

mentation in many countries and have been widely

although immunity develops following infection. A

employed since the 1970s. Teat disinfection is to reduce

vaccine is available, which requires an annual booster

to ensure adequate protection. Infection of human

beings may occur via infected urine droplets, particu-

larly in herringbone milking parlours and leads to a

febrile illness characterized by severe headaches. In a

proportion of cases this can lead to complications

including meningitis and encephalitis.

Coagulase-negative staphylococci and

Corynebacterium bovis

The incidence of coagulase-negative staphylococci has

increased as herd cell counts have decreased. Several

species of coagulase-negative staphylococci are com-

Fig. 23.4

Reduction in bulk milk cell count in England and

monly isolated from aseptically collected milk samples.

Wales between 1979 and 1988.

rates of new infection during lactation; the dry-cow

Erskine, R.J., Eberhart, R.J., Grasso, P.J. & Scholz, R.W. (1989) therapy serves to eliminate a high proportion of sub-Induction of Escherichia coli mastitis in cows fed selenium-clinical infections present at the end of lactation and to

deficient or selenium-supplemented diets.

American

prevent many new dry-period infections. Treatment of

Journal of Veterinary Research, ***50****, 2093–2100.*

clinical mastitis assists the elimination of infection and

Hill, A.W., Shears, A.L. & Hibbitt, K. (1979) The pathogenesis of experimental Escherichia coli mastitis in newly in the resolution of clinical signs of disease and culling

calved dairy cows. Research in Veterinary Science, ***26****, is employed to remove* *chronically affected cows.*

97–101.

Finally, the milking machine maintenance is intended to

Jackson, E.R. & Bramley, A.J. (1983) Coliform mastitis.

ensure efficient milking and prevent machine-induced

Veterinary Record (In Practice Suppl., Vol. 5, No. 4) 135–

infections as described above (therapy for mastitis is

46.

dealt with in Chapter 30).

Jasper, D.E. (1982) The role of Mycoplasma in bovine masti-A review of the progress in mastitis control follow-

tis. Journal of the American Veterinary Medical Association, ing the introduction of these techniques has been

***181**, 158–73.*

described by Booth (1988). This shows major reduc-

Marshall, V.M.E., Cole, W.M. & Bramley. A.J. (1986) Influence tions in clinical mastitis incidence and in the reduction

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***53**, 507–14.*

improving mammary gland immunity is described in

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tions for maintaining low infection rates. Proceedings Inter-

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196.

titis. International Dairy Federation Bulletin 217, Brussels.

Bramley, A.J. & Dodd, F.H. (1984) Mastitis control–progress Dodd, F.H., Higgs, T.M. & Bramley, A.J. (1984) Cubicle man-and prospects. Journal of Dairy

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tis. Lea & Febiger, Philadelphia, pp. 1–360.

Chapter 24

Summer Mastitis

J.E. Hillerton

Aetiology

337

Japan, and parts of the USA, as well as being reported

Epidemiology

337

from Greece, Australia, Zimbabwe and Brazil. The inci-

Transmission

337

dence varies greatly from country to country, as does

Pathogenesis

338

the severity of the infection. Most cases in North

Clinical disease

338

America are recognized when heifers calve with a non-

Treatment

339

functional quarter from which the causative bacteria

Control

339

can be recovered, whilst in Japan systemic illness is

more common.

The incidence of summer mastitis varies locally. It is

Summer mastitis is an acute or peracute multifactorial

greater in the more intensive dairy areas but does not

infection of the non-lactating bovine mammary gland

just depend on the density of cattle. It is only in the

although clinical signs are often not obvious until par-

dairy industry that the importance of the disease is well

turition. The disease is reported from all four continents

recognized. It can be prevalent in beef cattle but loss of

where dairy cattle are herded. It is, however, most

function of one-quarter is not so important economi-

prevalent in northern Europe and particularly common

cally in the suckler cow. The Dutch, Germans and *in some European cattle such as the Friesian/Holstein*

Danes believe that summer mastitis is associated

breeds, being rare in the Zebu.

with sandy soils, but these correlate well with the best

grassland. The high humus content, open structure and

free-draining of sandy soils are particularly suitable

***Aetiology** (see p. 334)*

for foraging, soil-dwelling insect larvae.

The disease is most common in summer and early

Bateriological analysis of summer mastitis secretion

autumn but can also occur in spring. As well as season,

shows a complex infection. Usually Arcanobacterium

it is particularly associated with calving pattern. In

(Corynebacterium) pyogenes predominates and the Ireland, with many spring-calving herds, the spring inci-severity of the infection is related to toxin production

dence is marked. The black and white dairy breeds

from synergistic growth with other bacteria that are

seem most susceptible and in the absence of preventive

anaerobic (see p. 338). Peptococcus indolicus is the

measures the incidence is greatest in older cows.

most common anaerobe but Bacteriodes melaninogeni-

cus and Fusobacterium necrophorum are often found.

An undescribed microaerophilic coccus, the Stuart–

Transmission

Schwann coccus is also found. It rarely grows in pure

subculture. Streptococcus dysgalactiae is also common It is a long and widely held belief that flies are involved

and believed by some to be a primary agent predispos-

in the transmission of summer mastitis.

ing to A. pyogenes infection.

The peak incidence of disease in northern Europe

Much of the reported variation in bacterial culture,

occurs in July, August and September when flies are

and especially isolation of anaerobes, probably results

most abundant on cattle. The sheep headfly (or planta-

from suboptimal collection and transport of samples,

tion fly), Hydrotaea irritans, is the most frequent visitor allowing anaerobes to die out.

to the teats of dry cows and heifers. Flies around pas-

tured cattle have been shown to carry the summer mas-

titis pathogens even in the absence of disease in

Epidemiology

the herd. The disease prevalence is coincident with the *geographical distribution of the fly in most of Europe.*

Summer mastitis is considered to be epidemiologically

Control of flies on cattle reduces the incidence of

most severe in northern Europe. It is also prevalent in

summer mastitis. Some 60 per cent of infections occur

in the front quarters, which, it has been suggested, flies

the teat with A. pyogenes alone. There is, however, no can reach more easily.

unequivocally accepted mechanism. Possibilities, each

Various studies using Hydrotaea irritans to transmit

with proponents, include colonization of the teat skin

summer mastitis have given incomplete results. The flies

or orifice spreading through the teat duct into the gland,

have been shown to carry the various bacteria and to

bacteria entering the gland by draining via a supra-

be able to regurgitate the bacteria on to teat skin

mammary lymph node from another site and invasion

several days after a previous meal. Contaminated teats

by haematogenous spread. All of the pathogens are

have been demonstrated to be one precursor to disease.

ubiquitous on cattle, easily recoverable from mucous

Recently a study in Sweden confirmed a much earlier,

membranes and various lesions, and so a number of

anecdotal, UK report that contaminated H. irritans

routes of invasion may occur naturally.

could transmit summer mastitis experimentally.

Summer mastitis also occurs frequently outside the

fly season and in areas where the sheep headfly is not

Clinical disease

found. No other obvious vectors have been suggested

in these situations. Cases of clinical mastitis, especially

Diagnosis of the later pathogenic stages of summer

in newly calved cows, involving the same complex of

mastitis is relatively easy and requires little experience.

bacteria, have been reported throughout the year.

Early stages are more difficult to distinguish from other

There are likely to be several risk factors to these infec-

infections.

tions including appropriate exposure to the bacteria

The infection is most probably ascending so the

and teat damage.

primary sites are in the teat or in lactiferous tissue near
Initial cases of summer mastitis in an outbreak prob-
the base of the teat. Initially, there is local inflammation
ably occur by chance. Increased incidence will depend
and oedema. Expression of udder secretion may reveal
on the density of animals at risk; hence there is a peak
a foul smell indicative of anaerobic bacteria. In summer
incidence in late summer-calving herds simply because
months the teat may be attractive to flies and if the
more animals are challenged when they are most sus-
animal is housed the hind legs attract biting flies.
ceptible. Probably the role of the fly is to increase the
Slightly later, behavioural changes in the animal related
challenge. It therefore is involved in secondary trans-
to toxaemia become apparent. The animal may be
mission. The fly may also contribute by stressing
lethargic, inappetant, stop cudding and will become
animals. Fly pestering can reduce milk yields by induc-
detached from the herd. These signs are easy to recog-
ing gross behavioural changes. Susceptibility to infec-
nize at pasture. In newly calved and housed animals the

tion during late gestation when there are other

first signs are often tenderness in the quarter, which can

environmental and husbandry stressors, especially poor

be confused with excessive intramammary pressure,

forage and heat, may increase with fly challenge.

and local temperature. The secretion will be dis-

coloured, thick and creamy, rather than colostral,

perhaps very clotted in a serous fluid, and frequently

Pathogenesis

foul smelling.

In addition to the extreme mastitis, in later stages

Damage to secretory tissue is caused primarily

pyrexia and lethargy develop. If the infection remains

by a toxin from A. pyogenes, with other virulence

local there may be rupture of mammary abscesses to

factors including a haemolysin, a coagulase and a

the exterior. More commonly, the animal becomes sys-

hyaluronidase. The activity and quantity of these

temically ill with progressive lameness from the hind

appears to be enhanced in mixed culture with P.

legs, swelling of joints and an elevated temperature. The *indolicus.*

bacteraemia/toxaemia may be fatal in a few per cent of

The route of invasion of the udder by a mixture of

cases; similarly there may be abortion. Perinatal death

bacteria is unknown but it seems unlikely that simulta-

is substantially increased and many calves, often born

neous invasion by up to five species of bacteria occurs.

prematurely, fail to thrive.

It is possible to isolate one or more of these pathogens

The infection develops rapidly after the initial recog-

from the udder of the lactating or dry cow in the

nizable signs so confirmation of summer mastitis by

absence of overt clinical signs so it is likely that some

bacteriology is rarely quick enough. Attempts have

predisposing factor(s) is needed to cause clinical

been made to develop cow-side diagnosis of anaerobic

disease.

involvement based on specific metabolites but no prac-

Evidence for the teat route of invasion in natural

tical technique is available. The time delay for confir-

infections comes from the frequency of summer masti-

mation is impractical. Evidence shows that 80 per cent

tis following teat-end damage. It has been possible to

of preliminary diagnoses of summer mastitis are correct

produce infections following surface contamination of

(Hillerton et al., 1987). The other infections would also

respond readily to the same therapy so unless drastic

control the disease is made by the 40–45 per cent of

action, such as teat amputation or immediate culling, is

farmers who regularly experience losses. Preventive

indicated misdiagnosis in favour of summer mastitis has

measures are neither simple nor foolproof and usually

no economic or welfare disadvantages.

are damage-limiting rather than totally preventive. The

basic aims are to limit exposure to infection from the

Treatment

herd, to prevent colonization of lesions and to prevent

spread of bacteria to the mammary tissue.

Assuming that summer mastitis infections will arise

A number of different approaches to treatment can be

anyway it is important to recognize these early and seg-

taken. The one selected should depend on the antici-

regate an infected animal to limit direct transfer of bac-

pated outcome of the case, which in turn depends on

teria via, for example, bedding systems and indirect

the clinical severity of the infection. In a small number

transfer by flies. Hydrotaea irritans do not pester

of cases the only recommendation is for immediate

housed cattle, so separate housing of infected animals

culling. Less drastic is to treat the infection purely as an

is good practice.

abscess; to amputate the teat and drain. This is practised

The epidemiological spread of infection is related to

commonly in northern Europe with non-pregnant

the density of susceptible animals and the abundance of

younger animals, which are often then reared for beef.

vectors. Reducing the density of late gestation cattle by

In cows and heifers near to or at parturition the

spreading the calving pattern and completely avoiding

prognosis depends on the speed of diagnosis. In most

the fly season of July,August and September in northern

cases in dry cows the infection is sufficiently well devel-

Europe are likely to be highly effective strategies.

oped that destruction of secretory function is virtually

Considerable effort is spent on fly control but this is

complete. A clinical cure can sometimes be achieved

the least effective method of disease control as persist-

but rarely a bacteriological cure. The prognosis is much

ent presence of insecticide on teats is hard to achieve.

better if the infection is diagnosed early, and therapy

The synthetic pyrethroids now in common use are

started immediately.

applied in ear-tags or as pour-ons to the back and prob-

The pathogens are susceptible to a wide range of

ably spread by diffusion in sebum. However, the teats

antibiotics including penicillin/streptomycin prepara-

lack hair and sebaceous glands are sebum deficient, so

tions. However, there is a poor cure rate when the only

limiting spread. Effective fly control on teats is only

therapy is infusion into the udder. This is because the

achieved by direct application or frequent reapplication

tissue destruction is extensive locally and so diffusion of

of insecticide, or by the use of two ear-tags per animal.

the antibiotic is limited. A greater success has been

There has been a gradual decline in the proportion

claimed for erythromycin, which diffuses more readily.

of dry cows suffering summer mastitis, and in the

Success has also been claimed for anti-anaerobe prepa-

number of herds affected, in England and Wales since

rations containing metronidazole. Chlortetracycline can

1988. This has been coincident with the control of flies

be useful in the lactating animal but should not be used

by use of ear tags and later by pour-on formulations.

in the dry gland as all secretory funtion will be destroyed.

Frequently, summer mastitis follows infected lesions

Claims have been made for a variety of other prepa-

on or near the teats. These can be prevented or limited

rations including proteolytic enzymes mixed with

by use of surgical tapes, ensuring that the teats are

antibiotics but controlled studies are rare. Usually, the

cleaned first and not bandaged too tightly, or by fre-

most successful outcome follows a coordinated effort:

quent application of teat disinfectant. Many farmers

frequent stripping of the quarter combined with par-

teat-dip dry cows and heifers daily. This allows frequent

enteral intramuscular antibiotics and an intramammary

inspection, trains the heifers to the milking parlour and

infusion. This conventional approach, although labour

ensures good teat condition. Prevention of teat lesions

intensive, affords the best prognosis for the udder. If

may reduce greatly the attractiveness for flies.

systemic involvement is established then treatment of

The best tested and most effective means of reducing

clinical signs to secure the health of the animal is all that

the incidence of summer mastitis is the general appli-

can be achieved as the function of the infected quarter

cation of prophylactic antibiotic infused into the teat at

has been lost.

drying-off. Following administration of synthetic peni-

The patient should be quarantined as it is a source of

cillins in a long-acting base, summer mastitis rarely

further infection.

occurs within three weeks. Longer effects are achiev-

able with some preparations. Where the incidence of

Control

disease warrants extra investment it is advisable to

repeat the application of antibiotic after three weeks.

Summer mastitis is so destructive and expensive that

The main problem is avoiding milk contamination

considerable investment in time and materials to

after an early calving. All the evidence available

shows a significant reduction of summer mastitis fol-

Reference

lowing use of dry-cow therapy. It can also be applied

to heifers if the antibiotic is introduced gently into the

Hillerton, J.E., Bramley, J.A. & Watson, C.A. (1987) The epi-teat duct.

demiology of summer mastitis: a survey of clinical cases.

Attempts to produce a vaccine against summer

*British Veterinary Journal **142**, 520–30.*

mastitis have met with little success. This remains a

long-term goal and will become more likely as multi-

valent vaccines are developed.

Chapter 25

Bulk Milk Testing and

Mastitis Monitoring

D.J. O'Rourke and R.W. Blowey

Cell counts

341

infections, there are certain other factors, some of which

What is a somatic cell count?

341

are physiological, that affect the cellular content of milk.

Factors affecting the somatic cell count

341

Determination of the cell content of milk

342

Interpretation of somatic cell counts

343

Stage of lactation

Total bacterial counts

345

The somatic cell count is high during the first week of

Sources of bacteria

346

lactation, then soon decreases and remains low for

Bulk tank analysis

346

Mastitis monitoring

348

several weeks after which a gradual increase occurs

Introduction

348

until the end of lactation. As the milk volume decreases

Recording systems

348

in the latter part of lactation, an apparent increase in

Analysis of information

349

cell numbers occurs from mere concentration of cells in

Target figures

350

a smaller volume of milk. The presence of high cell

Uses of mastitis monitoring

350

numbers in colostrum may be due to an excessive

desquamation of epithelial cells in a small volume of

milk in a gland resuming functional activity after a

Cell counts

dormant period (Schalm et al. , 1971).

What is a somatic cell count?

Lactation age

The majority of somatic cells found in milk are white

The somatic cell count increases with the lactation age

blood cells, with the remainder mainly epithelial cells

of the cow (Fig. 25.1) (Blackburn, 1966). On the basis

shed by the secretory tissue of the udder. White blood

of histopathological examination of the udders, the

cells are found throughout the body and their main

increase in the average number of polymorphonuclear

function is to protect against disease. When large

leucocytes with advancing lactation age was attributed

numbers accumulate they are visible as pus. The mea-

to an increase in the extent of subacute inflammation

surement of the number of somatic cells in milk is

of the ducts as well as an increase in the severity of

known as a somatic cell count.

lobular lesions.

Factors affecting the somatic cell count

Stress

Mastitis

A sudden upset in the cows' routine, for example a herd

Inflammation in the udder is in no way different from

blood test or coming indoors in the autumn, can cause

inflammation in other tissues. The cardinal signs of

a raised cell count for a day or two.

inflammation, namely swelling, redness, heat, pain and

loss of function may not always be of recognizable

Oestrus

intensity in mastitis. Signs of clinical mastitis are grossly

visible but subclinical mastitis may go unnoticed. The

Bulling cows tend to have increased cell counts that are

majority of mastitis cases are bacterial in origin. One of

probably stress related.

the basic host responses to a bacterial infection is the

infiltration of white blood cells from the blood into

Milking interval

the udder. This is accomplished through the processes

of diapedesis and chemotaxis. The degree and nature of

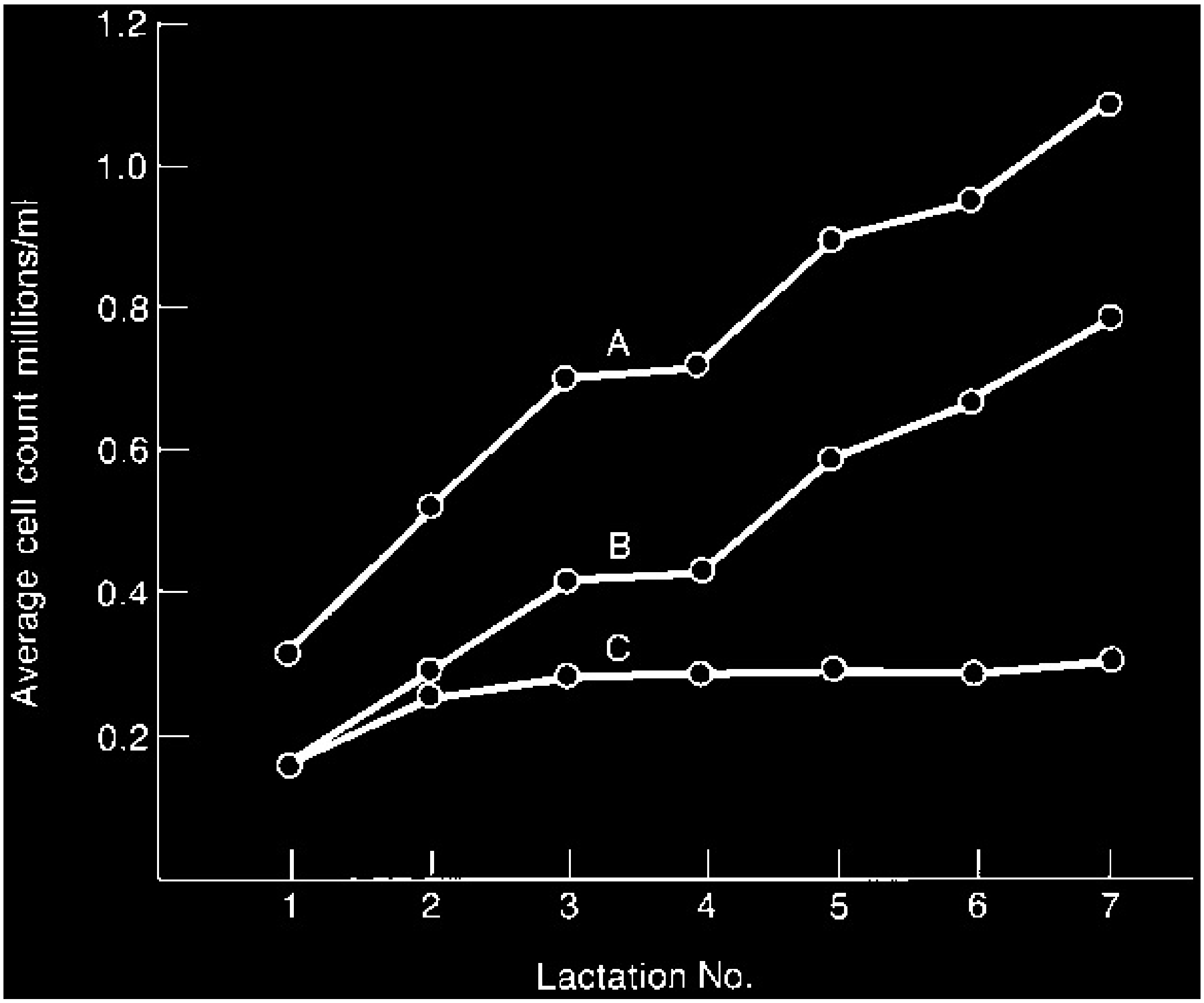
Irregular milking intervals will influence the somatic *the cellular response are likely to be proportional to*

cell counts in milk. Comparisons of somatic cell counts

the severity of the infection. In addition to bacterial

in milk have generally shown higher counts for shorter

341



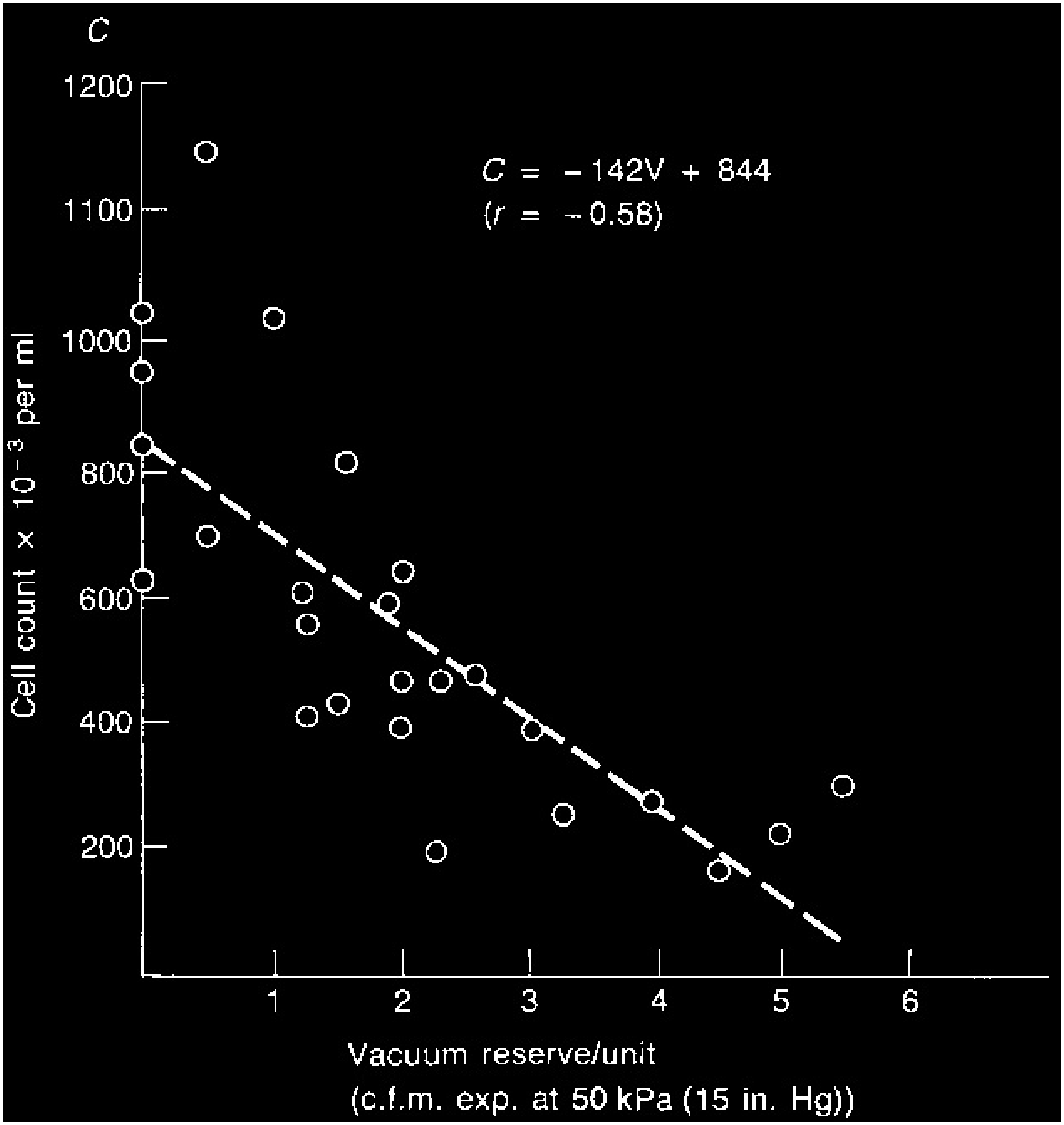


Fig. 25.1

Average cell count for each of seven lactations.

A, total cell count; B, polymorphonuclear leucocyte count; C,

count of cells other than polymorphonuclear leucocytes. Source: Blackburn

(1966), reproduced with permission of Cambridge

University Press.

Fig. 25.2

Relationship between mean cell count of herd bulk

milk (C) and vacuum reserve per unit (V). Source: Nyhan &

Cowhig (1967).

milking intervals. This variation in cell numbers is

explained on the basis of total volume of milk secreted

leading to a greater dilution of somatic cells during the

(1)

Distribution of cells in the smears may not be

longer milking interval (Schalm et al. , 1971).

homogeneous. The decision as to whether the

stained structures observed are actually cells

Milking machine

may be difficult in some cases and must be made

subjectively.

A significant correlation between cell counts and

(2)

To estimate the cell content every microscopic

milking machine reserve air was observed by Nyhan *field examined must be multiplied by a relatively*

and Cowhig (1967) in a survey of milking machine

large factor, and this can be a source of consider-

efficiency and mastitis in a random sample of 26 dairy

able error.

farms (Fig. 25.2). Six of the herds were milked with

machines that had a vacuum reserve of more than 0.11

Consequently, the primary object of microscopic count-

m3/min free air (4 ft3/min free air) and these were the

ing is the screening of other counting techniques.

only herds with a mean bulk milk cell count of <300 000

cells/ml. However, later work in Australia (Olney et al. , Electronic particle counting

1983) concluded that in the absence of mastitis infec-

tions vacuum fluctuations, vacuum level, overmilking or

This can be carried out by the following methods.

varying pulsator rates will not cause stress or irritation

that will lead to an increase in somatic cell counts.

Coulter counter (International Dairy Federation (IDF,

1981)): With the aid of the Coulter counter it is possible to determine rapidly and accurately the number of

Determination of the cell content of milk

particles over a certain size in a suspension. Prior to the

Reference method: microscopic counting

determination of the number of cells, the milk is treated

(Heeschen, 1975)

as follows.

The method of microscopic counting of cells in a dry

(1)

Cells are stabilized to make them resistant to

stained smear has been available for many years now

further treatments.

although it has some possible errors. The optical and

(2)

The milk to be examined is diluted with an

manual operations involved are tedious, especially in

electrolyte.

the case of serial tests, and the following sources of

(3)

The fat globules are dispersed to well below the

error must not be overlooked.

Coulter counter threshold.

The treated milk is passed through a 100 mm aperture

Table 25.1

Distribution of cow and quarter infections shown

located between two electrodes. When a particle passes

against cell count ranges. Source: Pearson & Greer (1974).

through the aperture, a small quantity of highly con-

ductive liquid in the circuit is displaced by a particle of

Cell count ranges

No. of

Infections

(¥103 cells/ml)

herds

lower conductivity. The increased resistance raises the

In quarters

In cows

voltage, producing a voltage pulse proportional to the

(%)

(%)

volume of the particle. The number of pulses indicates

the number of particles passing through the aperture.

219–490

12

9.61

25.8

The pulses are fed into a threshold circuit so that only

535–789

12

17.76

42

those exceeding a particular threshold value (T) are

1005–1700

5

29.54

54.4

counted.

Fossamatic (IDF, 1981): This instrument is an auto-

matic microscope for counting cells in liquids. Cells are

Table 25.2

Estimated infection prevalence and losses in milk

stained with ethidium bromide and are then excited

production associated with elevated BMCC. Source: Eberhart et al. (1982), reproduced with permission of the International Asso-with a high-energy lamp, causing them to emit light at *ciation for Food Protection.*

a characteristic wavelength. The emitted light energy is

detected electronically, the result being displayed and

BMCC

Quarters Production

printed out for each successive sample.

(¥103 cells/ml)

infected (%)

lossa (%)

200

6

0

Accuracy of these methods

500

16

6

The precision obtained in the Fossamatic instrument

1000

32

18

is comparatively high. However, it is not essentially

1500

48

29

different from that obtained in the Coulter counter. In

a

practical operation, the Fossamatic instrument has

Production loss calculated as a percentage of production expected at 200 000 cells/ml.

proved to be superior to other methods tested. This

applies to the rate of samples as well as the handling of

the instrument (Heeschen, 1975).

Table 25.3

Guidelines for interpretation of bulk milk cell counts.

In an International Dairy Federation (IDF) ques-

tionnaire in 1983 on the cell counting methods 20 coun-

Bulk milk cell count

Estimate of

tries indicated they used Fossamatic, 17 used Coulter

(¥103 cells/ml)

mastitis problem

counter and two used the microscope method.

<200

Slight

200–400

Average

Interpretation of somatic cell counts

400–700

Bad

Somatic cell counts can be carried out both on herd

>700

Very bad

bulk milk and individual cow's milk.

Herd bulk milk

The prevalence of quarters infected clinically, and

Monthly cell counting has been shown to provide a fair

perhaps more importantly subclinically, with major

estimate of the subclinical mastitis status of a herd; fur-

pathogens such as Staphylococcus aureus or Strepto-thermore, the annual mean can be updated on a rolling

coccus agalactiae and Strep. uberis, and to a lesser extent basis by substituting the current month's count of the

Strep. dysgalactiae, is the most important factor affect-same month of the previous year (Booth, 1985).

ing the BMCC. Fenlon et al. (1995) confirmed this in a A herd of cows with physiologically normal quar-survey of 30 dairy herds, where they found a good cor-

ters could expect a bulk milk cell count (BMCC) of

relation between the number of mastitis streptococci

<200000 thousand cells/ml. Herds with cell counts

(Strep. agalactiae, Strep. dysgalactiae and Strep. uberis) below this figure do exist (26 per cent of herds in

found in bulk tank milk and BMCC. Gram-negative

England & Wales; Booth, 1997) but evidence shows that

organisms such as Escherichia coli are usually rapidly even in these herds there is some subclinical infection

eliminated from the udder and do not tend to cause

(Tables 25.1 and 25.2). A BMCC of 200 000 cells/ml is

many subclinical infections. Unless milk from clinical

considered to be a realistic upper limit for herds with

cases reaches the bulk tank, infections of this type do

mastitis under control (Table 25.3).

not tend to influence the BMCC significantly; BMCC,

therefore, is a poor indicator of Gram-negative infec-

Can the BMCC be too low? There is a perception that

tions (David & Jackson, 1984).

too low a cell count can lead to an increase in suscep-
Both monthly and annual rolling mean figures must
tibility to mastitis. However, BMCC is not a measure
be examined to detect trends over a period of time
of resistance to mastitis. Resistance against mastitis
rather than figures for a single month. Where subclini-
depends on the teat barrier being intact and the ability
cal infections with major pathogens like Staph. aureus
of the cow to mobilize large numbers of efficient
are not well controlled it is possible to see a gradual
neutrophils in a short period of time. Timms (1990) con-
increase in BMCC over a period of time, rather than a
firmed this when he showed that cows with a low
sudden explosive increase. A sudden spectacular rise in
somatic cell count (SCC) were not at greater risk
the BMCC where the levels have been consistently
of mastitis infections when compared to cows with a
<250000 cells/ml could indicate an outbreak, with mas-
high SCC. In a survey of 125 herds with a low BMCC
titic milk reaching the bulk milk supply due to faulty
(<150 000 cells/ml) in the Netherlands the rate of clini-

detection.

cal mastitis was significantly related to certain variables

Fifteen countries reported a decrease in national

that increased the exposure of environmental mico-

mean cell in an IDF survey (Booth, 1995) (Table 25.4).

organisms: poor cubicle cleanliness, rubber mats in

cubicles and drinking water from sources other than

public water all increased the rate of clinical mastitis

Table 25.4

National mean cell counts in 1990 and 1993.

(Schukken et al. , 1990). Berry (1992) found that it is Source: Booth (1995). Reproduced with permission of the Inter-possible to have a low cell count and achieve a low inci-

national Dairy Federation.

dence of mastitis in a survey of 35 herds in England and

Wales with a BMCC of less than 70 000 cells/ml.

Country

Cell count

Change

Meana

(¥ 106/ml)

(%)

Why is the BMCC important? Within the dairy indus-

1990–93

try, BMCC has become the single most important test

1990

1993

used to measure milk quality, to regulate whether milk

can be sold and to determine the price paid for raw milk

Austria

379

313

-66 (17)

A

(Bennett, 1993; Wells & Ott, 1995; Leslie et al. , 1996).

Belgium

307

265

-42 (14)

G

Denmark

368

309

-59 (16)

A

Reasons to include BMCC as a pricing component

Finland

282

186

-96 (34)

A

include: (i) domestic consumer demands for quality, (ii)

Germany

274

237

-37 (14)

G

processor need for high-quality raw milk for further

Hungary

419

351

-68 (16)

A

processing, (iii) to help improve udder health and (iv)

Iceland

471

408

-63 (13)

A

pressure from international markets for documented

Italy

434

426

-8 (2)

A

high-quality dairy products (Wells & Ott, 1995). EC

Japan

260

280

+20 (8)

A

Directive 92/46 states that all milk (liquid milk or milk

Netherlands

320

280

-40 (13)

A

for manufacture) must have a BMCC of less than

New Zealand

345

255

-90 (26)

W

400 000 cells/ml.

Norway

206

194

-12 (6)

A

Buyers are offering incentives for low BMCCs (Table

Sweden

230

231

+1 (0)

G

25.5), but some may question whether they, the buyers, *Switzerland*

117

104

-13 (11)

A

UK

329

277

-52 (16)

G

need low cell counts in milk. Badinand (1994) indicates

that the quality of milk is reduced once the number of

a A, arithmetic; G, geometric; W, weighted.

cells is greater than 70 000 to 100 000/ml. Inflammatory

Table 25.5

Incentives to reduce cell counts. Source: Milk Marketing Board and Milk Marque (UK).

Cell count (¥103)

Apr 1994

Apr 1995

Oct 1995

Apr 1996

Cell count (¥103)

Apr 1997

0–150

+0.2 p/l

<250

–

+0.2 p/l

+0.2 p/l

–

151–250

–

251–400

–

–

–

-0.2 p/l

251–400

-0.5 p/l

401–500

-0.5 p/l

-0.5 p/l

-1.0 p/l

-2.0 p/l

>400

-6.0 p/l

500–1000

-1.0 p/l

-3.0 p/l

-4.0 p/l

-6.0 p/l

>1000

-2.0 p/l

p/l, pence/litre.

Table 25.6

Effects of mastitis on milk and milk products. Source: Munro et al. (1984), reproduced with permission of the Australian Journal of Dairy Technology.

Substrate

Alterations

Raw milk

Development of a rancid flavour; lower heat stability of whey proteins
Pasteurized milk

Reduction of flavour and quality

Recombined concentrated milk

Less stable proteins

Cheese

Reduced starter activity; changed clotting time; reduction of curd firmness; losses of fat and casein with the whey; lower yield

Butter

Impairment of flavour; less flavour; oxidative taste; longer churning time; inhibition of diacetyl production

changes in the mammary gland influence the process

Table 25.7

Interpretation of individual cow milk cell count.

of milk synthesis both quantitatively and qualitatively.

The changes in constituents of milk affect the major

Count (thousand cells/ml)

Interpretation

components (lactose, fat and proteins) as well as fatty

Less than 200

Probably uninfected

acids, protein fractions, caesins, whey proteins, anions

200 to 500

Suspicious: possibly infected

and cations, conductivity enzymes, etc. With increasing

in one quarter

numbers of somatic cells the growth of starter cultures

Over 500

Infected in at least one

in milk may be adversely influenced (Table 25.6). Ren-

quarter

netting time and heat stability of the milk can be

impaired (Heeschen & Reichmuth, 1995).

Individual cow cell counts (Table 25.7) can be of

Individual cow's milk

value to farmers and their veterinary surgeons for the

The normal somatic cell count in milk in various parts

following reasons:

of the same udder varies widely from near zero in unin-

• To estimate the proportion of cows in a herd that

fected areas to something in the order of three hundred

are infected;

million cells per litre in the worst infected areas. A cow

• To screen the herd in order to identify cows for

can have <200 000 somatic cells/ml with some small area *bacteriological examination;*

of the gland badly infected.

• To identify cows for possible culling (at least two

Many farmers have monthly somatic cell counts

samples at monthly intervals are required);

(SCC) carried out on the milk samples taken from cows

• As a guide to the effectiveness of dry-cow therapy;

for milk recording purposes. These can provide a rather

• In a herd with a high total bacterial count (TBC)

more detailed monitor of the herd mastitis situation

where the equipment has already been checked, as

than that provided by the monthly BMCC. The cost of

the first step in identifying the cows that may be the

monthly SCC testing for one year is very low and can

cause of the high TBCs.

be recovered in mid-sized herds by preventing one or

two clinical cases of mastitis. The recovery of the cost is

Stage of lactation can have some effect; counts are

many times the out-of-pocket expense because of the

high in the first week after calving and tend to rise

many uses of SCC data and the number of cows at risk *slightly in the last few weeks of lactation. First calvers*

in a year's time. SCC reach the highest level in milk

that have never been infected will normally have counts

within the first several hours after milking and reach a

of 100 000 cells/ml or less.

low point just prior to milking (Schalm et al. , 1971).

Anything less than a daily composite has reduced reli-

ability and repeatability. Repeated samples over days

Total bacterial counts

or months add perspective to the cow's udder health

history and improve the interpretation of SCC.

Although by no means a new technique, there has been

Monthly SCC data accumulated over a year for a cow

a recent increase in interest in the use of quantitative and

or herd describe more completely the mastitis history

semi-quantitative bacterial counts in bulk milk as an aid

of the herd for the previous year. Greater confidence is

in the monitoring and investigation of mastitis and milk

gained as more samples are represented.

hygiene problems. The majority of samples submitted *are for the investigation of herd problems with milk*

borne in mind that a considerable number of bacteria

hygiene, rising cell counts and/or a high incidence of

come from other sources, such as soiling on teats and

clinical mastitis. With the majority of countries now

the milking apparatus (Bramley et al. , 1984).

basing payment on both the cell count and bacterial

count of milk,the results also have economic importance.

External contamination of cows' teats

It is vital that any sample taken is kept refrigerated

during transit from the bulk milk tank to the processing

Attention to udder hygiene and housing, especially

laboratory, and this can produce practical difficulties.

cubicle beds and passage ways, is important in reducing

EC Directive 92/46 states that all milk (liquid milk or

contamination from the udder skin. The handling of

milk for manufacture) must have a total bacterial count

cows' teats before milking must always result in the risk

(TBC) of less than 100 000 bacteria/ml. Consequently,

of transfer of bacteria between teats and from one cow

milk supplies are subject to testing for TBC as a *to another. Herds where teats were dry wiped with*

measure of milk quality and bonus/penalty payments

paper towels had the lowest BMCC and TBC in both

are applied according to the level. The bacterial count

the summer and winter period, followed by those herds

obtained refers to all bacteria which includes sapro-

where only dirty teats were washed and dried with

phytic bacteria, faecal organisms such as E. coli as well paper towels (O'Rourke, 1987).

as other major udder pathogens.

Contamination from the milking equipment

Sources of bacteria

Contamination of the milking equipment is generally

Bacteria in milk comes from three main sources:

found to be the most frequent cause of high bacterial

counts. Probably the two major causes are cracked and

• From within the udder

perished rubberware and inefficient cleaning of the

• External contamination of cows' teats

plant (see Blowey & Edmondson, 2000a).

• The milking plant

If there is a problem with cooling and refrigeration

of milk all three sources may contribute to an increased

Bulk tank analysis

TBC.

The organisms counted and the standards currently

in use by one processing laboratory (Blowey &

From within the udder

Edmondson, 2000a) are shown in Table 25.8. Other

The milk from a healthy uninfected quarter contains

laboratories may use different criteria. In addition, a

virtually no bacteria. Neave (1975) found counts of up

semi-quantitative screen is carried out for all other

to 28 million bacteria/ml in a quarter with subclinical

bacteria isolated from that sample. The target values

Strep. uberis infection. However, the majority of quar-have been reduced in line with the increasingly strict

ters with subclinical infections (Staph. aureus, Strep.

standards being imposed by the milk purchasing

dysgalactiae and Strep. uberis) had counts of around companies (Blowey et al. , 2000).

10 000 bacteria/ml. Bacterial counts from quarters with

coliform infections were slightly lower.

TBC vs Bactoscan

Milk from cows with clinical mastitis should always

be withheld. Neave (1975) found counts of up to 680

Typically TBC is the number of viable bacteria per ml

million bacteria/ml, and several quarters with counts

of milk when cultured on milk agar medium at 37°C for

greater than 100 million bacteria/ml (although 105 or

106/ml is more usual). Two litres of such mastitic milk

Table 25.8

Target values for different bacterial types in bulk

added to 2000 litres of bulk milk may raise the TBC by

milk. LPC, laboratory pasteurised count.

100 000 bacteria/ml (Cousins, 1978).

Herds with satisfactory average TBC sometimes

Organism

Target value (cfu/ml)

experience occasional wild fluctuations. This may indi-

cate that mastitis cases are not being detected promptly

Thermoduric/LPC

<175

and mastitic milk is entering the bulk tank. It is there-

Coliforms

<20

fore essential for mastitis detection to be as thorough

Pseudomonas

<500

Total staphylococci

<200

as possible especially where milking is direct to pipeline

Staph. aureus

<10

(David & Jackson, 1984).

Strep. uberis

<2200

TBC levels can provide some information regarding

Total bacteria count

<5000

the mastitis situation in a herd. However, it must be

48 hours. It therefore measures the number of bacteria

Staphylococcus aureus count

which grow at a specific temperature on a specific

High Staph. aureus counts are commonly found in herds culture medium. Most bacterial counts are now meas-with high cell counts and indicate that additional atten-

ured automatically by Bactoscan. This counts all viable

tion to hygiene is needed during the milking process

organisms, irrespective of their favoured growth tem-

and careful postmilking teat disinfection, to prevent the

perature or cultural requirements. Bactoscan levels are

spread of infection. Spread of infection is by hands, teat

therefore higher than TBCs, by a factor of approxi-

wipes and especially the teat liners (inflations). In a pro-

mately four- to five-fold. However, there is no direct

portion of herds the Staph. aureus levels in bulk milk relationship between the two, as this will depend on the

are quite high and yet cell counts are acceptable. Advice

type of bacteria present in any particular sample

given in these circumstances is that the herd is at risk

(Blowey & Edmondson, 2000b).

from a rising cell count, and that there are probably a

number of carrier cows present in the herd.

Thermoduric count

The number of thermoduric organisms present in the

Total staphylococcal count

sample (i.e. organisms which are not killed by heating

to 64°C for 35 minutes) is taken as an indicator of poor

The total staphylococcal count was introduced because,

milking plant cleaning. This may be caused by inade-

with the elimination of Staph. aureus, there has been an quate quantities of hot water (less than 18 litres per

increasing number of herds with high cell counts caused

cluster), inadequate water temperatures, a lack of

by coagulase negative staphylococci (CNS). This range

swirling and jetting during the washing routine, inade-

of organisms includes Staph. epidermidis and Staph.

quate amounts of dairy chemical used or particularly

haemolyticus.

hard water leading to inactivation of the circulation

cleaner. Many farms are now able to achieve a ther-

moduric count of 10 cfu/ml or lower, although with

Differential screen

problem herds the count may rise to above 600 cfu/ml.

The differential screen is a semi-quantitative assess-

ment of other bacteria present in the milk sample. The

Coliform count

bacteria commonly found include:

Coliform counts or, more precisely, enterobacteriacae,

• Streptococcus uberis. Herds with high levels of

are taken as an indication of the amount of faecal con-

Strep. uberis in bulk milk samples tend to have more

tamination on teats. This could therefore indicate a

clinical mastitis and may have widely fluctuating

problem with poor housing, or poor premilking teat

Bactoscans. Strep. uberis can sometimes be associ-

preparation or both. High coliform counts could also

ated with somatic cell count problems, even when

arise from cows clinically or subclinically affected by E.

staphylococcal levels are low.

coli mastitis, with the milk entering the bulk tank. This

• Streptococcus dysgalactiae has been associated with could occur, for example, where foremilking is not prac-poor teat skin condition, particularly in heifers.

tised and where mastitis detection is poor. Fluctuating

High levels of total staphylococci or Staph. aureus cell count and Bactoscan values are often associated

may also be present, as both organisms are associ-

with increased levels of clinical mastitis, especially E.

ated with poor teat skin condition.

coli, Strep. agalactiae and Strep. uberis.

• Streptococcus agalactiae is sometimes identified

from herds that did not even know that the cows

were infected. Strep. agalactiae can be the cause of

Pseudomonas count

increased bulk milk tank somatic cell counts and

Pseudomonads are non-enteric coliforms, sometimes

high and fluctuating Bactoscans.

referred to as non-lactose-fermenting coliforms or

• Corynebacterium bovis has been associated with

NLFs. An increasing number of NLFs were found in

suboptimal postmilking teat disinfection. If staphy-

milk samples from clinical samples and high cell count

lococcal levels are rising and C. bovis is identified cows (Blowey et al. , 2000), and subsequent testing

in significant numbers in bulk milk samples, then it

showed that these were primarily Pseudomonas species.

would suggest that additional attention needs to be

The pseudomonad count is taken as an indicator of

paid to postmilking teat disinfection.

non-enteric, non-faecal environmental contamination,

• Other organisms include Strep. faecalis, Bacillus

and raised levels are likely to be found in herds with

species, yeasts and moulds. The presence of a wide

poor premilking teat preparation and/or poor environ-

range of these environmental organisms is often

mental hygiene.

associated with high coliform and Pseudomonas

counts and with an increased incidence of clinical

Holstein/Friesian herds in England (average herd size

environmental mastitis. Poor housing and/or poor

132 cows) over three years, recorded an incidence of

premilking teat preparation could be involved.

43.4 quarter cases per 100 cows per year. The disease

affected 25.9 per cent of the cows in the herd each year,

with 1.6 quarter cases per affected cow, giving an overall

Mastitis monitoring

recurrence rate of 19.4 per cent. This would suggest that

some cows are more susceptible to clinical mastitis

Introduction

than others. Although there has been little improve-
ment over the past 10 to 15 years, these figures repre-
There are few conditions in dairy cows that lend them-
sent a marked reduction in incidence compared with
selves to such a detailed objective numerical monitor-
the 1960s, when Kingwell et al. (1970) recorded an
ing as mastitis. Mastitis is still a significant problem in
incidence of 120 cases per 100 cows per year. The
dairy herds in all countries and many of the factors
marked reduction in incidence since this period has
leading to a high incidence are associated with hygiene
been associated with the implementation of the 'five-
and husbandry, i.e. they are under the direct control of
point plan', and the control of contagious infections.
the farmer or stockman. It is therefore vital that there
There has been little decrease in environmental
is a constant monitoring to ensure that all parties
infections however, possibly because the doubling
involved are made aware immediately a problem starts
of teat end milk flow rates (from 0.8 to 1.6 kg/Q/min)
to develop.

that has been associated with increased yields has led

One of the largest British surveys, starting with 45 000

to a 12-fold increase in susceptibility to new infections

cows in 378 herds, was completed in 1983 (Wilesmith

(Grindal & Hillerton, 1991).

et al. , 1986). Defining a 'case' of mastitis as one quarter affected and with a separate case commencing if seven

days had elapsed since the disappearance of clinical

Recording systems

signs, they found an incidence of 54.6 cases per 100 cows

The precise system used by the farmer to keep mastitis

in 1980, declining to 41.2 cases per 100 cows by 1982.

records is not particularly important, provided:

This is in broad agreement with the data of Blowey

(1986), reporting a much smaller survey of 22 herds

• It is used accurately and kept up to date;

monitored by a veterinary practice, where the incidence

• All information is recorded, namely date, cow

of mastitis fell from 51.0 cases in 1979 to 31.8 cases

identity, quarter affected, treatment used, with-

per 100 cows in 1985 (Table 25.9). More recently *drawal period and results of bacteriological samples*

Kossaibati et al. (1998), in a study of 144 well-recorded (if taken);

Table 25.9

The average performance of the 22 herds monitored (Blowey, 1986).

Period of

Number

Herd

Rolling

Annual

Percentage

Mastitis

Intramammary

Intramammary

Percentage

records

of herds

size

mean

milk

cows

cases/

tubes used

tubes used

cases

being

herd

sales

affected

100

per cow

per case

which

recorded

milk

(l)

cows

treated

recurred

cell

count

(¥103/ml)

Oct. 1979–

Sept. 1980

22

91.7

346

6011

26.5

51.0

2.6

5.1

25.0

Sept. 1980–

Aug. 1981

24

105

302

5820

25.4

49.6

2.7

5.8

16.3

March 1981–

Feb. 1982

22

101

310

5921

25.8

459

2.4

5.6

14.9

April 1982–

March 1983

16

123.7

302

5949

27.2

493

2.5

5.0

16.1

April 1983–

March 1984

16

123.8

255

5651

23.6

42.7

1.9

4.2

13.1

April 1984–

March 1985

23

111.5

243

5479

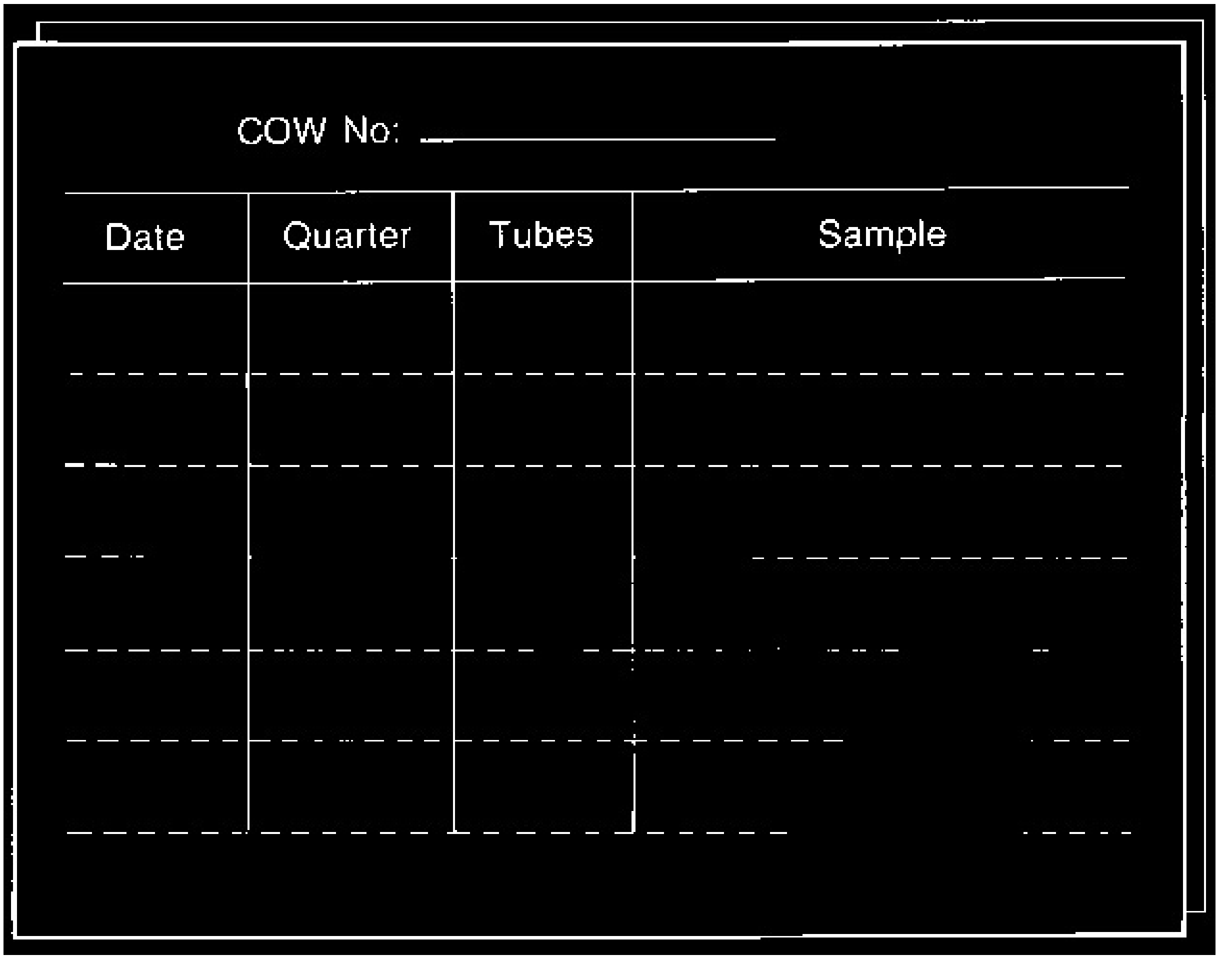
19.6

31.7

2.1

7.1

10.3



COW No: ____________

Date	Quarter	Tubes	Sample

• The records are in a form that is acceptable and

that a cow's lifetime mastitis history is readily available.

usable for the person compiling them;

Whatever system is used, it must be capable of produc-

• They are easily accessible and regularly reviewed

ing information on previous disease, to assist with deci-

by both the farmer and his veterinary adviser and

sions on culling.

any necessary action is taken following this review.

An analysis of data needs to be carried out at least

Analysis of information

every six months. Intervals longer than this would fail

Regular checks must be carried out by analysing the

to achieve the aims of the monitoring (detailed later

recorded information in order to:

in this section, p. 350). It is also important to be seen to

be using the data, thereby maintaining the interest and

• Assess the incidence of mastitis on each farm and

enthusiasm of the herdsman for continuing with the

hence the efficacy of the control procedures in use;

recording. Wall charts are the simplest method of

• Compare the performance of the farm with ‘stan-

recording; computers may be used, while others use a

dard targets’ or with the herds of other members of

specific mastitis recording booklet, with a page for each

the group being monitored.

cow (Fig. 25.3; Blowey, 1983). This has the advantage

The wide variety of criteria that can be used to monitor mastitis are shown in Table 25.10, which is part of a 'league table' taken from a herd recording programme (Blowey, 1984). Bulk milk cell count is clearly the traditionally used parameter, but this is mainly a reflection of subclinical Staph. aureus, Strep.uberis or Strep. agalactiae contagious mastitis. It provides relatively little information on the incidence of environmental mastitis. The percentage of cows affected gives the proportion of cows in the herd that have been clinically affected by mastitis during a 12-month recording period. Any one of these cows may have had mastitis in one or more quarters and any one quarter may have had two, three or more mastitis incidents over a 12-month period. Defining a case as one quarter affected once, and a remission of clinical signs for six days or more being needed before a new case commences, then the case incidence of mastitis can be calculated. As far

Fig. 25.3

A page from a herdsman's mastitis recording book.

as the farmer is concerned, this will be a more accurate

This is kept during the life of the cow.

reflection of the ‘amount of mastitis’ occurring in the

Table 25.10

A ‘league table’ derived from mastitis data analysis.

Herd

Number

Rolling

Mean

For whole herd

For mastitic cows

number

of cows

mean

herd

Percentage

cell

yield

cows

Cases

Tubes

Tubes

Average

Recurrence

Quarters

count

(annual

affected

per 100

used per

used per

number

(%)

per

(¥103)

sales) (l)

cows

cow

case

of cases

cow

1

65

321

5800

38

60

3.5

5.7

1.6

15

1.4

2

81

745

6000

21

30

0.9

2.9

1.5

12

1.3

3

46

275

5850

19

40

4.1

9.4

2.2

45

1.2

4

134

267

5178

21

30

1.2

4.6

1.2

1.2

6

95

346

29

70

9.8

13.5

2.5

33

1.6

7

110

333

6500

27

70

2.7

3.8

2.6

40

1.6

8

132

272

6036

28

60

1.8

2.9

2.2

29

1.6

9

50

441

30

70

2.1

3.1

2.2

36

1.4

10

60

210

18

60

1.7

2.8

3.4

35

2.2

herd. If a herd has a low percentage of cows affected,

Table 25.11

Case incidence and tube usage over a 3-year

but a high number of cases per 100 cows (for example

recording period. Source: Wilesmith et al. (1986).

herd 7, Table 25.10), then that herd has a problem with

either (i) a large number of down-calving cases, with

1980

1981

1982

maybe all four quarters affected at the same time or (ii)

Cases/100 cows

54.6

49.8

41.2

a proportion of ‘chronics’ in the herd, which have had

Tubes used/100 cows

280

273

259

repeated attacks of mastitis in one or more quarters

(33–1032)

(23–1112)

(19–1003)

over the lactation. This can be expressed as the pro-

Tubes used/clinical

portion of treated cases that recurred and is clearly very

case

6.1

6.1

5.8

high for herd 7.

(1.1–29.4)

(0.9–53.5)

(0.9–19.5)

These two situations can be separated by monitoring

the percentage that recurred, namely the proportion of

treated quarters that required a second or subsequent

treatment during a 12-month recording period. Addi-

Table 25.12

Targets for herd mastitis incidence. Source:

tional information can be obtained by calculating

Blowey & Edmondson (2000a).

indices for the cows affected, namely for 'mastitic cows'

(Blowey, 1984). For example, in this category (i) 'cases

Target

Interference

per mastitic cow' gives an indication of the average

level

frequency with which a cow gets mastitis during a 12-

month period and (ii) 'quarters per mastitic cow' then

Percentage cows affected

gives a further indication of whether it is one quarter

per annum

20

25

being regularly affected, or all four quarters affected

Cases/100 cows per annum

('mastitis rate')

30

40

at once.

Milking cow antibiotic tubes/

In many instances, intramammary antibiotic tube

cow in herd per annum

1.4

2.5

usage is obtained from different sources, e.g. the vet-

Milking cow tubes used

erinary practice or other sales invoices. This has the

per case

4.5

6.0

advantage in that it provides a check on the accuracy

Percentage cases requiring

of the data being supplied by the farmer. For example,

a repeat treatment

if it is calculated that 10 tubes are used for each case

during a 12-month period

10

20

treated, there are several possible explanations:

Percentage dry cows affected

per annum

1.0

2.5

(1)

The cases treated are very slow to respond, either

because the wrong antibiotic is being used, or

because there is an unusually resistant organism

or because treatment is not instigated until the

case is quite well advanced.

Similarly, in the data of Blowey (1986) (Table 25.9),

(2)

Tubes are being used at a rate well in excess of the

tube usage fell from 260 to 210 tubes used per 100 cows *manufacturer's recommendations.*

in a period when mastitis incidence declined from 51.0

(3)

Tubes are being used for purposes other than the

to 31.7 cases per 100 cows per annum. Tube usage would

treatment of mastitis.

therefore appear to give some indication of mastitis

(4)

Not all cases of mastitis are being recorded. This

incidence, although it is not a figure that should be used

is the most likely cause of an extremely high tube

in isolation.

usage per case.

The mean tube usage per cow in the herd and per

Target figures

case treated as recorded by Wilesmith et al. (1986) was slightly higher than that recorded by Blowey (1986)

Targets for mastitis incidence have been suggested by

(Table 25.9). However, on individual farms Wilesmith

some authors and are shown in Table 25.12. These can

et al. (1986) found that average tube usage over a 12-

be used by an individual farmer to assess the progress

month recording period varied from 0.9 to 53.5 tubes

of a control scheme.

per case treated (Table 25.11). It was for this reason that

they concluded that tube usage was not a reliable

Uses of mastitis monitoring

indicator of mastitis incidence within a herd. However,

coincident with a decrease in mastitis incidence from

Most points have been referred to already, but an

54.6 to 41.2 cases per 100 cows per annum, there was

appraisal of the uses of recording makes a useful

a decline from 280 to 259 tubes used per 100 cows.

summary of the subject.

• To monitor the progress of an individual cow. Any

*fits of a mastitis control scheme. Veterinary Record, **119**, cow that has had four or more cases in one quarter*

551–3.

during a 12-month period should be considered for

Blowey, R.W., Davis, J.R. & Edmondson, P.W. (2000) Bulk

culling, or at least for special treatment.

milk analysis – an opportunity for greater on-farm involve-

• To monitor herd status. Is mastitis incidence

*ment. UK Vet, **3**, 26–30.*

Blowey, R.W. & Edmondson, P.W. (2000a) In Mastitis Control acceptable or should more effort be put into

in Dairy Herds. Farming Press, Miller Freeman, Ipswich, control? The surveys of both Blowey (1986) and

UK, p. 142.

Wilesmith et al. (1986) showed a marked decrease

Blowey, R.W. & Edmondson, P.W. (2000b) In Mastitis Control in mastitis incidence over the recording period and

in Dairy Herds. Farming Press, Ipswich, UK, p. 133.

it is likely that the simple discipline of recording,

Booth, J.M. (1985) Bulk milk somatic cell counting: methods

leading to an increased awareness of the problem,

in use and a proposal for the standard presentation of data.

will lead to improvements.

In Proceedings of the International Dairy Federation

• A recording system provides an opportunity for

Seminar Progress in the Control of Mastitis, Kiel, Germany, greater veterinary involvement in on-farm advice

pp. 274–81.

and discussion. Recording in itself often provides

Booth, J.M. (1995) Progress in the control of mastitis. In

the herdsman with greater motivation in mastitis

Proceedings of the International Dairy Federation Seminar

*Progress in the Control of Mastitis, Tel Aviv, Israel, **4**, 3–10.*

control, and this is particularly the case if league

Booth, J.M. (1997) Progress in mastitis control – an evolving

tables are supplied, indicating how well a specific

problem. Proceedings of British Mastitis Conference, 3–8.

herd compares with the others being monitored.

Bramley, A.J., McKinnon, C.H., Staker, R.T. & Simpkin, D.L.

• If problems occur, an analysis of the records can

(1984) The effect of udder infection on the bacterial flora of sometimes indicate the likely epidemiology of the

the bulk milk of ten dairy herds. Journal of Applied Bacte-organisms involved and hence the control measures

*riology, **57**, 317–23.*

required. For example, a herd with a high percent-

Cousins, C.M. (1978) Milking techniques and the microbial

age of cases requiring repeat treatments is likely to

flora of milk. In Proceedings XXth International Dairy Con-be affected by staphylococcal or streptococcal cow-

gress, Paris.

to-cow transmitted mastitis. Alternatively, because

David, G.P. & Jackson, G. (1984) The collection and inter-

a heavily contaminated environment tends to

*pretation of herd mastitis data. British Veterinary Journal, **140**, 107–14.*

expose all cows to the same level of infection, a high

Eberhart, R.J., Hutchinson, L.J. & Spencer, S.B. (1982) Rela-incidence of environmental mastitis would be seen

tionship of bulk tank somatic cell counts to prevalence of

in the records as a high percentage of cows affected,

intramammary infection and to indices of herd production.

almost an equal number of cases per 100 cows,

*Journal of Food Protection, **45**, 1125–8.*

but only low numbers of cases per mastitic cow

Fenlon, D.R., Logue, D.N., Gunn, J. & Wilson, J. (1995) A study and a low percentage of cases recurring. For herds

of mastitis bacteria and herd management practices to

with environmental mastitis, clinical case incidence

identify their relationship to high somatic cell counts in bulk will commonly be high but the cell count remains

*tank milk. British Veterinary Journal, **151**, 17–25.*

low.

Grindal, R.J. & Hillerton, J.E. (1991) Influence of milk flow rate on new intramammary infection dairy cows. Journal of

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Heeschen, W. (1975) Determination of somatic cells in milk

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quality and mastitis control in Canada: progress and

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milking teat preparation. In Proceedings British Cattle

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tis. Lea & Febiger, Philadelphia.

erties and yield and quality of milk products. Australian

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Wells, S.J. & Ott, S.L. (1995) Individual and bulk milk tank machine vacuum reserve and mastitis. Veterinary Record, somatic cell count results: what is the quality of the US milk ***81****, 122–4.*

supply? In Proceedings 34th Annual Meeting of National

Olney, G.R., Scott, G.W. & Mitchell, R.K. (1983) Effect of Mastitis Council, pp. 11–22.

milking machine factors on somatic cell count of milk from

Wilesmith, J.W., Francis, P.G. & Wilson, C.D. (1986) Incidence cows free of intramammary infection. Journal of Dairy

of clinical mastitis in a cohort of British dairy herds. Veteri-Research, ***50****, 135–52.*

nary Record, ***118****, 199–203.*

Chapter 26

The Milking Machine

D.J. O'Rourke

The equipment

353

the claw. The milk and air travel along the long milk

Functions of main components of a milking machine

353

tube to the container (bucket). A pulsator is normally

Milking machine testing

355

situated on the lid of the container and this admits air,

Static test

355

which aids in the collapse of the liners during the closed

Dynamic test

356

phase of pulsation. Air is also admitted through the

Milking machines and mastitis

357

regulator, which is situated on the vacuum pipeline.

Developments in milking machine technology

357

The flow pattern is similar in the milking pipeline

Shields

357

Ball claw

358

machine except that the milk and air from each claw

Hydraulic milking

358

flow through the milk pipeline to a common receiver

Automatic milking systems

358

where air and milk are separated (Fig. 26.2). Depend-

Automatic cluster removers

359

ing on the type of milk pump used, air may be admit-

Large-bore pipelines

359

ted when milk is released from the receiver and

High- and low-line plants

359

pumped to the bulk tank.

Liner design

359

The flow pattern of the recorder type of machine is

Backflushing

360

similar to the milking pipeline machine except that air

Automatic teat disinfection

361

admitted at the claw is separated from the milk at the

Control measures

361

recorder jar (Fig. 26.3). Air has to be admitted at this

point through a special inlet or through the teatcups at

the end of each milking operation to force the milk

The equipment

from the recorder jar to the receiver jar (which is under

vacuum). Some air may pass along with the milk as the

A milking machine installation consists of a pipework

jar empties, especially if the controls are not very

system linking various vessels and other components,

expertly handled. This air is separated from the milk at

which together provide the flow paths for air and milk.

the receiver jar.

The forces necessary to move air and milk through the

system arise from the fact that the system is maintained

at a vacuum. Thus it is atmospheric pressure that forces

Functions of main components of

air, intramammary pressure that forces milk, into the

system and the combination of these forces causes flow.

a milking machine

A milking machine has five basic components and

any machine, no matter how big, can be broken down

Vacuum pump: To extract air and maintain the

into these components (Figs 26.1–26.3):

machine under vacuum.

• Vacuum pump: to supply the vacuum

Interceptor: To prevent the ingress of foreign matter

• Regulator: to control the vacuum level

into the vacuum pump.

• Pulsators: to open and close the liners

• Clusters: to attach to the cow

• Containers: to store the milk

Sanitary trap: To prevent milk vapour from entering

the pulsators.

Figure 26.1 shows diagrammatically the flow of air

and milk through a bucket milking machine. Milk

enters the teatcups and travels through the short milk

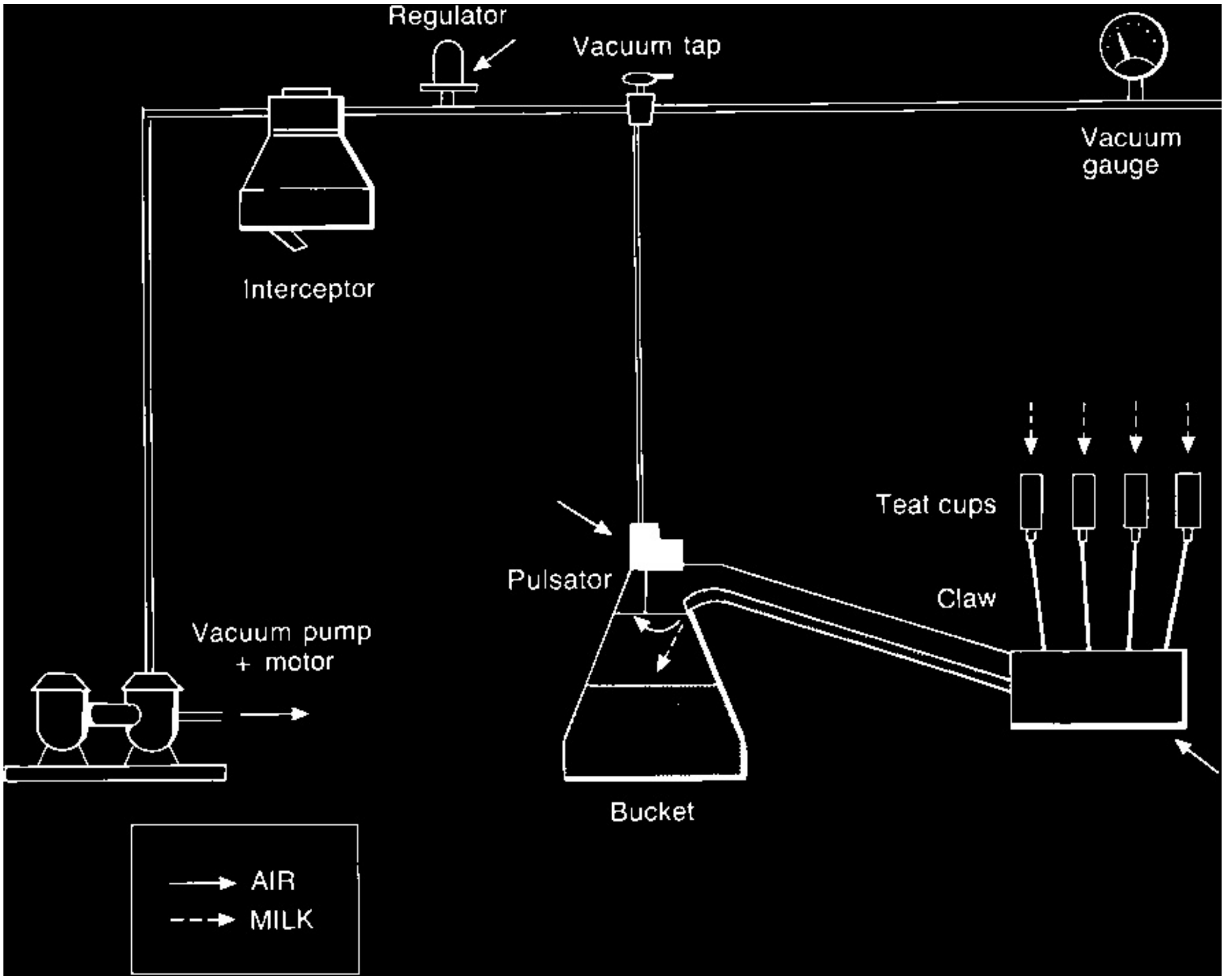
Vacuum regulator: To maintain a constant vacuum

tubes to the claw where air is admitted to break up

level. It limits the maximum level by admitting air

the columns of milk and improve milk flow away from

into the plant when a predetermined vacuum level



Regulator
Vacuum tap
Vacuum gauge
Interceptor
Teat cups
Pulsator
Claw
Vacuum pump + motor
Bucket
AIR
MILK

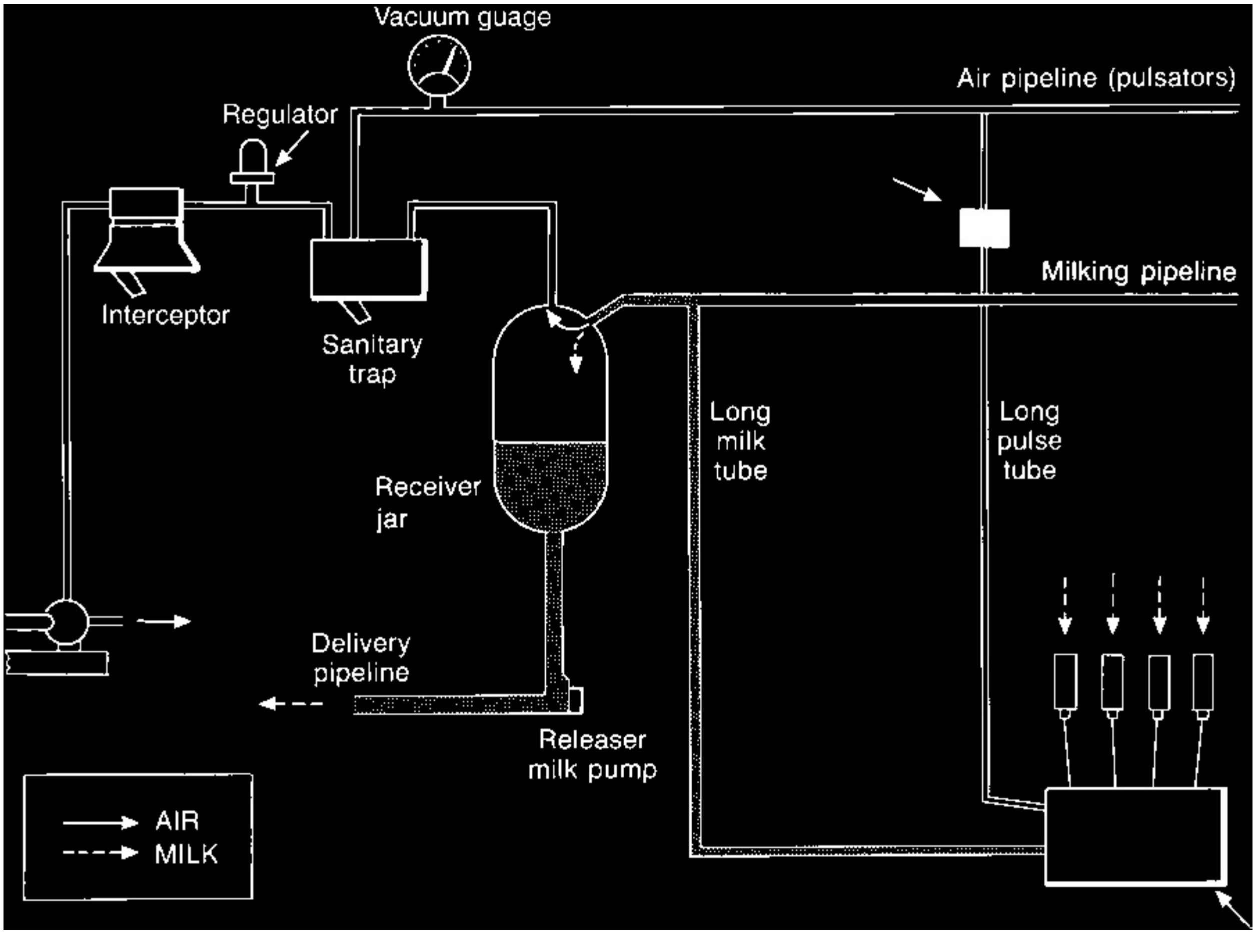


Fig. 26.1

Bucket milking machine.

Fig. 26.2

Milking pipeline machine.

has been reached. When the vacuum level drops, the

sation chamber the liner collapses, milk flow stops and

regulator closes; this stops admission of air and the

the teat is massaged. In fact, milk generally flows when *vacuum level rises until the preset level of vacuum*

the liner is more than half open. The exact function of

is reached, at which time the regulator opens again and

pulsation has not been established but is now thought

admits air.

to be relief of congestion around the teat orifice. Figure

26.4 shows a typical pulsation chamber waveform

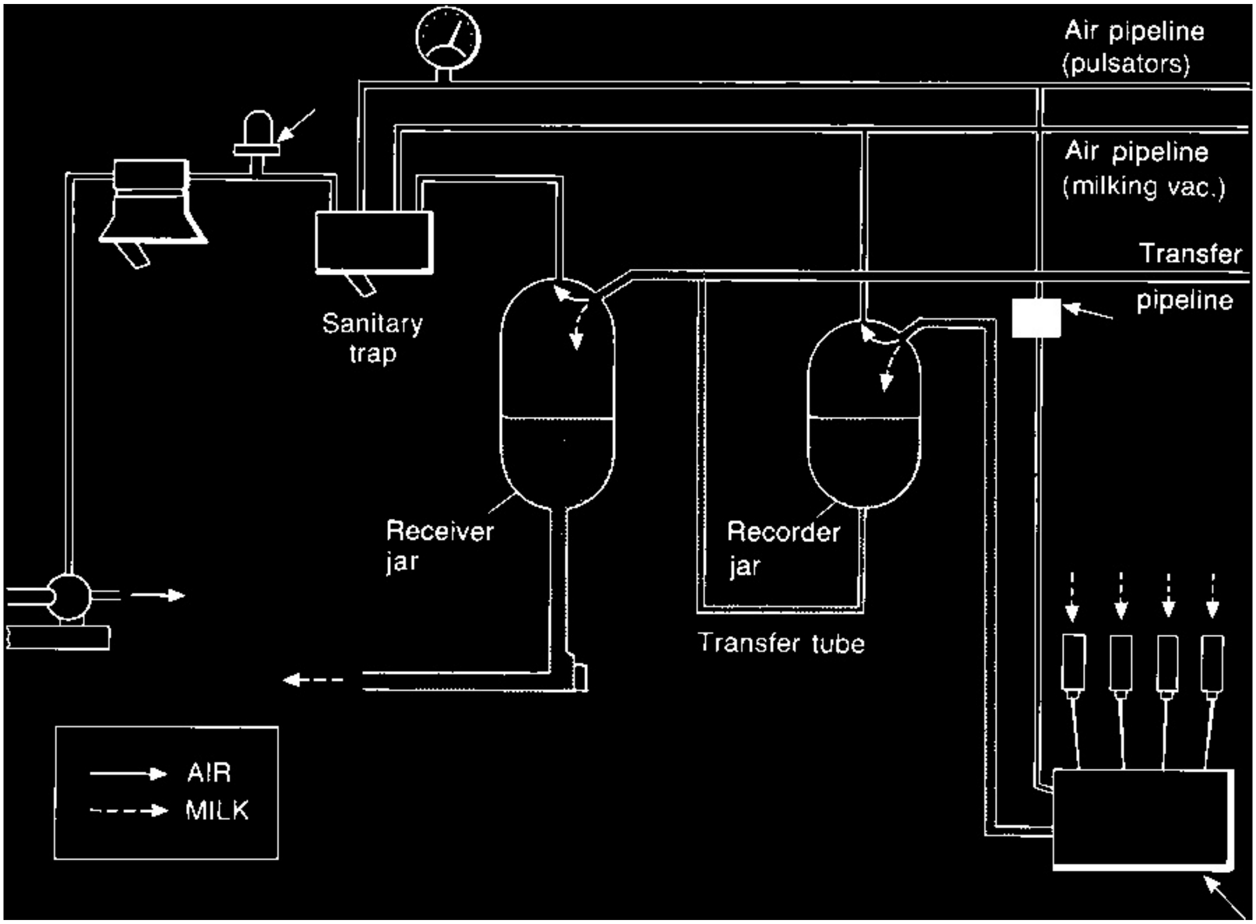
Pulsation: This causes the liner to open and close: when containing four phases: (i) a phase, liner opening; (ii) b

there is vacuum in the pulsation chamber the liner

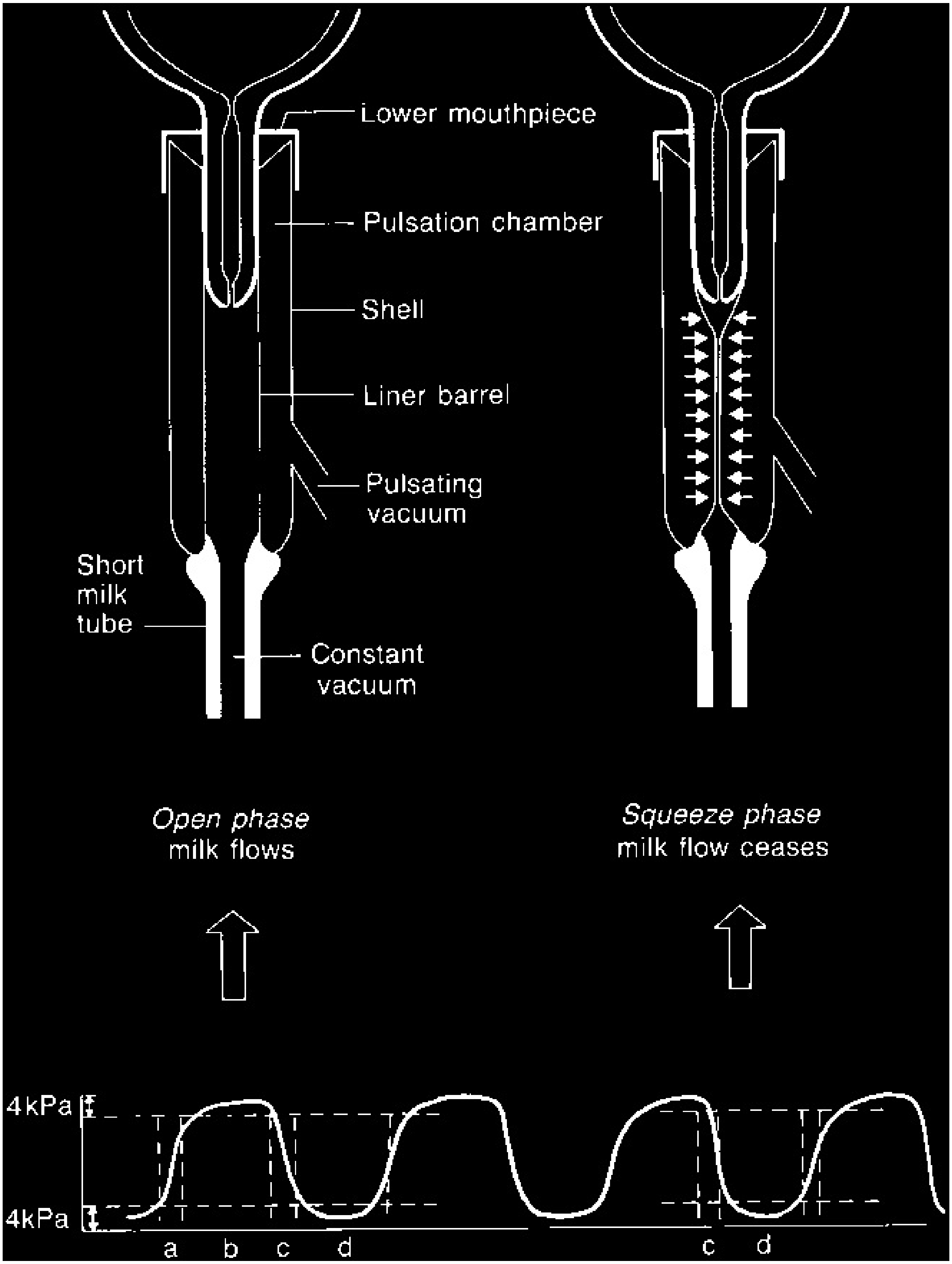
phase, liner fully open; (iii) c phase, liner closing; and

opens and milk flows; when air is admitted into the pul-

(iv) d phase, liner fully closed.



Air pipeline
(pulsators)
Air pipeline
(milking vac.)
Transfer
pipeline
Sanitary
trap
Receiver
jar
Recorder
jar
Transfer tube
AIR
MILK



Lower mouthpiece
Pulsation chamber
Shell
Liner barrel
Pulsating vacuum
Short milk tube
Constant vacuum
Open phase milk flows
Squeeze phase milk flow ceases
4kPa
4kPa
a b c d
c d

Fig. 26.3

Recorder milking machine.

Milking machine testing

Milking machines are tested to assess whether they are in good mechanical condition and conform to working standards as laid down by the standards institution of that country where used. Static and dynamic tests are used.

Static test

This type of test has been carried out for many years. It is basically an engineer's test to check for correct functioning of the components of the machine. The machine is set for milking and plastic bungs placed in the liner mouthpieces. No milk flows and, therefore, the test does not give an indication of how the machine will perform during milking.

There are three measurements to look for when interpreting a static test report:

(1)

Effective reserve. Vacuum within the plant is *created by the vacuum pump. Air is used by the*

pulsators, air holes in the claws and leaks in the

plant, etc. The spare vacuum capacity left after

compensating for these leakages is called the

effective reserve. The effective reserve is used to

Fig. 26.4

Pulsation chamber waveform.

compensate for additional leakages during cluster

application and removal and cluster fall-off.

Liners: The performance of liners is related to various (2)

Pulsation. Table 26.1 shows the recommendations

dimensions of liners and various other physical proper-

for pulsation characteristics.

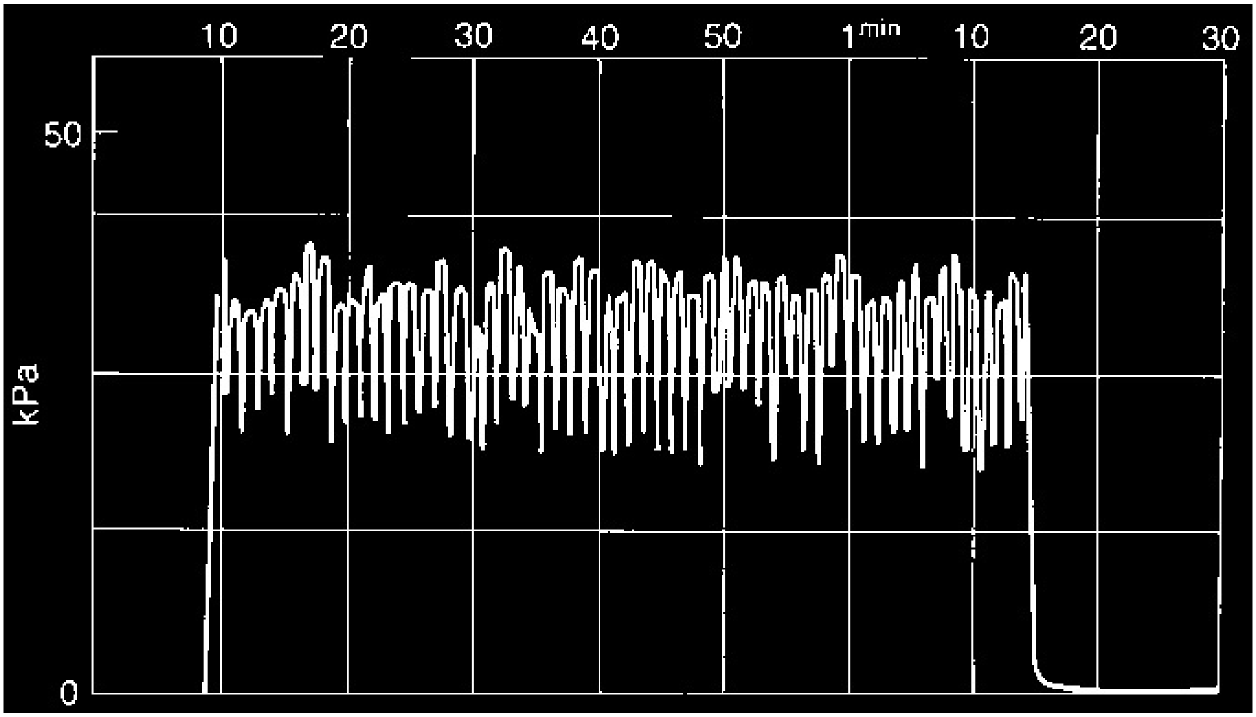
ties of the liner. The liner is the major determinant

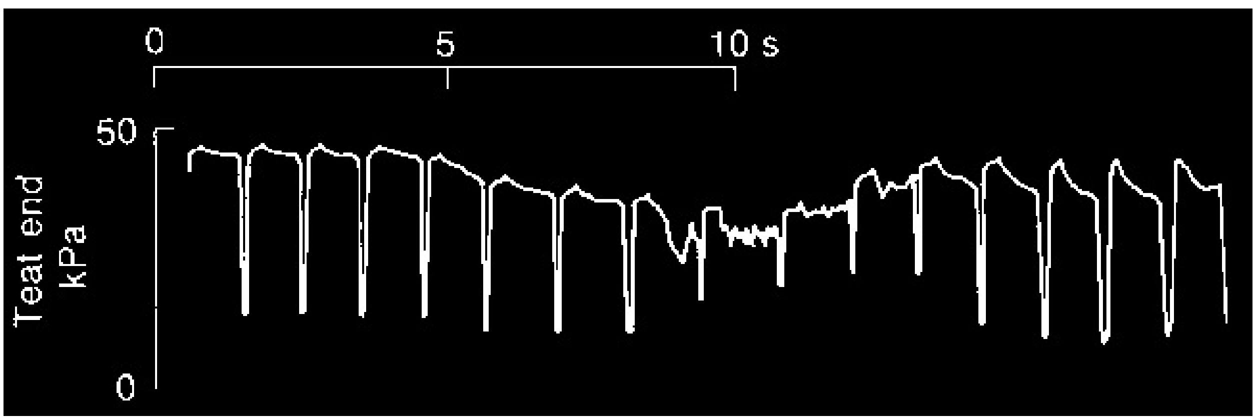
(3)

Leakages: The static test will measure the air con-

of milking characteristics (O'Shea, 1982).

sumption of the major components in the machine


10
20
30
40
50
1 min
10
20
30
50
kPa
0


0
5
10 s
50
Teat end kPa
0

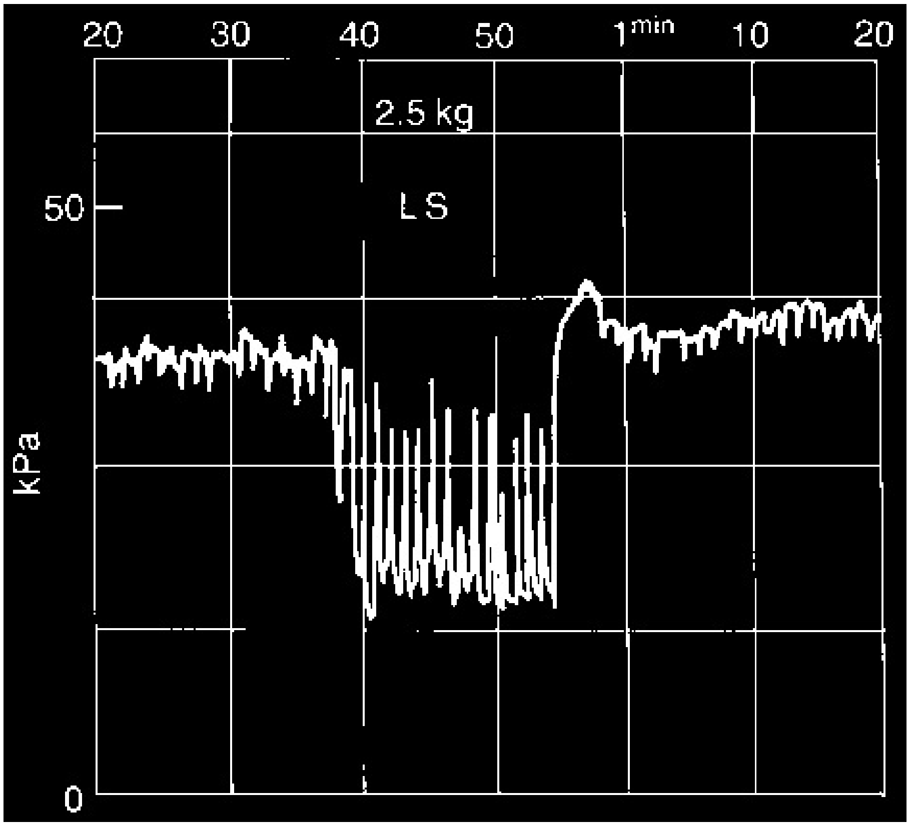


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Table 26.1

Recommendations for pulsation characteristics.

Source: O'Shea (1982), reproduced with permission.

Parameter	Acceptable range
Rate	53–63 c/min
Ratio (atb : ctd)	55–70%
d-value	

Not less than 15%

and there is a set of standards for the maximum

consumption allowed. It is worth checking that the

results of the test are within the normal range.

Fig. 26.5

Vacuum changes (cyclic fluctuations) at the teat end

during milk flow.

Practical tips

As a veterinary surgeon in practice there are two simple

ways of checking the effective reserve of a machine:

(1)

Put plant in milking position with plastic bungs in

the liners. For every five units, open one and let air

in. If the effective reserve is sufficient the vacuum

level, as read at the vacuum gauge, should not

drop by more than 2 kPa (about 3/

Fig. 26.6

Vacuum changes (irregular fluctuations) at the teat

4

inch Hg)

(O'Shea, 1982).

end during milk flow. Source: Nyhan (1968).

(2)

Again put plant in milking position with plastic

bungs in the liners. By letting air in the plant, via

the gate valve, drop vacuum to 33 kPa (10 inches

Hg). Close off air leakage. The vacuum should

return to 50 kPa (15 inches Hg) within 3 seconds

(Mein, 1984).

Dynamic test

Dynamic testing was indicated in only 1 per cent of

herds (O'Callaghan et al., 1982) where there was a mastitis problem and the static test had revealed no faults.

At that time, equipment was either very sophisticated

and expensive (UV recorder) or crude (pulsation pen

recorder). In recent years, with the advent of computer

Fig. 26.7

Liner slip at the teat end during milk flow. LS, liner

technology, new recording machines specially designed

slip; 2.5 kg, flow rate of 2.5 kg/min.

for dynamic testing have been developed.

In dynamic testing the vacuum level is measured at *the clawpiece and other areas of the machine, e.g. the*

recorder jar, throughout the milking of a number of

• Irregular fluctuations: occur as a result of changes in cows. This allows the determination of what is happen-airflow during milking, which leads to a drop in

ing when milk and air are flowing in the machine and

vacuum (Fig. 26.6).

also assessment of the ability of the milker to use the

• Liner slip: sudden air admission between the liner

machine properly.

and the teat (Fig. 26.7). A problem exists if more

There are three measurements to look for when

than five slips or falls per 100 cows require correc-

interpreting a dynamic test reading:

tion by the milker(s) (Mein, 1984).

• Cyclic fluctuations: generated within the claw as a

It should be noted that 50 per cent of the faults detected

result of pulsation (Fig. 26.5).

in a dynamic test are operator related .

Milking machines and mastitis

most frequent in cows with high milk flow rate (O'Shea

et al., 1980).

The milking machine can act as vector in three ways: (i)

Further work carried out on simulated liner slips at

cow-to-cow transfer of bacteria via contaminated clus-

Moorepark in the early 1980s (O'Shea et al., 1981)

ters; (ii) internal flow between clusters within the plant;

yielded the following results:

and (iii) quarter-to-quarter transfer within the cow via

• There were equal numbers of new infections with

the claw.

inaudible and audible liner slips.

A farm survey in Ireland in 1967 showed a highly

• Liner slips at start of milking or the end of milking

significant regression of bulk milk cell count on effec-

only, or during the total milking caused almost

tive reserve of the miking plant, i.e. as effective reserve

equal numbers of new infections.

decreased cell count increased (Nyhan & Cowhig,

• Liner slips increased new infections when teats

1967). Subsequent work showed that unstable vacuum

were heavily contaminated with environmental

(a combination of large irregular fluctuations and

bacteria (Escherichia coli

and

Streptococcus

moderate cyclic fluctuations) caused higher new infec-

dysgalactiae).

tion rates than stable vacuum.

Further work carried out at the National Institute for

Liner slip is now considered to be the major mechanism

Research in Dairying (NIRD) at Reading in the early

of spread of mastitis at milking (O'Shea et al., 1981).

1970s (Cousins, 1972; Cousins et al., 1973; Thiel et al., Baxter et al. (1990) found that new intramammary

1973) found that large irregular fluctuations or large

infection rates (IMI/100 cow days) were 0.379 in cows

cyclic fluctuations per se did not increase new infection milked with high-slip liners and 0.277 in those milked

rates. However, any combination of large irregular

with low-slip liners (p = 0.056). Clinical cases per 100 cow fluctuations with *substantial cyclic fluctuations caused a*

days were 0.211 in the high-slip group and 0.158 in the

large increase in new infections. The results also sug-

low-slip group ($p > 0.05$). Rogers and Spencer (1991) gested that infections were most likely to be initiated

found that variation between cows in machine liner slips,

towards the end of milking.

and manual milking machine adjustments within and

During the late 1970s research workers at Moorepark

across lactation number and days in milk can be partially

in Ireland (O'Callaghan et al., 1976; O'Shea et al., 1976, explained by udder and teat morphology. Wider teats

1979, 1981; O'Shea & O'Callaghan, 1978, 1982) showed

(distances between teats) were associated with

that plant vacuum stability per se had little effect on increased liner slips and increased manual milking

new infection rate. It was suggested that the effect of

machine adjustments. More tilted udders (rear quarters

generalized vacuum instability is mediated via

lower than front quarters) were associated with

increased liner slip,

i.e.

sudden air admission

increased liner slips and tended to be associated with

between the liner and the teat. Liner slip, in turn, is

increased manual adjustments. In addition, poor unit

largely a function of liner design and also of vacuum

alignments, larger teat diameter and longer teats tended

stability.

to be associated with increased liner slips.

When slip occurred in one quarter, impacts of milk

droplets were detected in other quarters connected by

Developments in milking

the claw to the teat in which the slip occurred and a

machine technology

higher number of new infections occurred in these

impacted quarters.

Shields

This liner slip theory is compatible with many other

results. Liner slips are more frequent at foreteats; in-

During the late 1970s research workers at Reading

fections are more often seen in hind quarters (Rabold

developed shields (deflector plates) in the teatcup

& Picher, 1980). Slip frequency is most common at
chamber between the short milk tube and the teat end
morning milkings and high flow rates and infections are
(Fig. 26.8). Trials on 15 herds in England and 16 herds

Fig. 26.8

Shielded liner. Photo courtesy
of Institute of Animal Health (IAH),
Compton.

Fig. 26.9

Ball claw cluster. Photo
courtesy of Institute of Animal Health
(IAH), Compton.

in Australia showed that shields prevented about 10 per
problem. Grindal and Griffin (1989) carried out four
cent of quarters from becoming infected (Griffin et al., trials comparing

hydraulic milking with the valve claw-1980a).

piece with airbleeds. Milk flow rate was increased by 20

per cent and milking time was decreased by 26 per cent

Ball claw

with hydraulic milking. Quarter infection ratios were

low in both groups with only two out of 88 quarters

In the early 1980s research workers at Reading devel-

infected with challenges with Streptococcus agalactiae

oped a cluster to prevent the transfer of pathogens

and S. dysgalactiae in each treatment group.

between teats during milking (Griffin et al., 1980b). It was a simple practical modification of the clawpiece for

Automatic milking systems

each of the four short milk tube connectors (Fig. 26.9).

Field trials showed an overall 14 per cent reduction in

About 100 automatic milking systems are currently in

new infection rate due to the clawpiece (Griffin et al., use on farms in Germany (Schon et al., 1997). Milking

1982). However, there was an unexpected larger reduc-

robots are used at 200 Dutch dairy farms and it was

tion (17 per cent) in new infection rates from environ-

forecast that >800 farms would be using them by 2000 *mental sources of exposure (Streptococcus uberis,*

(Ipema et al., 1998). Data (1996–98) on milk quality

coliforms and others) than from those (8 per cent)

were compared between 28 Dutch dairy farms using

transmitted mainly at milking time within the udder or

milking robots and those with machine milking three

on teat sores (Staphylococcus aureus, Strep. agalactiae times/day (28 farms) and twice/day (49 farms). Para-and Strep. dysgalactiae).

meters were somatic cell count, pH of milk fat, freezing

point, clarity, fatty acids, milk fat and milk proteins.

The use of a milking robot resulted in increased somatic

Hydraulic milking

cell counts and pH of milk fat, and decreased percent-

Following research on the ball claw, Griffin and Grindal

ages of milk fat (from 4.43 to 4.37 per cent) and milk

carried out an experiment to ascertain the effects of

proteins (from 3.49 to 3.42 per cent). The main differ-

blocking the air bleed on new infections. Initial results

ences are due to the construction, design and cleaning

from a closely controlled small scale experiment in a

of milking robots and cooling tanks (Klungel et al., *research herd showed that teat end condition was*

1998).

improved and that it was at least equal in preventing

Working and utilization of a milking robot were

mastitis to milking with the valve clawpiece with air-

studied in a herd of 40 cows during the first 12 weeks

bleeds (Griffin, 1985). This new method of milking was

of lactation (Pomies et al., 1998). After a training period, christened 'hydraulic milking'. Research at Compton

cows had free access to the robot for 18 hours/day.

on the ball claw under hydraulic milking conditions has

During starting phase, frequency of breakdown of the

shown that as the liner starts to open, high vacuum

robot was 1.4 times/week, the rate of automatic attach-

levels (up to 90 kPa) are generated beneath the teat

ment of the cluster when a cow entered the robot was

(Grindal, 1987). Although high vacuum levels have

80 per cent (70 per cent within the first two attempts)

been shown to increase teat damage during conven-

and manual attachment was 2.6 per cent. Five cows

tional milking (Smith & Peterson, 1946), further trials *were removed from the robot due to problems on the*

with hydraulic milking have not shown this to be a

front right quarter (reference for attachment of

Table 26.2

Recommendations for sizes of milking pipelines.

sonable, while the 62 mm (21/2 inches) and 75 mm (3

Source: O'Callaghan et al. (1982).

inches) may not have been thoroughly evaluated

(Spencer, 1981).

Number of units

Minimum bore of milking

pipeline (mm)

High- and low-line plants

2–5

31

Milking systems can be divided into two types depend-

6–8

38

ing on the level of the milking pipeline in relation to the

9–20

cow's udder. Where the milking pipeline is above the

udder it is called a high line and a low line if it is below

the udder.

cluster). The number of daily milkings was 2.4 and the

Midi-level pipelines (1.2 to 1.5 m above cow standing

daily milk yield was 27.9 kg. Clinical mastitis and milk

level) are recommended. Very high pipelines increase

composition and quality were similar to normal values

the level of cyclic fluctuations at the teat end (Thiel

of the herd, except for butyric acid bacterial counts,

et al., 1968). Low-level pipelines (under the cow stand-which were three times higher in the robotic-milked

ing level) decrease fluctuations and increase milking

cows.

rates by 3 to 8 per cent (Phillips & Copeman, 1969).

However, low-level plants are susceptible to contami-

nation by urine and faeces. In herringbone parlours one

Automatic cluster removers

unit must be used per stall, which is only 60 per cent as

Automatic cluster removers (ACRs) are an important *efficient as two stalls per unit (O'Callaghan et al. , 1982).*

development in eliminating overmilking and improving

In midi-level pipeline plants vacuum fluctuations are

labour efficiency. Persistent and excessive overmilking

reduced by having air admission holes in the claw (Thiel

can cause external damage to the teat, which may

et al., 1968) but if these holes are not kept patent mas-increase the susceptibility to udder infection

titis levels are likely to increase (Hopkirk et al., 1943).

(Shepherd, 1985). However, ACRs are not recom-

mended in two stalls per unit herringbone parlours.

Liner design

Limited overmilking does not increase new infection

rate. ACRs do not reduce the work routine time, unless

Liner design can have a greater effect on milking char-

operators have been spending time moving up and

acteristics than any other machine factor. Six-fold

down the pit to remove clusters as soon as cows have

differences in strip yield, eight-fold differences in the

stopped milking. ACRs improve throughput in rotary

incidence of liner slips and 33 per cent differences in

parlours, provided teat disinfection is automated; in this
milking times between liner types have been reported.
case one operator less is needed. ACRs which admit air
Machine-induced congestion and oedema is reduced
blasts into the claw (to activate the automatic shut-off)
by milking with a ‘narrow-bore’ liner with a soft mouth-
at cluster removal should not be used (O’Shea et al.,
piece. The internal diameter of a liner is usually meas-
1984). Ramussen (1993) showed that early cluster
ured at a point 75 mm below the mouthpiece. Liners
removal (400 g/min), when compared to normal level
should have a barrel diameter about 1–2 mm less than
for cluster removal (200 g/min), decreased machine-on
the average diameter of the teats after milk letdown
time by 0.5 minutes, increased average milk flow rates
(approximately 21–22 mm). Liners should be designed
slightly, improved teat condition significantly and
to fit teatcup shells. The mouthpiece should not be dis-
reduced the change in teat end thickness during milking
torted by the shell, but the liner should be held firmly
of first lactation cows. Early removal did not affect milk

enough not to twist easily in the shell. Teatcup shells

yield or composition or the incidence of subclinical

should all be the same length (within 2 mm) to ensure

mastitis.

uniform liner tension and to distribute the cluster

weight more evenly between the four quarters

(National Mastitis Council, 1996).

Large-bore pipelines

In North America narrow liners with a supple mouth

These are used in the USA, where it is not uncommon

are preferred, as these are thought to reduce the risk of

to see milk lines of 75 mm (3 inches) in diameter. At

oedema of the teats. It is considered that the diameter

present, standards for sizes of pipelines are recom-

of the liner should be 1–2 mm less than that of the teat

mended by the International Dairy Federation (Table

after milking, thus providing sufficient friction between

26.2). At a National Mastitis Council Meeting in the

the liner and the teat. The liner should also be long

USA, it was stated that the American standards for

enough to enclose the teat completely. The liner must

38 mm (11/2 inches) and 50 mm (2 inches) pipes are rea-

be well aligned in the teatcup. Liners may be made from

natural rubber, synthetic rubber, silicone or a mixture

Results from studies carried out at NIRD (Neave,

of these products; the material used will largely deter-

1971) indicated that circulating water at 85°C through

mine the lifetime of the liner (Levesque, 1998). Most

the cluster for at least 5 seconds is the best way to

manufacturers recommend that rubber liners are used

achieve near sterilization of liners between milkings,

for between 2000 and 2500 cow milkings and then

although a cold hypochlorite flush reduced numbers of

changed. The recommended life of silicone liners is

bacteria to very low numbers (Table 26.3).

5000 cow milkings or 5 months – whichever comes first.

Laboratory experiments showed a large reduction

Theoretically they have a longer life than rubber liners

in bacteria (about 99 per cent) after backflushing with

as silicone does not absorb fat. However, in practice

cold water (Jasper & Bushnell, 1978) and an initial *they are more susceptible to tearing and puncturing*

flushing with an iodine disinfectant appeared to give

than rubber liners and are likely to split if cows step

better results. The authors concluded that even though

on them, as well as being three to four times more

complete sterility may not be achieved, backflushing

expensive.

should be helpful in reducing cow-to-cow transfer of

pathogens on liners. Around this time automatic back-

flushing systems using cold water rinses with or without

Backflushing

a chemical disinfectant between cold rinses were

Liners are a potent method of disseminating pathogens

developed.

both within and between cows. The number of

Eriksen and Rasmussen (1994) carried out a 9-week

pathogens recoverable from liners after milking

experiment with 283 cows in two groups, a control and

infected cows is related to the number of bacteria in

an experimental group. The teatcup liners of the exper-

milk from the infected cow. Consequently, it is recom-

imental group were backflushed with the Airwash
mended that clusters should be disinfected between the
system between milking each cow. The liners were
milking of infected cows. The most common practice is
flushed with a combination of compressed air and luke-
to dip the cluster in a disinfectant solution for a couple
warm water through small inlet valves placed in the
of seconds. Such a practice generally reduces the
short milk tube. The flushing sequence was water for
number of pathogens transferred from cow to cow.
4 s and compressed air for 2 s, repeated for 30–40 s.
However, such practice has often been rendered inef-
Automatic backflushing of liners reduced the total
fective because contamination of milk neutralized the
bacteria count by 50 per cent, coliforms by 68 per cent
disinfectant solution, air locks within the cluster pre-
and Staphylococcus aureus by 61 per cent without
vented entry of the disinfectant or the milker failed to
having any effect on udder health and somatic cell
carry out the procedure correctly.
count.

Table 26.3

Disinfection of teatcup clusters after removal from cows with mastitis. Source: Neave (1971), reproduced with permission of The British Cattle Veterinary Association.

Treatment of cluster	***Time***	***No. tested***	***% positive after disinfection***	***No. of Staph. aureus recovered per cluster***
Cold water flush	*5 s*	*19*	*100*	*100 000–800 000*
Cold hypochlorite circulation	*3 min*	*19*	*100*	*50–2000*

(0.03%)

Circulation of water at 66°C

3 min

18

22

0–80

Circulation of water at 74°C

3 min

85

0

0

Circulation of water at 85°C

5 s

530

3

0–15

Table 26.4

A comparison of teat disinfection methods. Source: Anon (1983).

Dipping

Hand spraying

Auto spraying

Time taken (min/cow)

0.08–0.10

0.04–0.08

Nil

Teat-end coverage (%)

95–100

79–97

96–99

Volume used (ml/cow)

5–10

10–13

30

Chemical type

Various

Iodophor

Dilute hypochlorite

Automatic teat disinfection

milking machine on the rate of new mastitis infections.

Journal of Dairy Research, ***40****, 289–92.*

Several automatic teat disinfection systems are avail-

Eriksen, L. & Rasmussen, M.D. (1994) Automatic backflush-

able. These are fitted to the exit race of the parlour

ing of teatcup liners by the Airwash system. [Danish] Effek-

and consist of a pressure spray unit fitted with a set of

ten af afskylning af pattekopperne med Airwash-systemet

nozzles. The spray is activated by an electronic control

pa bakterieforekomst og yversundhed. Forskningsrapport

unit, which detects the presence of the cow (Hunter,

fra Statens Husdyrbrugsforsog. Statens Husdyrbrugsforsog,

1985). Table 26.4 shows that with automatic teat spray-

Tjele, Denmark: 1994. No. 25.

ing it is possible to achieve as good coverage as dipping.

Griffin, T.K. (1985) The use of valve clawpieces in the control of mastitis. In Proceedings of the International Dairy Feder-Automatic spraying will use more chemical. However,

ation Seminar Progress in the Control of Mastitis, Kiel, as it is outside the parlour it is possible to use the much

Germany, p. 625.

cheaper chemical hypochlorite.

Griffin, T.K., Bramley, A.J., & Dodd, F.H. (1980b) Milking machine modifications in the control of bovine mastitis. In

Proceedings of the International Workshop on Machine

Control measures

Milking and Mastitis, Moorepark, pp. 19–29.

Griffin, T.K., Grindal, R.J., Staker, R.T., Shearn, M.F.H.,

The milking machine is only one component that can

Bramley, A.J., Simpkin, D.L., Higgs, T.M. & Westgarth, D.R.

be involved in mastitis. Mastitis control involves con-

(1982) Development and evaluation of control techniques

tinued implementation of each of the recommendations

for bovine mastitis. Control of intramammary infection by

in the five-point control programme. Changing some of

modification of the design of the milking machine. Report

the components in the milking machine may help in

of the National Institute for Research in Dairying, Reading,

the short term, but only a concerted effort in carrying

pp. 37–8.

Griffin, T.K., Mein, G.A., Westgarth, D.R., Neave, F.K.,

out the full programme will control mastitis in a herd

Thompson, W.H. & Maguire, P.D. (1980a) Effect of deflector in the long run.

shields fitted in the milking machine teat cup liner on bovine The following points are recommendations that

udder disease. Journal of Dairy Research, **47**, 1–9.

should help to reduce mastitis resulting from the

Grindal, R.J. (1987) Effect of ball-valve milking clusters on

milking machine:

*udder disease. Veterinary Record, **121**, 250–2.*

Grindal, R.J. & Griffin, T.K. (1989) Effect of hydraulic milking

• Maintain proper vacuum levels.

on milking performance, teat condition and lipolysis.

• Attach and remove clusters properly to minimize

*Journal of Dairy Research, **56**, 45–53.*

massive changes in vacuum and resulting from

Hopkirk, C.S.M., Palmer-Jones, T. & Whittlestone, W.G. (1943) entry of air into the clawpiece.

The effect of closed air admission holes on the health of the

• Make sure clusters are attached properly on each

udder of dairy cows. New Zealand Journal of Agriculture, cow.

***66**, 30–1.*

• Select liners with low slip characteristics. Replace

Hunter, A.C. (1985) Milking Routine. In Hygienic Milk Pro-

rubber liners every 2500 milkings or every 6

duction. The Scottish Milk Marketing Board, p. 42.

months, whichever comes first, and siliconized at

Ipema, B. Smits, D. & Jagtenberg, C. (1998) Practical experi-5000 milkings or every 5 months, whichever comes

ences with milking robots. [Dutch] Praktijkervaringen

first.

met melkrobots. Praktijkonderzoek Rundvee, Schapen en

*Paarden, **11**, 37–9.*

• Dry teats before attaching clusters in order to

Jasper, D.E. & Bushnell, R.B. (1978) Influence of premilking reduce the number of bacteria.

sanitation on transfer of infection during milking. In

• Have the machine tested at least once a year.

Proceedings of the International Symposium on Milking

Machines and Mastitis, 17th Annual Meeting of the National Mastitis Council, Louisville, Kentucky, pp. 231–41.

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33–6.

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versity of Reading.

Mastitis, Werribee, Australia.

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Chapter 27

Skin Infections of the Bovine Teat and

Udder and Their Differential Diagnosis

J.K. Shearer, J.R. Townsend and E.P.J. Gibbs

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Infectious lesions of the teat

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(see Table 27.1)

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Differential diagnosis of skin lesions of the bovine teat

Bovine herpes mammillitis (BHM)

Aetiology

Introduction

Bovine herpes mammillitis (BHM) is caused by bovine

herpesvirus 2 and is closely related, if not identical, to

Teat lesions in milking cattle are due to a variety of

Allerton virus (p. 887), the causative agent of pseudo-

causes, infectious and non-infectious. Viral skin infec-

lumpy skin disease; it is unrelated to bovine herpes

tions of the bovine teat and udder are principally due

virus 1, the aetiological agent of infectious bovine

to pseudocowpox virus, bovine herpesvirus 2 and papil-

rhinotracheitis.

lomavirus, but, on occasions, teat lesions may occur in

The genome is linear double-stranded DNA, 220 kbp.

association with a generalized viral infection, such as

The virus produces intranuclear inclusions and syncytia

foot-and-mouth disease, vesicular stomatitis, or mucosal

in infected cells.

disease. Although the vernacular use of ‘cowpox’ to *describe any teat infection is common, cowpox (as*

caused by cowpox virus) is an unusual disease and has

Epidemiology

been recognized only in Europe. There are several

bacterial and non-infectious skin conditions of the teats

Also known as bovine ulcerative mammillitis, BHM

and udder that can be equally as troublesome as viral

was first recognized in Scotland. The virus has since

infections. Irrespective of cause, when teat infections

been isolated from affected cattle worldwide in coun-

occur in a milking herd they predispose cattle to sec-

tries such as the USA, Australia and Brazil.

ondary bacterial infection by Staphylococcus aureus,

In the northern hemisphere, BHM commonly occurs

Streptococcus dysgalactiae and other bacteria. Cows,

as a seasonal disease between August and December.

and particularly newly calved heifers, become difficult

In a completely susceptible herd, the disease spreads

to milk and the milking time may be prolonged by as

quickly with nearly all cows developing infection over

much as 50 per cent.

one to two months. In other herds, only the newly

Currently, there are no vaccines in use to protect

calved heifers introduced into the milking herd for the

cattle from any of the viral teat diseases and treatment

first time are affected. Recrudescence of clinical disease

Table 27.1

Infectious conditions of the teat and udder skin of

Pseudocowpox

cattle.

Aetiology

Cowpox and vaccinia

Initially confused with cowpox virus, it was not until

Pseudocowpox

1963 that it was demonstrated in the USA that pseudo-

Bovine herpes mammillitis (BHM)

cowpox virus was a member of the genus Parapoxvirus.

Bovine papillomatosis (warts)

Pseudocowpox virus is closely related to the virus of orf

As part of generalized disease, e.g.

foot-and-mouth disease

(contagious ecthyma, contagious pustular dermatitis) of

rinderpest

sheep, and also to the bovine papular stomatitis virus.

lumpy skin disease

The virus contains a linear double-stranded DNA,

mycotic dermatitis

130 kpb, and produces intracytoplasmic inclusions in

infected cells.

is unusual, even though latent infections do occur.

Whether latently infected older cattle are the reservoir

Epidemiology

of infection from which the newly calved heifers

Referred to in the past as false cowpox, varicella, water-

become infected is conjectural. It is thought that sus-

pox, udderpox and natural cowpox, pseudocowpox

ceptible pregnant cows may become infected some time

occurs in most countries of the world. It is the most

before parturition, but do not develop the lesions until

common infectious cause of teat lesions in North

calving.

America and the UK. Lesions of pseudocowpox may

The method of transmission of the virus between

be seen in a herd during any season of the year. The

farms with closed herds is unknown, although biting

immunity is short-lived, lasting four to six months; thus,

flies have been incriminated as possible vectors.

pseudocowpox is commonly seen as a chronic problem

in most herds. Although herd morbidity may reach 100

Clinical signs and lesions

per cent, only 5–10 per cent of the herd may be infected

at any one time. Nevertheless, it may occur as an acute

Bovine herpes mammillitis is a disease initially char-

herd problem, which spreads rapidly affecting a major-

acterized by a painful oedematous teat swelling. The

ity of the cows in the herd. Lesions in such primary out-

incubation period ranges from three to seven days. The

breaks are frequently more extensive.

disease is generally more severe than either cowpox or

pseudocowpox and the lesions are ulcerative rather

than proliferative. Newly calved heifers are usually the

Clinical signs and lesions

most severely affected, particularly if they have post-

parturient oedema of the udder. Initial lesions are

The clinical presentation of pseudocowpox is variable.

followed by the development of an irregularly shaped

Usually no systemic illness is noted and vesicle forma-

vesicle (0.5–5.0 cm in diameter) (Plate 27.1). Within 24

tion may not be observed. After an incubation period of

hours, the vesicles rupture, leaving an ulcerated surface

about six days, localized erythematous and oedematous

that exudes copious serum (Plate 27.2). Upon drying,

areas appear on the teats. These lesions are painful,

this exudate forms a thick, dark reddish-brown scab

making cows difficult to milk. Within 38 hours, a small

(Plates 27.3 and 27.4). In the absence of secondary

orange papule develops, followed by the formation of

infection, healing is complete in three weeks by granu-

an elevated small dark red scab (2–3 mm) (Plate 27.9).

lation and regrowth of the epithelium (Plates

In some cases, a vesicle will form in the centre of the

27.5–27.8). Lesions on the udder may coalesce with

papule, but this is rare with pseudocowpox in contrast to *those of the teat and may extend to the perineum*

bovine herpes mammillitis. The progressive enlarge-

resulting in vulvovaginitis as a sequel to infection of the

ment of the edges of the lesions (Plate 27.10) leads to

skin of the mammary gland.

umbilication of the central scab. Healing of the lesion is

centrifugal and the primary scab is often shed after 10 to

12 days, leaving the classical raised 'horseshoe' or 'ring'

Differential diagnosis

lesion, which is pathognomonic for pseudocowpox

Bovine herpes mammallitis usually occurs in summer

(Plate 27.11). As adjacent lesions enlarge, they may coa-

and autumn. The oedema of teats, vesication and

lesce to form linear scabs extending the entire length of

ulceration and extensive scab formation over most of

the teat (Plate 27.12). Pseudocowpox lesions are pri-

the teat surface are strongly suggestive of BHM. Epi-

marily found on the teat; however, 5–10 per cent of

demics of BHM can occur in a region, which can lend

affected animals develop lesions on the udder. Healing

support to the diagnosis.

usually occurs within four to five weeks, leaving no scars.

In herds where 'teat chaps' are common, pseudocowpox

tion of the causative BPV strain of a teat wart may be

virus can be detected in many of the lesions.

possible through gross examination. BPV-1 has been

In humans, pseudocowpox virus causes localized

demonstrated to be responsible for fibropapillomas of

infection on the fingers or hands, commonly called

the penis and teats. The teat warts have a filamentous

'milker's nodule'. These nodules are painful and may

or frond-like appearance. These warts are normally

extend to the entire arm of the person affected.

seen on younger animals and will typically regress over

a period of 1–12 months. BPV-5 produces small 'rice

grain' fibropapillomas, so named because of their white

Differential diagnosis

and elongated appearance. These warts are seen in

In contrast to BHM, pseudocowpox is a chronic

cattle of all ages, and, if natural regression occurs, it does problem in most herds. Lesions are proliferative, pro-so over periods of greater than a year. The *warts*

gressing to small ‘ring’ or horseshoe’ type lesions rather

produced by BPV-6 are papillomas that have a frond

than ulcerative. Atypical lesions (Plates 27.13–16) may

appearance and are considered the most common type

be observed and confused with warts or mild traumatic

of teat papilloma. These frond papillomas may regress,

injuries to the teats and udder but, in general, a careful

usually in a time frame of greater than a year.

examination of the herd will allow the clinician to dif-

ferentiate pseudocowpox from other diseases. It must

Cowpox

be remembered that pseudocowpox is often present in

herds where the major problem may be due to BHM or

Aetiology

even cowpox.

Cowpox virus shares with Jenner a central role in the

development of vaccines and the control of smallpox in

Papillomatosis (teat warts) *(see p. 882)*

man. The current use of vaccinia virus (the derivative

virus used for protection of man from smallpox) in a

Aetiology

new role as a recombinant vaccine vector for many

Bovine teat papillomatosis (teat warts) is a common

diseases, maintains attention on cowpox. Few people

finding of dairy cattle throughout the world. The

realize that cowpox was considered an unusual disease

causative agents of teat warts are several distinct strains

even in Jenner's time. Occasional outbreaks of cowpox

of bovine papilloma virus (BPV). The strains most com-

still occur in Europe, but from the perspective of the

monly implicated are BPV-1, BPV-5 and BPV-6. These

dairy industry they are of little importance.

strains of BPV are classified as members of one of two

The causative agent of the cowpox is an ortho-

subgroups. Strains in subgroup-A, which include BPV-

poxvirus, very similar to, but distinguishable from,

1 and BPV-5, produce warts with both dermal and

vaccinia virus by its biological properties in laboratory

epithelial components (fibropapillomas). Subgroup-B

animals and its larger genome (220 kbp compared with

strains, of which BPV-6 is a member, produce warts with

185 kbp for vaccinia virus). The virus produces intra-

only epithelial proliferation (papillomas). The virus

cytoplasmic inclusions in affected cells.

contains a closed, circular, double-stranded DNA

approximately 8000 bp in size.

Epidemiology

Epidemiology

The epidemiology of cowpox is unknown. Cowpox

virus has been isolated from skin infections in man and

The method of infection is thought to be similar to

carnivores in which no direct contact with cattle could

other bovine cutaneous warts in that transmission is by

be established. It is currently thought that rodents are

direct contact with infected animals or fomites. The

reservoirs of the virus.

virus needs cutaneous damage, such as abrasions, to

Once infection is present within a herd, however, the

gain entry into susceptible tissue. After infection occurs,

disease appears to spread by the milking machine and

incubation times of 1 to 6 months have been demon-

the hands of milkers. Between and within herds, biting *strated under experimental conditions. Abattoir studies*

insects may also be responsible for mechanical trans-

have shown that teats often have multiple warts and

mission. At present, the disease is confined to western

that prevalence increases with increasing parity.

Europe. In other areas of the world, outbreaks of teat

lesions, clinically indistinguishable from cowpox but

caused by vaccinia virus from an uncovered vaccination

Clinical signs and lesions

site in an attendant, have been reported. Since the

Because of the tendency of BPV strains to produce

eradication of smallpox in 1979, most countries have

morphologically distinct warts, presumptive identifica-

discontinued vaccination against smallpox, although

military personnel and others are now vaccinated

Clinical signs and lesions

because of the threat of bioterrorism. Currently, there

Following an incubation period of only 24–48 hours,

is little likelihood of vaccinia infections occurring nat-

fever and vesicle formation will be observed in cattle *urally on the teats of cattle in most parts of the world,*

infected by vesicular stomatitis virus. The vesicles will

but if widespread use of vaccinia recombinants

develop into erosions on the mouth (especially the

becomes popular, either in man or domestic animals,

tongue), teats and, rarely, the coronary band. The oral

a resurgence in vaccinia mammillitis in cattle is

lesions will lead to the clinical signs of excessive saliva-

conceivable.

tion and feed refusal. The teat lesions produced by VS

are often indistinguishable from those produced by

foot-and-mouth disease. For this reason, VS is consid-

Clinical signs and lesions

ered of great regulatory importance.

The incubation period is approximately five days, after

which an irregular prodromal fever and tenderness of

Laboratory diagnosis

the teats is noticed. A roseolar erythema occurs at the

site of future pock development: oedema may be local-

Sample collection

ized to the area of the erythema or may involve the

An accurate diagnosis of the cause of teat lesions

whole teat. A vesicle forms three to four days after

may be possible with a thorough examination of both

the initial onset of signs (Plate 27.17) and rapidly

affected and apparently healthy cows within a herd (or

progresses to a pustule, which subsequently ruptures

group in larger herds). However, for a definitive diag-

and suppurates (Plate 27.18). The classical development

nosis, laboratory confirmation is required. An accurate

of a thick red scab ranging in size from 1 to 2 cm in

laboratory diagnosis requires adequate tissue samples

diameter and said to be pathognomonic for cowpox

to be submitted. For submitting good quality samples

may now form (Plate 27.19), but more frequently an

when a virus is suspected as the causative agent, the

ulcerated surface is observed (Plate 27.20). Healing is

clinician should remember the following guidelines.

centripetal and, in uncomplicated cases, takes place

within three weeks. Immunity to reinfection is said to

• During the early stages of the disease, the titre of

be lifelong.

the virus is highest at the affected sites.

• Viruses require living cells and may be inactivated

by disinfectants, light exposure, pH extremes and

Vesicular stomatitis *(see p. 710)*

desiccation.

• Secondary bacterial infection of skin samples is

Aetiology

common in later stages of the diseases.

Vesicular stomatitis (VS) is a sporadic disease of cattle

• Skin scrapings should come from animals with early

in the US, but is endemic in other areas of the western

lesions and be transported on cold packs.

hemisphere. VS is caused by a vesiculovirus of the

• Samples for virus isolation should be collected into

family Rhabdoviridae. Vesicular stomatitis virus has a

virus transport media and transported on cold

genome that consists of a single-stranded, negative-

packs.

sense RNA approximately 11 kbp in length.

• To avoid erroneous results, more than one animal

and multiple lesions should be sampled.

• *An area that will be collected as a skin scraping or*

Epidemiology

biopsy should be washed with saline, not alcohol

(alcohol will inactivate the viruses).

The epidemiology of vesicular stomatitis virus is not

• *Scrapings should extend to the periphery and base*

completely understood at this time. The disease is seen

of a lesion.

most commonly in the form of sporadic outbreaks, but

the inter-epidemic host is, as yet, unknown. Outbreaks

A wide range of laboratory tests may be used for

are seen less frequently in more temperate climates

making the diagnosis of the viral agent responsible for

and after the first frost of the year. The virus is prob-

a teat lesion. Brief descriptions of common diagnostic

ably transmitted by direct contact with contaminated

laboratory tests are included below.

milking equipment, ingestion of contaminated ma-

terials, and a number of different biting insects. The

Diagnostic techniques

antibodies produced by natural infection seem to

Electron microscopy

provide little protection from reinfection. Persistent

viral infection has been theorized, but has not been

Electron microscopy has emerged as a very accurate

clearly demonstrated.

and useful test for practitioners. The advantages of

electron microscopy include a rapid diagnosis and the

thetic ointments have also been recommended, but in

ability to detect non-viable virus and combined viral

large herd outbreaks this type of treatment may be

infections.

difficult to justify financially. Large multiple-use con-

tainers of ointments should be avoided, as they may

become contaminated with virus and serve as a source

Tissue culture

of new infections. Strict hygiene must be followed if

applying ointments by hand, as the hands of treatment

Virus isolation using tissue culture is an alternative

personnel may transfer the infection to uninfected teats.

if electron microscopy is not available. Acceptable

A commonly recommended alternative therapy is the

samples may be derived from early scabs, vesicular fluid

spraying of a teat dip containing emollients (such as 10

or scrapings of the raw surface of lesions. Some strains

per cent glycerin) to reduce bacterial and viral numbers

of pseudocowpox may fail to grow in vitro, but vaccinia and soothe damaged skin.

virus can be distinguished from cowpox virus on tissue

Teat warts, on the other hand, may often go ignored

culture.

until an increase in size interferes with milking and

requires treatment. Surgical removal of the warts, either

by excision or cryosurgery, may be effective. Auto-

Histological identification

genous and commercial vaccines have also been used

Collection of a biopsy of a teat lesion is seldom easy. If

as treatments, with varying degrees of success. Vaccine

one is collected, the tissue should be preserved in 10 per

failures in the past were possibly due to a combination

cent formol saline or preferably Bouin's solution. Each *of using one strain of BPV to treat a lesion caused by*

of the infections discussed above has a characteristic

a different strain and a lack of cross-protection between

histopathology if an early lesion is sampled. Combined

strains. Vaccination has been reported to be effective

with immunohistochemistry, this technique is useful for

for the prevention of warts caused by BPV-1 and BPV-

the differentiation of the specific causative strain of

6, but not for BPV-5. Autogenous vaccines probably

BPV responsible for teat warts. The disadvantage of

provide the best potential for success.

this diagnostic technique is the difficulty in collecting

a teat biopsy and the necessity of an early lesion of

sampling.

Prevention and control

Although the treatment of individual cows suffering

Paired serum samples

from teat lesions is necessary, it is also important to

institute prevention and control strategies within the

Paired serum samples collected during the acute stage

herd. Ideally, new herd additions should be quarantined

of the infection and 14 days later may provide a diag-
for at least 14 days before their introduction into the
nosis. A diagnostic 4-fold rise in serum antibodies is
herd. All infected cows should be isolated or, more rea-
observed in cowpox and BHM, but pseudocowpox gen-
sonably, milked last. All milking equipment should be
erally does not elicit a serological response. A primary
thoroughly disinfected after use on an infected cow.
problem with this test is that the cow may already be
Milkers should wear gloves in the parlour and disinfect
past the acute stage of the illness by the time she is
the gloves between cows. Concerted efforts should
tested. This is especially true of BHM, for which acute
be made to reduce the fly and insect population. Teat
stage serum samples must be taken within two days
skin condition must be preserved by removing sources
of the appearance of lesions. For practical purposes,
of trauma, including improperly functioning milking
however, a clinical diagnosis of BHM may be made by
equipment and poorly maintained housing. Finally,
the detection of high BHV-2 antibody titres in a single

the use of autogenous vaccines (such as in the case of

sample.

papillomatosis) may provide some protective benefit.

Treatment

Non-infectious lesions of the

There are many differing opinions on the treatment of

***teat end** (see Table 27.2)*

ulcerative teat lesions produced by viruses. However,

all the treatments have the similar primary therapeutic

Introduction

objectives of promoting healing and limiting secondary

bacterial infection. Many treatment protocols rely on

In addition to infectious lesions of the bovine teat and

the use of different combinations of astringents and

udder are those caused by traumatic events, chemical

topical antibiotics. Topical corticosteroids and anaes-

injury, environmental conditions, insects and the

Table 27.2

Non-infectious conditions of the teat and udder skin

ing the cross-breds did not differ in frequency of occur-

of cattle.

rence. Adjusting production figures for length of

record, cows with one blind quarter produced only 59

Traumatic, e.g.

kg (130 lb) (1.7 per cent) less milk for the lactation.

barbed wire

Despite the seemingly insignificant impact on perform-

grazing kale

ance, records indicated that animals with blind quarters

mud

were culled an average of 57 days earlier than herd

'treads'

mates.

Irritant chemicals, e.g.

incorrect strength disinfectants

any corrosive agent

Teat trauma *(see p. 1127)*

Photosensitization

Excessive postparturient oedema

Traumatic lesions of the teat are most commonly the

Milking machine induced

result of the cow stepping on her teats or wire cuts. They

Insect induced

are a troublesome problem for the veterinarian as well

as the dairyman. Histologically, the teat wall contains

an abundance of elastic connective tissue that provides

for expansion and contraction of the teat as it fills and

milking machine. As discussed earlier, teat lesions,

evacuates milk in the lactating cow. The near constant

regardless of cause, are frequently colonized by

movement associated with these physical dynamics of

staphylococci and Strep. dysgalactiae. Lesions occurring the teat combined with milking preparation procedures

at the teat end increase the risk of mastitis. Conse-

and milk collection complicate the normal process of

quently, high new infection rates and increased

healing.

numbers of clinical cases of mastitis are common seque-

The dairyman's challenge is in getting cows with teat

lae in herds where lesions involving the teat end are

lesions milked. Because these lesions are generally

prevalent (Plate 27.21). Lesions of the teat barrel are *painful and cows resist preparation and milking proce-*

less likely to cause mastitis directly, but do cause greater

dures they are difficult if not hazardous to milk.

milking difficulty. The increased risk of mastitis occurs

A further complication is mastitis. Teat lesions are

more as an indirect response to the pain experienced

readily colonized by bacteria and thus serve as an

by the cow during milking, resulting in reduced milkout

important reservoir of infection. Udder preparation

and milking speed.

cloths, hands of the milker and milking machine

components facilitate the transfer of infectious organ-

isms between quarters of the same cow and can be

Theleitis

responsible for cow-to-cow transmission as well.

This is a non-specific condition of the inner wall of the

Emphasis on milking hygiene procedures becomes

teat often associated with inflammation due to trau-

crucial in control of new infections whenever teat

matic injury or infectious conditions of the teat and

lesions are present.

udder. Inflammation involving the teat results in a

Depending on severity and the period of time prior

thickening and hardening of the wall of the teat cistern

to discovery, teat lacerations may be repaired surgically.

that in the most severe scenario could lead to partial or

Fresh superficial lacerations of the teat skin (within 12

complete occlusion of the teat. Theleitis is believed to

hours of occurrence) in which the vascular supply has

be a significant, if not primary, reason for the develop-

not been significantly damaged have the best progno-

ment of non-functional teats or 'blind quarters'.

sis. These are generally amenable to surgical closure. If,

However, a Florida study suggests that many blind

on the other hand, such lesions go unnoticed for a

quarters are due to non-mastitis/theleitis related

couple of days and become heavily contaminated,

factors. Blind quarters are generally described as those

cleansing in mild disinfectant solution and removal of

with an absence of mammary tissue or those which lack

the skin flap tissue is likely to be the best therapeutic

a functional teat or teat sphincter. Duraes et al. (1982) approach.

studied the incidence of blind quarters in 1177 first par-

Teat lacerations (see Chapter 66) that extend into the

turitions in a Florida herd where all five major dairy

teat cistern are of greater concern and generally carry

breeds (Holstein, Guernsey, Jersey, Brown Swiss and

a more guarded prognosis. Exposed edges of the teat

Ayrshire) plus Holstein–Guernsey cross-breds were

cistern lining must be sutured using a suture pattern

represented. A total of 38 (3.2 per cent) heifers had 48

that will turn the edges inward creating an impervious

(1 per cent) blind quarters at calving. The highest inci-

seal. If this is not achieved healing cannot occur and

dence occurred in Holsteins. The other breeds includ-

draining fistulae will often develop. The teat wall

muscle layers and skin may be closed separately. Most

Activities associated with milking such as udder

advise intramammary and/or systemic therapy for four

preparation, the milking process and postmilking

to five days as a precaution against the development of *teat dipping all exacerbate chapping problems. Chaps*

mastitis. A protective bandage allowing access to the

usually occur as horizontal cracks in the teat skin.

teat end for milking is recommended. Some suggest

Serum exudates from these cracks result in the forma-

that milk be retrieved from the gland through the use

tion of linear scabs (Plate 27.22). The surrounding teat

of teat cannulas. Mastitis is a frequent secondary

skin may appear dry or leather-like and flake.

complication.

The primary significance of chaps is that they are

Pastured cattle have a lower incidence of teat trauma

readily colonized by staphylococci and Strep. dysgalac-

than confined cattle. Housing factors of primary impor-

tiae and thus constitute a threat to individual cows

tance are associated with the amount of space available

affected as well as the herd. Drying of the teats and

to the cow for resting and rising. Further, individual cow

udders before cows leave the milking parlour, particu-

characteristics and conformation increase the potential

larly during inclement weather conditions, is an impor-

for teat trauma in some cows.

tant preventive measure. Further, the use of teat-dip

products containing hydroscopic skin softening agents

such as glycerine or lanolin is helpful in controlling

Chemical injury

chapping problems.

Postmilking teat dipping is widely advocated for control

and prevention of new mastitis infections. However,

this practice has also increased the potential for chem-

Freezing or frost-bite

ical injury of teats and teat ends. The accidental or inad-

Initially, frozen teats will appear reddened or pale. If

vertent use of concentrated udder wash or cleaning

severe, the lesion progresses to the state where a scab

products in place of teat dip has been observed to cause

forms over the distal half of the teat. In time, usually

serious teat lesions with a single application.

several days, this scab will loosen and fall off, exposing

Teat lesions may also occur as a result of the appli-

a raw, denuded teat end. As a second scab begins

cation of an improperly mixed or defective teat-dip

to develop the duct may become occluded. Milking
product. Iodophor-based teat dips, primarily because of
becomes difficult and may require opening of the streak
their widespread use, are frequently the offenders.
canal surgically.
However, the problem has been observed with
In less severe cases, scab formation does not occur
quaternary ammonium dips, chlorhexidine-based dips,
and cows become receptive to milking after only a few
dodecyl benzene sulfonic acid and hypochlorite teat
days. Cows immediately leaving the milking parlour
dips. Lesions appear as dry, roughened, proliferative
with wet teats (from dip or milk) to areas with inade-
regions around the teat end that are usually discoloured
quate protection during cold weather may develop
by the teat dip. This discoloration may be present on
frost-bite on the teat ends. Freezing of the droplet on
40–50 per cent of the teats in the affected herd. Chang-
the teat end confines the lesion to the teat-end orifice
ing to a dip with better conditioning properties will
area. The result is as described above for frozen teats.

result in the rapid improvement of teat skin health.

Treatment consists of attempts at keeping the teat

In the case of the iodophor dips, problems have

duct patent and preventing the development of masti-

arisen secondary to freezing of the dip on farm or in

tis. Severely affected cows may need to be culled.

transit. When these solutions freeze they separate,

Drying of the teats and udder prior to exit from the

sending emollients to the bottom of the container while

milking parlour and provision of adequate wind breaks

leaving excessive amounts of the active ingredients in a

and shelter for milking cows is essential. The suspen-

layer suspended above. The subsequent application of

sion of teat dipping procedures should be considered

this concentrated iodine can cause teat irritation and

during extremely cold winters.

lesions. Depending on the degree of insult these lesions

can be quite severe.

Sunburn

Environmental injury

Severe reddening and drying of the teats and udder are observed in sunburn conditions, when blisters may form.

Teat chaps

Lesions are most severe on unpigmented skin or where

Teat chapping is a common problem in the more tem-

the skin is devoid of hair. The application of moisturiz-

perate regions of the world where climatic conditions

ers, ointments and salves to the affected areas is advised

favouring dampness and cooler temperatures prevail.

for treatment. For burns caused by fire see p. 934.

Photosensitization (see p. 884)

hyperkeratosis observed. On the other hand, a Wiscon-

sin study indicated that hyperkeratosis of teat ends

This condition occurs when photodynamic agents are

appeared to increase in relation to the compressive load

eaten in their preformed state. Upon exposure to sun-

of the milking machine liner.

light, the unpigmented skin areas develop an erythema

and oedema, which results in severe lesions that most

commonly appear on the lateral aspects of the teats and

Black spot

udder (Plate 27.23). Medial aspects of affected teats

remain soft and cool. These lesions are highly suscep-

This condition is observed as a lesion of the tip of the

tible to secondary bacterial infection.

teat commonly associated with excessive vacuum levels

and overmilking. It is a particularly troublesome

problem as the lesions are quite painful and frequently

Milking machine-induced teat lesions

harbour mastitis pathogens, notably Staphylococcus sp.

Fusobacterium necrophorum is also usually present in

The milking machine is assumed to be a major cause of

the lesions, but difficult to isolate. The specific location

teat lesions. However, most lesions associated with the

of this lesion at the tip of the teat end significantly

milking machine are mild unless malfunction results in

increases the risk of mastitis in affected animals.

extremely high vacuum or pulsation failure. Damage

Control of the condition requires correction of the pre-

may be by direct trauma to the teat or indirect, occur-

disposing cause and application of an effective teat dip

ring over an extended period of time through the induc-

containing emollients or other skin conditioning agents

tion of degenerative changes in the teat. These changes

such as glycerol.

in teat tissue health are primarily associated with cir-

culatory disturbances, resulting in oedema and hyper-

keratosis.

Proper pulsation is essential for the

Insect-induced teat lesions

circulation of blood and lymph in the teat. When

normal circulation is disrupted teat-end health

Summer mastitis is an acute suppurative disease of the

diminishes.

non-lactating mammary gland (see Chapter 24). First

Direct damage to the teat may be caused by exces-

described in Europe, it has been reported in the USA

sive milking vaccum, inadequate pulsation and careless

and other countries as well. It occurs sporadically

use by the operator. Although rare, subcutaneous

throughout the year in Europe, with annual incidences

haemorrhages in the teat epithelium and prolapses of

in England and Wales estimated to be around 2 per cent *teat duct tissue are possible consequences with severe*

of heifers and dry cows. In the USA, some estimate

malfunctions of milking equipment or its use.

incidences of 5–6 per cent on certain farms during the

summer months.

While some questions remain, in both the USA and

Calluses and hyperkeratosis of teat ends

Europe epidemics of summer mastitis have been coin-

cident with periods of greatest fly challenge. Further,

Because of its appearance, hyperkeratosis of the teat

data indicate that effective fly control reduces disease

end is often mistakenly diagnosed as a prolapsed

incidence. These findings support the possibility of

sphincter. Hyperkeratosis of teat ends is a common

insect involvement. European data suggest that biting

finding in hand milked dairy cows as well as beef cattle.

flies are responsible for the initial damage to the teat

Histopathology of this material will confirm it to be

end and implicate the cattle fly, Hydrotaea irritans, as excess keratin, which some refer to as callouses. These

the infectious vector in summer mastitis (see Chapter *callouses may be rough or smooth and thus logically*

24).

implicated as possible risk factors for mastitis.

However, according to studies in the USA, the presence

of hyperkeratatic lesions at the teat end had no effect

on the prevalence of mastitis unless accompanied by

Differential diagnosis of skin lesions

erosions or scabs.

of the bovine teat

The exact cause of hyperkeratotic lesions in dairy

cattle is unknown, but appears to be related to certain

The following is an aid to the diagnosis of lesions of the

milking practices and milking-machine-related factors.

udder and teats in severely affected milking herds (see

For example, high levels of milk production and

Table 27.3; Plates 27.1–32). With the exception of teat

extended milking times, failure to apply appropriate

chapping and milking machine damage, the aetiology of

premilking stimulation and overmilking increased the

which appears to be complex, most outbreaks of teat

degree of lesions. Vacuum levels and pulsation ratios *lesions in cows are due to three types of virus: (i)*

(within normal limits) had no effect on the degree of

cowpox, (ii) pseudocowpox and (iii) BHM.

Table 27.3

The clinical appearance and diagnosis procedures for teat conditions (other than BHM, cowpox, bovine vaccinia mammillitis and pseudocowpox).

Condition

Clinical appearance

Confirmatory diagnostic

procedure

Blackspot (Plate 27.27)

Scabby infection of teat orifice with

Isolation of F. necrophorum

Fusobacterium necrophorum but often

(often unsuccessful)

other organisms

Chaps (teat) (see Plate 27.22)

Skin fissures often through dermis.

None. Parapox virus particles

Haemorrhage may occur with scab

may be found but their

formation at the fissure edge. Often

importance unknown. Heavy

horizontal lesions

bacterial contamination of

lesion common

Folliculitis and impetigo

Pustule with surrounding erythema

Isolation of Staphylococcus aureus

Foot-and-mouth disease (see Plate

Vesiculation of teat, buccal and

Presence of virus. Notifiable

27.24)

interdigital mucosae. Pyrexia

in most countries

Mud abrasion (Plate 27.28)

Abrasions on lateral surface of the udder

Photosensitization (see Plate

Lesion progresses from erythema, oedema

27.23)

to serous exudation through skin. There is *then necrosis, ulceration and scab formation.*

Pigmented areas of teat unaffected

Ringworm (Plate 27.29)

Typical grey crusty lesions

Isolation of Trichophyton verrucosum

Theleitis and serous exudate from udder

Teat swollen, painful with udder skin

Isolation of bacteria

skin in peracute mastitis (Plate 27.30)

involved. Cow febrile and toxic

Vesicular stomatitis

Vesiculation of teat, buccal and

Virus isolation. As similar to foot-and-

interdigital mucosae

mouth may need to notify

Warts

Filiform (Plate 27.31)

Pedunculated attachment to teat

White nodule (Plate 27.32)

Broad attachment to teat. Variable in size.

Some warts intermediate between filiform *and nodule*

Accurate diagnosis is important for varius reasons. A

Reference

major factor is the zoonotic potential of cowpox and

pseudocowpox. Secondly, there is the need to differen-

Duraes, M.C., Wilcox, C.J., Head, H.H. & Van Horn, H.H.

tiate foot-and-mouth disease as occasionally vesicles

(1982) Frequency and effects on production of blind quar-

occur on the teats before their appearance in the mouth

ters in first lactation dairy cows. Journal of Dairy Science, and foot (Plate 27.24).

***65**, 1804–807.*

When investigating an outbreak it is best to examine

as many cattle as possible because the lesions in a single

cow may not be typical. Often mixed disease occurs

Further reading

(Plates 27.25, 27.26) and an assessment of the develop-

ment of lesions rather than just examination of the most

Farnsworth, R.L. (1996) Observations on teat lesions. In

severely affected cattle helps in the diagnosis.

Proceedings of the National Mastitis Council, pp. 93–8.

Farnsworth, R.L. & Seiber, R.L. (1979) Relationship of teat On occasion the clinical appearance of the lesions

end lesions to intramammary infections. In Proceedings of

can be modified by environmental factors, thereby

the National Mastitis Council, pp. 17–24.

making recognition of the condition difficult. Such

Francis, P.G. (1984) Teat skin lesions and mastitis. British factors include the teat cluster, mud or coloured teat

*Veterinary Journal, **140**, 430–6.*

dips. In these problems laboratory diagnosis be-

Gibbs, E.P.J. (1984) Viral diseases of the skin of the bovine teat comes essential, although it is advisable in all disease

and udder. Veterinary Clinics of North America. Large

investigations.

*Animal Practice, **6**, 187–202.*

Gibbs, E.P.J., Johnson, R.H. & Osborne, A.D. (1970) The dif-Sieber, R.L. & Farnsworth, R.J. (1978) The etiology of bovine ferential diagnosis of viral skin infections of the bovine teat.

*teat lesions. In Proceedings of the National Mastitis Council, Veterinary Record, **87**, 602–609.*

pp. 5–15.

Gibbs, E.P.J. & Rweyemamu, M.M. (1977) Bovine her-

Sieber, R.L. & Farnsworth, R.J. (1984) Differential diagnosis pesvirus, 1, 2 & 3.

Veterinary Bulletin, ***47***, *317–43, 411–*

of bovine teat lesions. Veterinary Clinics of North America.

25.

Large Animal Practice, ***6****, 313–21.*

Chapter 28

Factors Affecting Milk Quality

R.W. Blowey and R.A. Laven

Introduction

373

(g/kg milk) may be reduced, but the overall fat pro-

Feeding and milk composition

373

duction (g/day) may be increased.

Feeding before calving

373

Feed constituents

373

Dietary fat

375

Feeding before calving

Dietary protein

376

Severe underfeeding, leading to cows calving down in

Feeding systems

376

condition score 2 (overall scale 1–5, see p. 10) or less,

Non-nutritional factors

377

Age of cow

377

will reduce milk yield, fat, protein and lactose and

Stage of lactation

377

although these effects are greatest in early lactation,

Season of the year

377

they will persist throughout it. The extent of the depres-

Disease

377

sion is approximately 20 g/kg (0.2 per cent) in milk fat

Genetic variation

378

and 10 g/kg in protein. Less severe underfeeding has

little effect on milk protein, and provided that high

quality diets are provided after calving, some of the

effects on milk quality can be eliminated (Garnsworthy

Introduction

& Topps, 1982).

Feeding a high energy density diet (11.7 MJ/kg DM)

precalving significantly increases milk fat concentration

Most countries with a developed dairy industry now

in early lactation; however, this effect does not persist

pay producers on the basis of both total volume sold

and there is no significant effect on fat yield and no

and compositional quality, and with the slowly increas-

effect on protein concentration or yield.

ing move for a larger proportion of milk to be used for

Very fat cows have an increased fat content in their

manufacturing, this trend is likely to continue. In addi-

milk, and it has been estimated that milk fat increases

tion, many countries also have a milk quota system *by 2 g/kg for each 1.0 unit rise in condition score. This*

and to maximize profitability, a farmer must produce a

effect lasts for the first five to six weeks of lactation only, specified amount of milk of optimum quality. Much

and is related to fat concentration only; indeed total fat

attention has therefore been paid to factors affecting

yield is often depressed in very fat cows.

milk quality, the most important aspects of which are

reviewed in this chapter. The composition of average

Friesian/Holstein milk is given in Fig. 28.1. Feeding has

Feed constituents *(see p. 112)*

by far the greatest impact on milk quality and as such

The greatest effect arises from the forage : concentrate

will be discussed first.

ratio in the ration and its influence on milk fat content.

Milk fat is synthesized from the fatty acids acetate

and butyrate, products of the ruminal fermentation of

Feeding and milk composition

forage and other feeds containing fibre. As the level

of concentrates in the ration increases, the proportions

This is an extremely complex area to study, since it is *of acetate and butyrate fall and that of propionate rises.*

often difficult to differentiate the separate effects of,

There is also a decrease in ruminal pH and a depressed

for example, plane of nutrition, system of allocation of

activity of cellulolytic degradation, which can eventu-

food, frequency of feeding and feed composition.

ally result in depressed dry matter (DM) intake. The

Superimposed on this are effects of feeding before and

extent of the depression varies with the materials being

after calving and the problem of differentiating

fed, but as an approximate guide, forage : concentrate

between compositional values and overall yield. For

ratios should not be allowed to fall below 60 : 40 (or

example, in a high-yielding cow the milk fat content

50 : 50 if fed as a total mixed ration). For example,

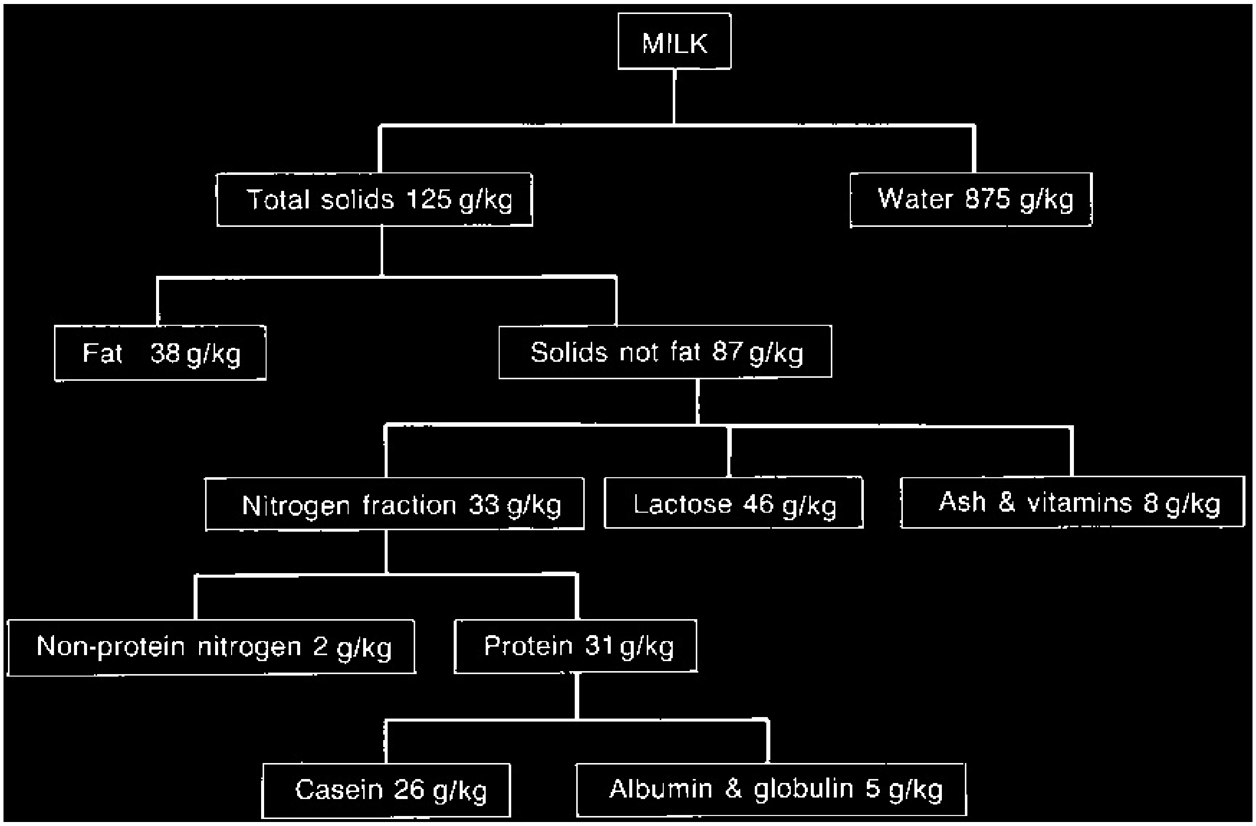


Fig. 28.1

The compositional quality of

milk.

Table 28.1

Effect of proportion and type of concentrate in a mixed diet on milk production in early lactation. Source: Sutton et al.

(1985).

600 (g/kg diet)

700 (g/kg diet)

Starchy Fibrous

Starchy

Fibrous

concentrate

concentrate

concentrate

concentrate

Consumed (kg air dry feed/day)

Hay

7.2

3.5

Concentrates

10.8

14.0

Dietary ADF (g/kg DM)

192

231

136

180

Milk yield (kg/day)

26.3

26.5

32.0

25.5

Fat concentration (g/kg)

41.5

42.9

22.6

36.2

Fat yield (kg/day)

1.09

1.12

0.73

0.91

ADF, acid detergent fibre.

Sutton (1986) calculated that milk fat fell by 5 g/kg (0.05

• Digestible fibre, for example sugar-beet pulp, cotton

per cent) for every 100 g/kg decrease in the proportion

seed, citrus pulp, etc.

of hay in the diet, even when the overall energy content

• Fats and oils.

of the ration remained constant. However, there was

Table 28.1 (Sutton et al. , 1985) shows that concentrates a good deal of variation *and probably a better way of*

containing a high level of digestible fibre cause less

estimating dietary effect is to express the overall fibre

depression of milk fat and produce an overall higher

content of the diet on the basis of acid detergent fibre

fat yield (kg/day), even though total milk volume is

(ADF). Milk fat has been shown to fall when overall

reduced due to lack of starch. This was particularly

dietary ADF drops to below 200–250 g/kg DM. This

noticeable at the higher levels of concentrate feeding.

is equivalent to approximately 450 g long forage/kg

It is, of course, the amount of starch in the ration and

dietary DM, although on much higher forage diets, milk

its conversion into propionate and glucose that is one

yield could be depressed.

of the main determinants of the volume of milk pro-

The type of concentrate also has an effect. The energy

duced. The energy in digestible fibre products such as

fraction of a concentrate can be derived from four main

sugar-beet pulp is derived from cellulose and hemicel-

sources, namely:

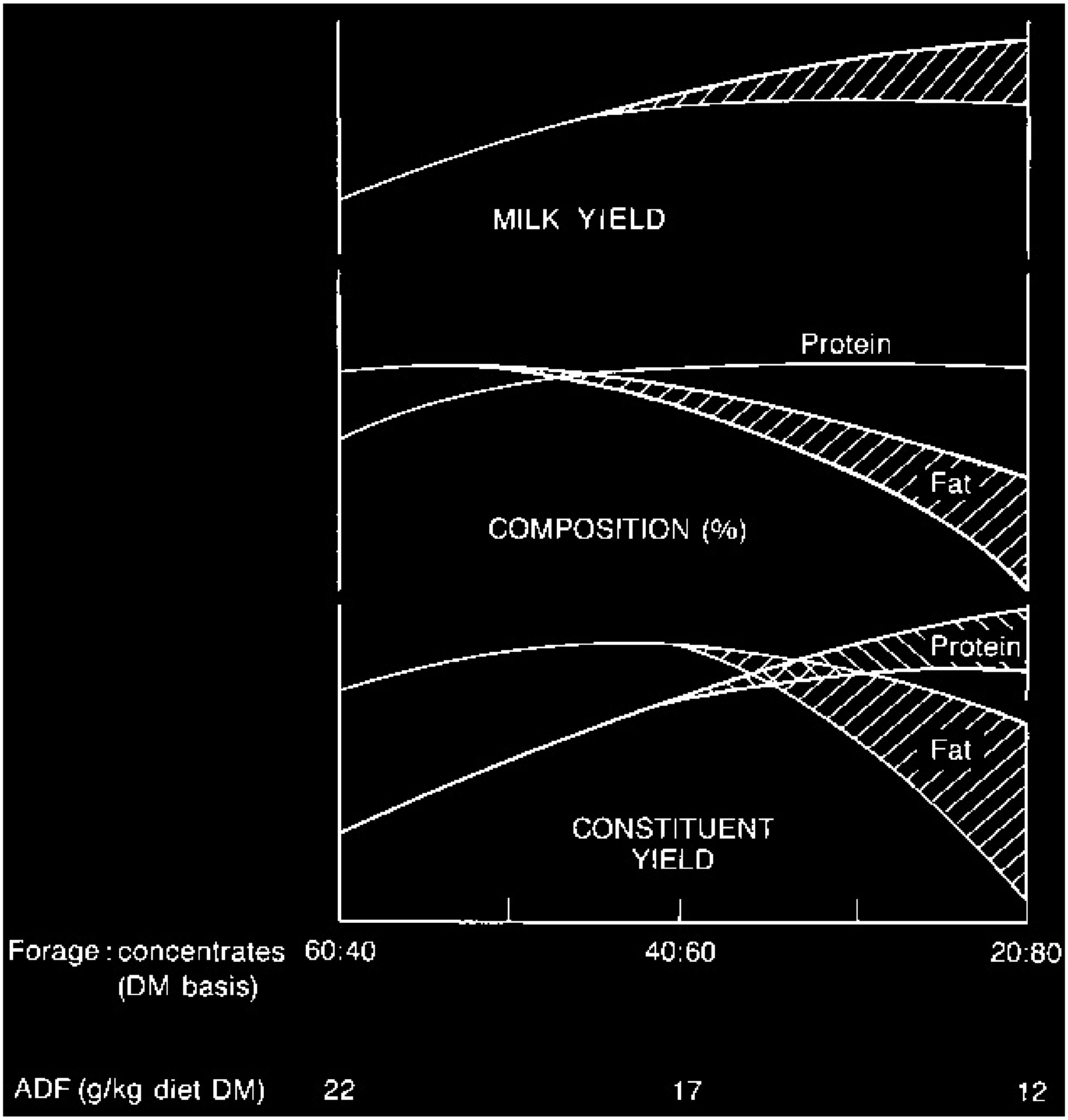
luloses and is slowly fermented. Maize is also slowly fer-

• Sugar, for example molasses.

mented and as such causes less depression of milk fat,

• Starch, for example barley and maize.

compared with other more rapidly fermented starch



and milk quality, but this will depend on the economic milk price : concentrate cost ratio prevailing at the time, and a full discussion is well outside the scope of this review.

Of course, low forage intakes may not occur intentionally. Poor quality fodder such as very wet, very acid or very butyric silages will depress intakes and thereby increase the concentrate : forage ratio. A more common problem is probably inadequate access. Self-feeding consolidated silage, particularly behind an electric wire, may depress intakes of even good quality material by as much as 5–10 per cent and could further exacerbate the problem.

There is no requirement for 'long fibre' in the basal ration to maintain milk quality, and diets containing long fibre length generally give the same milk quality as finely chopped silage (Thomas, 1984). However, there is some evidence that silage diets give better milk quality than rations of equal metabolizable energy intake based on hay. Fine grinding of forage will *depress milk fat when used as the sole ration, but if used*

Fig. 28.2

The relationship between forage : concentrate ratio or

as a supplement to conventional forage it has no effect

acid detergent fibre (ADF) and milk yield and composition.

(Thomas, 1984).

Dietary fat

sources such as barley. Uncooked ground maize will, to

Manufacturers may increase the energy content of

a certain extent, pass through the rumen and into the

a concentrate by adding fat, either directly into the

small intestine. This possibly explains why maize-based

product or by fat-spraying the outside of the cubes. Fat

concentrates give an overall lower level of yield than

'prills' may also be added to the ration, e.g. a complete

conventional barley products. Both features are par-

diet, as a separate constituent. Provided that saturated

ticularly noticeable at higher concentrate intakes. Root

(or 'hard') fats such as tallow, coconut or palm kernel

crops, e.g. fodder beet, have most of their energy stored

oil are used, and only to a maximum of 5–6 per cent,

as the sugar sucrose. Generally, they produce better this will increase the fat content of the milk. However, levels of fat, but lower yields than a comparable amount milk protein content will be slightly depressed, but as of starch.
milk yield is likely to increase, overall milk protein yield The effect of diet on milk protein is different from remains constant. Levels of fat above 7 per cent inter- that seen with milk fat. On high-forage diets, increasing fere with ruminal function, leading to a depression of the proportion of concentrate in the ration (especially both total milk yields and the fat and protein contents. high-starch concentrate) will increase milk protein, but Increased levels of unsaturated ('soft') fats, such as only up to a level of 50–60 per cent of concentrate in maize, cotton seed, groundnut and especially fish oils, the diet. Beyond this, milk yield may rise and milk fat should not be used because they will coat the surface concentration will fall, but protein levels will remain of fibre particles in the rumen, thereby depressing fibre constant. The net effect is an overall rise in protein

digestion and leading to a fall in the milk fat content.

yield. These changes are represented diagrammatically

However, if the fat can be protected from rumen degra-

in Fig. 28.2.

dation (such as with heating or formaldehyde treat-

Increasing the intake of rumen bypass protein will

ment), the fat will bypass the rumen, resulting in no

also increase milk protein, even if requirements for

depression of fibre digestion. This will allow the long-

metabolizable protein have been met. This effect is

chain fatty acids to be utilized more fully and overall

enhanced if the amount of rumen bypass starch is

milk fat will therefore rise. Protecting unsaturated fat

increased, suggesting that the mammary gland requires

also has a significant impact on the fatty acid composi-

a balance of precursors and energy to produce higher

tion of milk. As a result of hydrogenation of dietary

levels of dietary protein.

fatty acids in the rumen, milk fatty acids are primarily

Clearly, within a quota system there will be an

(75 per cent) saturated fat. Protecting unsaturated fat

optimal level for a farmer, both in terms of milk yield

can significantly increase the proportion of unsaturated

fats in milk (and reduce the proportion of saturated

Table 28.2

Effect of number of daily meals of starch-based

fat). Mansbridge and Blake (1997) showed that inclu-

concentrates on milk yield and composition. Source: Sutton

sion of either full fat soybeans or partially oil-extracted

(1986).

rapeseed in the diet resulted in a significant reduction

Concentrates

in the proportion of palmitic acid (the predominant

(kg/day)

10.0

11.5

12.8

14.0

saturated milk fatty acid) in milk. Additionally, feeding

(g/kg diet)

600

700

800

900

oil-extracted rapeseed significantly increased the

concentration of oleic acid (a mono-unsaturated fatty

ADF (g/kg diet DM)

192

162

124

99

acid) and linolenic acid (a polyunsaturated fatty acid),

Milk yield (kg/day)

while feeding full fat soyabeans resulted in significant

2 meals

19.3

19.7

20.6

23.0

increases in linoleic and linolenic acid. Milk and milk

6 meals

20.8

20.2

24.5

21.4

products produced from cows fed protected diets could

Milk fat (g/kg)

be a valuable aid in reducing saturated fat intake.

2 meals

34.3

32.6

31.6

17.9

6 meals

36.2

39.2

35.3

29.7

Dietary protein *(see p. 106)*

Milk protein (g/kg)

2 meals

31.4

33.2

31.7

32.0

The effects of dietary protein on milk quality, including

6 meals

31.8

34.1

31.2

33.2

milk protein, are less well defined. It is the energy

content of the ration that has the major effect on milk

protein, particularly at high forage intakes. Severe

dietary protein deficits will depress milk protein,

although this may be partly because the requirements

trate, rather than the steady supply of propionate that

of the ruminal micro-organisms have not been met and

will be a feature of more frequent feeding. The effect

as such total dry matter intake, and therefore the

of increased levels of insulin is to promote lipogenesis

overall dietary energy intake, is inadequate.

in adipose rather than mammary tissue.

Table 28.2 shows that milk protein is unaffected by *frequency of feeding, or by the level of concentrate fed*

Feeding systems

at these high levels of concentrate : forage ratio.

It is possible to overcome some of the effects of high

Complete diets (see p. 120) offer an opportunity for

concentrate, low forage diets by feeding the cows more

even feeds of concentrate throughout the day. When

frequently. In a series of experiments at the National

milk fat is low, due to depression by an excessive con-

Institute for Research in Dairying (Sutton, 1986),

centrate : forage ratio, feeding the same constituents in

cows were given concentrate diets varying from 600 to

a complete diet will lead to an increase in the fat

900 g/kg (namely 40 per cent to 10 per cent forage) fed

content. Milk protein may also increase on complete

either twice daily or up to six times daily. The results

diets, but this is thought to be due to the effects of an

are given in Table 28.2 and show that for all levels of

increased dry matter intake, rather than any particular

concentrate feeding, milk fat was higher with a greater

effect on frequency of feeding.

frequency of daily feeds. As one might expect, the dif-

Since the introduction of milk quotas in the UK (see

ferential was greatest at the highest level of concentrate

p. 24), there has been a greater tendency to feed forage,

feeding, where twice daily feeding had produced a

and concentrates have been fed on a ‘flat-rate’ basis,

severe depression of milk fat. The concentrate used was

rather than the more traditional system of a basic allo-

a standard material containing high levels of starch.

cation for maintenance and an increasing quantity of

Had a highly digestible fibre product been used, it is

concentrate depending on yield. Provided that good

unlikely that the depression of milk fat would have

quality forage is available ad libitum (and this is essen-been so great – hence the response to more frequent

tial to the success of the system), there is no significant

feedings would also have been considerably less. It is

effect on milk quality throughout the lactation. Since

generally assumed that diets leading to high propionate

high levels of ‘starchy’ concentrates promote high

and low acetate in the rumen will reduce milk fat.

yields, cows calving onto a 'flat-rate' system tend to

However, increasing the frequency of feeding does not

'peak' at a lower level in early lactation and hence the

seem to depress propionate concentrations sufficiently

'dilution' effect of high yields depressing milk quality is

to account for the full benefit to milk fat synthesis. It

not seen. Any reduction in milk quality on a flat-rate

would appear that high plasma insulin concentrations

system is compensated for by slightly higher quality

are the main factor depressing milk fat and that the

later in lactation. If access to forage is restricted, then

release of insulin is stimulated by peaks of propionate

clearly decreasing concentrate in early lactation will

production, such as occurs after a large feed of concen-

depress milk protein.

The depression of milk fat caused by high-concen-

Table 28.3

The effect of silage feeding at grazing on milk

trate diets can also be counteracted by the use of

quality. Source: Phillips & Leaver (1983).

buffers. The most commonly used compound is sodium

bicarbonate, fed at 12.5–15 kg/t, or 100–125 g/cow per

Grazing

Restricted grazing

day. The extent of the improvement depends on the

and silage

original level of milk fat, the response being greatest in

Milk yield (kg/day)

19.9

18.9

herds where butterfat is already low due to high levels

of starchy concentrate being fed twice daily. Feeds such

Milk composition

as sugar beet pulp also have a good buffering capacity

Fat (g/kg)

35.6

39.4

(sometimes also known as the cationic exchange capac-

Protein (g/kg)

35.1

34.8

ity), whereas others, such as maize gluten, can lead to a

Solids yield

more acid fermentation. It is interesting to speculate

Fat (g/day)

708

745

on the effects of the use of sulphuric acid as a silage

Protein (g/day)

698

657

additive. This is a 'strong' acid, thus requiring a greater

buffering, and could exacerbate milk fat problems in a

way that formic or lactic acids would not.

to February) due to the fact that a large number of cows

Non-nutritional factors

are at peak yield and relatively few are pregnant.

Changes in lactose follow an opposite pattern. The

Age of cow

lactose content of colostrum is low, but rises rapidly

after calving to reach a peak by two weeks into lacta-

Heifers generally have the highest milk quality, there *tion. This level is maintained until six weeks, but there*

being a fall of about 3 g/kg (0.3 per cent) in fat and

is then a steady fall, the rate accelerating towards the

7 g/kg (0.7 per cent) in solids not fat (SNF) per lacta-

end of lactation. Changes in lactose are therefore a

tion thereafter. The rate of decline continues until

mirror image of changes in fat and protein.

approximately the fifth lactation, after which it becomes

more gradual. The decline in SNF is primarily due to a

decline in lactose and mainly occurs during the first

Season of the year

three lactations. Protein declines by only approximately

In the UK there is a sharp fall in milk fat at the end

1 g/kg (0.1 per cent) per lactation over this period.

of winter, when cows are turned out to grazing. This

can be partly offset by providing access to hay or straw,

although intakes of such forages are often poor when

Stage of lactation

highly palatable grass is available and, if only 1–2 kg are

Milk quality is, of course, very high at calving

consumed, this will have little benefit. To overcome the

(colostrum has at least double the dry matter content,
situation (and to improve grassland management and
i.e. 25 per cent, of normal milk, see p. 211), but then
conservation), a system of ‘storage’ or ‘buffer’ feeding
declines as yield increases, reaching a minimum at
has been introduced, whereby cows are kept in at night
about 50–70 days after calving. Milk fat may drop by as
on silage. Experiments carried out at Crichton Royal
much as 10 g/kg (1.0 per cent) and protein by 3 g/kg (0.3
Farm (Table 28.3) showed that this significantly
per cent) over the period. This depression is partly due
improved butterfat and although yields were marginally
to a ‘dilution’ effect of high yields and partly to the
lower, overall fat yield was increased. However, protein
inherent inability of the early lactation cow to consume
yields were lower.
sufficient energy to meet the demands of production.
Often there is also a fall in milk protein during the
Feeding high levels of ‘starchy’ concentrates and, in
winter housing period (November to March in the UK),
so doing, boosting the volume of milk produced, can in

probably due to a lower energy content of the diet at

some circumstances exacerbate the decline in milk

this time of the year and also to a stage of lactation

quality. Both milk fat and protein tend to increase after

effect. Protein levels then rise rapidly in April and May,

70 days, but milk protein only rises significantly if the

following turnout to spring grazing. There is very little

cow becomes pregnant, and the rapid rise in both fat

seasonal change in lactose concentrations.

and protein that occurs in later lactation (e.g. six

months after calving) is greater in the pregnant animal.

Disease

Farms practising 'block calving', for example from

August to October, often experience a marked fall in

Liver fluke (see p. 276) can depress both milk fat and

milk quality two to three months later (e.g. November

milk protein and this depression in milk quality may be

Table 28.4

Approximate breed variations in milk yield and

Management factors

quality. Source: MMB (1983).

Milking intervals would appear to have an effect on

Milk yield

Milk fat

Protein

milk quality in that on twice-daily milking, the fat

(kg)

(g/kg)

(g/kg)

content is higher in the afternoon. This is entirely

due to a 'carryover' effect (Dodd, 1984). At the end of

Ayrshire

4988

39.0

33.8

milking, some 10–20 per cent of the milk present

British Friesian

5610

37.8

32.6

remains in the udder and cannot be removed. The fat

British Holstein

6292

37.3

32.0

content of this milk is very high, 150 g/kg (15 per cent)

Guernsey

4017

46.4

36.3

or higher, and it is withdrawn at the next milking. If

Jersey

3876

51.9

38.5

there is an uneven interval between milkings, milk pro-

duced after the shorter interval will have a higher

fat content because of the reduced 'dilution' effect of

the additional milk produced. The total daily fat pro-

duction remains constant, irrespective of the variation

in milking interval and therefore of fat content. Increas-

seen in the absence of any other clinical signs of fluke.

ing the frequency of milking to three or even four times

Heavy infestations of lice (see p. 741) and gastroin-

daily does not alter milk quality significantly, although

testinal worms (see p. 267) may also reduce milk

yields may rise by 10–15 per cent.

quality, but these are unlikely in adult milking cows.

Mastitis (see Chapter 23) leads to a reduction in

yield, lactose and butterfat. For example, a herd with a

References

cell count of 750 000 cells/ml could be losing 750–900

l/cow per year, 50 g/kg (0.5 per cent) lactose and a

Crabtree, R.M. (1984) Milk compositional ranges and trends.

smaller amount (30 g/kg, 0.3 per cent) of milk fat. Milk

In Milk Compositional Quality and its Importance in Future protein levels will increase slightly with mastitis, but

Markets (ed. by M.E. Castle & R.G. Gunn), pp. 35–42.

the protein is of lower quality, with increased levels of

BSAP Occasional Publication No. 9, Edinburgh.

globulin and decreased casein. High cell count milk is

Dodd, F.H. (1984) Herd management effects on compositional

therefore of reduced value for manufacture.

quality. In Milk Compositional Quality and its Importance in Future Markets (ed. by M.E. Castle & R.G. Gunn), p. 77.

BSAP Occasional Publication No. 9, Edinburgh.

Garnsworthy, P.C. & Topps, J.H. (1982) The effect of body con-

Genetic variation

dition of dairy cows at calving on their food intake and per-

formance when given complete diets. Animal Production, It is well known that Channel Island cattle such as

***35**, 113–19.*

the Jersey and Guernsey have higher milk quality than

Mansbridge, R.J. & Blake, J.S. (1997) Nutritional factors

other breeds. Approximate breed values are given in

affecting the fatty acid composition of bovine milk British Table 28.4. Of course there are large variations between

*Journal of Nutrition, **78** (Suppl 1), S37–S47.*

individual animals within a breed, and this is the basis

National Dairy Council (NDC) (1997) United Kingdom Dairy

of genetic selection. The selection of animals on the

Facts and Figures, pp. 1–208. National Dairy Council,

basis of yield alone could lead to a decrease in fat and

London.

protein contents and care should be taken to ensure

*Phillips, C.J.C. & Leaver, A.D. (1983) The effect of offering that bulls with a high improved contemporary compar-silage to set-stocked dairy cows. Animal Production, **36**, 507.*

ison (ICC) for both fat and protein are selected. There

Sutton, J.D. (1986) In Principles and Practice of Feeding Dairy Cows, pp. 203–18. NIRD Technical Bulletin No. 8.

is less genetic variation within breeds for protein

Sutton, J.D., Bines, J.A. & Napper, D.J. (1985) Composition of and lactose than for fat and hence the greatest rate of

starchy and fibrous concentrates for lactating dairy cows.

genetic progress will be made by selecting for fat. For

*Animal Production, **40**, 533.*

example, the range of fat content within a breed is over

Thomas, C. (1984) Milk compositional quality and the role of

20 g/kg, whereas genetic variation for protein is only

forages. In Milk Composition Quality and its Importance

approximately 10 g/kg (Crabtree, 1984). The genetic

in Future Markets (ed. by M.E. Castle & R.G. Gunn), pp.

variation for lactose is even lower.

69–76. BSAP Occasional Publication No. 9, Edinburgh.

Chapter 29

The Enhancement of Bovine Mammary Gland Immunity Through Vaccination

K.P. Kenny, T. Tollersrud and F.D. Bastida–Corcuera

Introduction

379

Anatomy of the bovine mammary

Anatomy of the bovine mammary gland

379

gland *(see Chapter 22)*

Defence mechanisms of the gland

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Immunoglobulin in lacteal secretions

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Biological activity of antibody

380

The bovine udder comprises four mammary glands.

Complement

381

The main arterial supply is from the bilateral external

Cells of the mammary gland

381

pudendal arteries. The venous return is via the external

Cytokines

382

pudendal veins and the subcutaneous abdominal veins.

Intramammary infection

382

There are two lymph vascular systems: a superficial and

Virulence factors and immune response to major

a deep set. The superficial set drain the cutaneous area

pathogens

383

and the teat walls. The deep set is associated with the

Escherichia coli

383

finer branches of the arteries and veins. The lymphatics

Klebsiella spp.

384

drain into the superficial inguinal (supramammary)

Mycoplasma spp.

385

lymph nodes and the lymph passes to the deep inguinal

The summer mastitis complex

385

Staphylococcus aureus

385

node.

Streptococcus spp.

386

The mucosa of the teat or streak canal is arranged in

Mucosal immune system

388

longitudinal folds and is lined by stratified squamous

Generation of immune response

388

epithelium which constantly undergoes keratinization.

Limitations of vaccination

389

A slightly projecting fold marks the proximal end of

the teat canal, the Furstenberg's rosette area. The teat

cistern (sinus) is the cavity directly proximal to the teat

canal, and this continues into the parenchyma of the

Introduction

udder as the gland cistern (lactiferous sinus), which pos-

sesses a two-layered columnar epithelium. The secre-

The examination of immunological methods to increase tory tissue is divided into lobes which are composed resistance of the dairy cow to pathogens which cause of lobules and there is an extensive duct system. The mastitis has been ongoing for almost a century. This is epithelium of secretory alveoli is a single layer of a controversial area of bovine immunity with the exis-cuboidal cells. The alveoli are surrounded by a stromal tence of two schools of thought on the role of immuno-layer which is more pronounced in the non-lactating logical intervention in mastitis control programmes. gland.

The first believes it is not possible to generate protec-tive immunity in the mammary gland and control meas-ures should be based on management, therapeutic strategies and genetic selection (Mellenberger, 1977).

Defence mechanisms of the gland

The second opinion is vaccination has a role in a mastitis control programme (Colditz & Watson, 1985). Non-specific and specific defence mechanisms exist in The latter view, founded on an improved knowledge of the bovine mammary gland (Outteridge & Lee, 1988).

the bovine immune system and the principal pathogens

Non-specific factors include teat and teat duct shape

of the gland, is supported by reports which indicate

and structure, teat duct patency and teat duct keratin.

heightened resistance to infection with certain

Teat duct keratin owes its protective properties to fatty

pathogens. The success of coliform mastitis vaccines has

acids and basic proteins. During milking there is a

spurred novel studies on Streptococcus uberis mastitis.

mechanical flushing of the teat canal. The enzyme

Such vaccines will complement conventional control

lysozyme can cleave certain bacterial cell walls, but is

measures which are less effective against environmen-

present at very low concentrations in bovine secretions.

tal pathogens.

Lactoferrin can bind iron and reduce the availability of

iron to micro-organisms, but citrate inhibits this pro-

Table 29.1

The concentration of immunoglobulin in serum and

tein. The lactoperoxidase/thiocyanate/hydrogen perox-

colostral secretions. Values are expressed in mg/ml.

ide system has activity against micro-organisms. Com-

plement can be activated by the lipopolysaccharide of

IgA

IgM

IgG1

IgG2

Gram-negative organisms and cause lysis of these

Serum

0.37

3.0

11.2

9.2

bacteria by the alternative pathway.

Colostral whey

4.7

7.1

48.2

4.0

Four specific defence mechanisms operate in the

Milk whey

0.08

0.08

0.5

0.06

gland. These are mediated by antibodies directed

against epitopes of the pathogens or their toxins, in con-

junction with phagocytic cells and complement. The

secretions, but not in milk. Around 50 to 100 per cent

mechanisms include prevention of bacterial adherence

of milk IgA is produced locally. Plasma derived IgA is

to epithelial cells, neutralization of bacterial toxins,

selectively transported into most mucosal secretions by

opsonization of pathogens and direct lysis of pathogens.

vesicular transport following its binding to secretory

The key role of humoral immunity reflects the extra-

component on epithelial cells. There are conflicting

cellular location of mastitis pathogens. A role for cellu-

reports concerning the origin of milk IgM with some

lar immunity has not yet been established although *indicating it is entirely serum derived while others*

laboratory studies have shown the ability of staphylo-

suggest that 75 per cent is locally synthesized. Most

cocci and streptococi to achieve an intracellular loca-

milk IgG1 is serum derived. About 90 per cent of IgG2

tion in cultured mammary epithelial cells.

found in milk is locally produced. To increase specific

Two methods can be employed to heighten resist-

IgG1 in milk one must increase the serum level of spe-

ance. One could increase non-specific protection which

cific IgG1, whereas for IgA one must generate appro-

would be widely effective against all pathogens. The

priate plasma cells in the lamina propria.

strategic use of cytokines at key points in the lactation

cycle has yielded encouraging results. The administra-

Biological activity of antibody

tion of gamma-interferon lessens the severity and dura-

(see Chapter 22)

tion of experimental Escherichia coli infection, but

there are no reports of field trials describing the effect

Antibody molecules can be considered as having two *of such administration on naturally occurring infec-*

components. Firstly the two antigen binding sites rec-

tions. An alternative approach is to stimulate specific

ognize and bind antigen. Secondly, the Fc portion of the

immunity for each mastitis pathogen. The latter is dif-

molecule is considered the effector part because it can

ficult because there are many causative bacteria. The

fix complement components and interact with specific

challenge is to characterize the virulence factors of the

Fc receptors on phagocytic cells. For certain protective

principal pathogens, identify their protective epitopes

effector functions, antibody must not only be directed

and then establish and maintain sufficient protective

against a particular epitope but must be of the correct

antibody in milk.

isotype.

Secretory IgA serves to protect mucosal surfaces

from colonization and penetration by undesirable

Immunoglobulin in lacteal secretions

micro-organisms. It can augment the bacteriostatic

(see p. 323)

effects of lactoferrin and can function as an opsonin.

Four classes of antibody have been described in the

Lacteal IgA is largely associated with milk fat globules.

bovine (Butler, 1986): IgA, IgE, IgG and IgM. IgG1 and

IgG1 and IgG2 are efficient at fixation of complement

IgG2 are two subclasses of IgG. The half-life in serum

and able to neutralize bacterial toxins. Cytophilic anti-

of IgA, IgM, IgG1 and IgG2 is 3, 5, 17 and 22 days respec-

bodies are capable of attaching to certain cells in such

tively. Serum IgA of cattle is probably synthesized by

a way that these cells can subsequently adsorb specific

bronchial or gut associated lymphoid tissue, while IgM

antigen. It has been shown that IgG2 is cytophilic for

and IgG are most likely synthesized by the spleen and

bovine blood neutrophils and for ovine mammary neu-

peripheral lymph nodes. Immunoglobulin concentra-

trophils. Bovine macrophages were found to be capable

tions in serum and colostral secretions are listed in

of binding both IgG1 and IgG2 in vitro. Live vaccines

Table 29.1.

are believed to preferentially stimulate IgG2. IgM is 10

Antibody present in lacteal secretions may be syn-

to 20 times more effective than IgG in complement fix-

thesized locally or derived from serum via selective

ation. This ability to fix complement may explain why

transport or transudation. Inflammation of mammary

IgM is bactericidal for Gram-negative pathogens. In

epithelium causes an increase in the passage of anti-

this manner it can also opsonize micro-organisms for

bodies from blood to lacteal secretions via transuda-

uptake by phagocytic cells. IgM can also agglutinate

tion. IgA is the major immunoglobulin in most bovine

bacteria and permit them to be flushed out at milking.

Table 29.2

The cellular composition of gland secretions (%).

***PMN**a*

Macrophage

Lymphocyte

Epithelial

Colostrum

62

35

4

0

Milk

3

79

16

2

Dry gland secretion

3

89

7

1

a PMN, polymorphonuclear neutrophil.

Complement *(see Chapter 58)*

Table 29.3

Lymphocyte composition using flow cytometry.

The complement system consists of more than 29 dis-

T cell

B cell

Null

Macrophage

tinct plasma and membrane proteins, several of which

are enzymes. The system is activated either by antibody

Peripheral blood

48

20

10

22

binding to the bacterium (classical pathway) or by car-

Milk

52

14

9

25

bohydrate structures on the surface of the organism

Dry gland

43

19

11

27

(alternative pathway). Triggering of the system results

secretion

in a sequence of biochemical reactions in which one

component activates another component in a cascade

fashion. Complement thus bridges the innate immune

system based on recognition of foreign carbohydrates

and the induced immune system based on specific anti-

Cells of the mammary gland

body formation.

The terminal part of the reaction is the formation

In dry and lacteal secretions the predominant cell type

of a membrane attack complex which causes lytic

is the macrophage while in colostrum the polymor-

lesions to form in the membrane of the invading micro-

phonuclear neutrophil (PMN) serves this role. The

organism. Resistance to complement (serum resist-

number of cells per millilitre in dry period secretion is

ance) is the only virulence factor identified among

greater than that of normal milk. The cellular composi-

strains of Gram-negative bacteria isolated from cases of

tion of gland secretions is outlined in Table 29.2.

bovine mastitis. Serum-sensitive bacteria are either

Identification of cells in milk and blood can be

killed or do not grow in normal milk, whereas serum-

performed by microscopic examination of stained

resistant organisms generally multiply, and only the

smears. Flow cytometry is a sensitive technique which

latter are able to cause mastitis.

allows further differentiation of the mononuclear

There are several effector mechanisms by which

cell population in blood and gland secretions (Table

complement aids phagocytosis. When the complement

29.3). It is unclear why these two techniques yield

cascade is activated, component C3b is deposited on the

different results for the macrophage content of dry

surface of the bacterium. This C3b coating promotes

gland secretion.

adherence to and ingestion by phagocytes, which

Mammary lymphocytes can respond to mitogens

possess surface receptors for C3b. Products of com-

and particulate and soluble antigens; however, these

plement activation include C3a and C5a which are *responses are lower than those of peripheral blood chemoattractant for neutrophils and C5a can activate lymphocytes from the same animal. T lymphocytes can neutrophils. The inflammatory mediators responsible produce cytokines which effect recruitment and activa- for the influx of neutrophils into milk have not been tion of other cell types. T cells may be further subdi- conclusively identified. Infusion of activated comple- vided according to their accessory molecules (CD4 or ment induces inflammation in dry glands but not in CD8) or antigen receptors (alpha-beta or gamma- lactating glands. Levels of complement in lacteal delta). The majority of T cells in milk express alpha- secretions are highest as lactation ends, in the dry beta T cell receptors. The ratio of CD8+ to CD4+ cells period and in colostrum. In normal milk the concen- in blood is 1.5, while in mammary secretions it is 0.85. tration of C3 is 1–4 per cent of serum, but milk does Some activated CD8+ cells may suppress the prolifera- contain anti-complementary activity. In mastitis there is tion of CD4+ cells in the course of S. aureus mastitis and an increase in* *complement components in milk due to*

this may adversely effect antibody production by B

transudation.

cells.

The mammary macrophage functions in phagocytosis

may reflect the poor phagocytic efficiency of these cells

and killing of bacteria, eliminates fat in the involuting

or the unfavourable nature of the non-lactating gland

gland and plays a role in local immunity through

for them. Fc receptor function is impaired by dry secre-

antigen processing and presentation. After they have

tion and colostrum.

phagocytosed bacteria, mammary macrophages gener-

PMN function has limitations, as evidenced by

ate chemoattractants for PMN, while after exposure to

chronic infections with some pathogens persisting in the

endotoxin they release cytokines. Although critical for

face of a high SCC. To increase the efficacy of phago-

phagocytosis of Strep. uberis they may provide an intra-cytosis one could increase and maintain a high level *cellular location for Staph. aureus and their phagocytic of opsonin in milk through immunization, select for*

capacity is reduced by dry secretion. A considerable

cows with superior phagocytic ability or decrease PMN

population of macrophages exists beneath the alveolar

mobilization time in response to pathogen invasion.

and ductal epithelium.

Antigen-specific inflammatory responses can be estab-

Milk from normal uninfected glands contains less

lished in the gland by parenteral immunization and one

than 300 000 cells per millilitre and the predominant

of the effector inputs of vaccination is the more rapid

cell is the macrophage. Subclinically infected quarters

response of the PMN to infection. One could also

contain around 750 000 cells per millilitre, while the

increase and maintain a high PMN concentration in

secretion of infected quarters contains millions of cells

milk; however, this will adversely affect milk quality.

per millilitre and in both these instances the pre-

dominant cell is the polymorphonuclear neutrophil

leukocyte (PMN). A pre-existing leukocytosis confers

Cytokines

increased resistance to infection; however, increased

Cytokines are a group of regulatory proteins which act

amounts of serum factors in the milk typically accom-

as intracellular communication signals and are secreted

pany this leukocytosis. When intramammary devices

in very low amounts by a variety of cell types. Most

increase cell counts to 900 000 per millilitre in strip-

cytokines possess multiple biological properties and

pings, protection against a wide variety of mastitis

regulate the activity of cells which participate in specific

pathogens is achieved. Such high cell counts are not

and non-specific immunity. Some can also alter phy-

desired by the dairy industry.

siological processes and cause pathological changes.

There is a large pool of mature neutrophils present

The immunomodulatory capacity of these molecules is

to fight infection. The half life of the cell in the blood-

complex and interactions exist between cytokines – the

stream is about nine hours, with a substantial number

cytokine network. Tumour necrosis factor (TNF), inter-

developing in the bone marrow. Upon infection of the

leukin-1 (IL-1), interleukin 2 (IL-2), interleukin 6 (IL-

gland, PMNs adhere to capillary endothelium via recep-

6) and interleukin 8 (IL-8) have been detected in milk

tors and pass through it by diapedesis. They then

during inflammation. These and other cytokines have

migrate down chemotactic gradients and enter the

been shown to affect bovine mammary leukocytes in

lumen of the gland through the mammary epithelium.

vitro and to a lesser extent in vivo. Their role as vaccine Antibody and complement promote contact and recog-adjuvants and therapeutic agents is being evaluated.

nition of the pathogen, which is ingested and exposed

to the microbiocidal system of the PMN. Both oxygen

dependent and independent pathways exist within neu-

trophils to kill ingested microbes. Some bacteria such

Intramammary infection

as Staph. aureus possess defence mechanisms against

(see also Chapter 23)

oxidative damage by neutrophils and may survive

within the phagosome. PMNs are viable for 1–2 days in

To induce mastitis a pathogen must pass the teat canal *the mammary gland, then undergo apoptosis (pro-*

and enter the gland, survive the bacteriostatic and bac-

grammed cell death) before ingestion by macrophages.

tericidal mechanisms and use the available nutrients to

Phagocytosis by mammary PMNs is much less effi-

replicate. Colonization of the gland reflects both the

cient than that by blood PMNs. PMN function in the

adherence capacity of the pathogen and its ability to

mammary gland is impaired by milk fat globules, casein

utilize nutrients in lacteal secretion to multiply. Strep.

and the lower glycogen content of milk PMN compared

agalactiae and Staph. aureus adhere readily to ductular to blood PMN. PMN function can also be impaired by

epithelial cells, while Escherichia coli, Klebsiella spp.

bacterial toxins. Cows vary in both the ability of their

and Arcanobacterium pyogenes adhere poorly. If they

PMN to phagocytose and in the capacity of their milk

are to maintain infection within the gland, bacteria must

to support phagocytosis. Despite high levels of phago-

multiply at a rate which exceeds that at which they

cytic cells in the gland during the dry period, the gland *are eliminated. The outcome of infection depends on*

is very susceptible at this time to new infection. This

the rate of growth of the organism, the production,

absorption and activity of toxins and the immune status

all of these quarters had peracute toxic mastitis after

of the host.

parturition.

Following infusion of 500 colony forming units

(CFU) of E. coli, newly calved cows mobilize PMN

Virulence factors and immune

slowly and appear to be refractory to the presence of

response to major pathogens

irritants in the udder. This permits great bacterial repli-

cation and a large subsequent release of endotoxin

which is often fatal (Hill, 1979). Killing of some E. coli ***Escherichia coli*** *(see also Chapter 23)*

strains within the udder requires a neutrophilia only,

Escherichia coli mastitis is an opportunist infection.

whereas for others up to 30 per cent serum products

When 290 E. coli isolates were examined, 82 per cent *are required. For virulent strains a PMN response and*

could be grouped into 63 O-serogroups, the remainder

opsonin are typically required. In decomplemented

being untypable (Linton & Robinson, 1984). Mastitis

non-immune serum, colostrum and whey, the main

isolates do not possess the virulence factors associated

opsonin for E. coli is IgM and there is no absolute

with invasive or enteropathogenic strains of E. coli and requirement for complement in the opsonization of E.

cannot be distinguished from faecal isolates. Serum

coli by the adult dairy cow. Later research found IgG2

resistance, which is the capacity to withstand killing by

from immune bovine serum or whey opsonic for E. coli.

complement, is the key feature of mammary isolates.

Encapsulated isolates are more resistant to uptake by

The contribution of a capsule is unclear because most

PMN and require greater amounts of opsonin than non-

unencapsulated strains are serum resistant. Serum-

encapsulated isolates.

sensitive strains are killed rapidly, with over 90 per

The Gram-negative cell wall consists of an inner cyto-

cent killed in 15 minutes by freshly collected 10 per cent

plasmic membrane and a cell wall which is composed

normal bovine.

of mucopolysaccharide–peptidoglycan, phospholipid

When serum-resistant strains gain access to the

protein and lipopolysaccharide. LPS is composed of

lactating gland they commence to multiply and

three distinct subunits. The outermost O polysaccharide

lipopolysaccharide (LPS), also called endotoxin, is

is linked to the core polysaccharide which is covalently

released from the bacterial cell wall. Endotoxin is found

bound to the lipid A. Free lipid A in soluble form

in 50–100 per cent of lacteal secretions and 15 per cent

expresses all the typical in vivo properties of endotoxin.

of blood samples of cows with coliform mastitis. The

Resistance to the bactericidal activity of normal serum

exaggerated response of the host to endotoxin is often

is attributable to the O antigen of the LPS. When com-

responsible for the severity of this mastitis. Fever,

pared to serum-sensitive strains, LPS from serum-

disseminated intravascular coagulation, hypotension, *resistant strains is relatively enriched in long-chain O*

shock, complement activation and death can occur.

antigen subunits. These O polysaccharides may mask

Macrophages are the principal method by which

lipid A which could activate the alternative comple-

endotoxins are removed. In the presence of LPS

ment pathway. If the longer polysaccharide chains do

macrophages become activated and secrete IL-1, IL-6

bind C3b, the distance from the outer membrane of the

and TNF. These cytokines mediate endotoxic events

bacteria is too far for insertion of the complement

and are responsible for many of the clinical signs asso-

membrane attack complex.

ciated with this condition.

The O polysaccharides are made up of a series of

E. coli does not adhere to mammary epithelial cells.

identical repeating oligosaccharide units containing

The organisms grow in secretions and there is little

three to five sugars each. The O polysaccharide is

tissue invasion. Mammary lesions in E. coli mastitis are immunodominant and displays great diversity in length *confined to the superficial layer of the teat and lactif-*

and sugar constituents whereas the core polysaccharide

erous sinus where extensive sloughing and necrosis

is conserved. Antibody to the O polysaccharide antigen

of epithelial cells is evident. Secretory tissue is not

or LPS affords protection against homologous chal-

involved. The response of cows to E. coli infection of lenge only. Because of the great diversity of the O poly-the gland may be a function of the physiological state

saccharides of LPS, a search for shared epitopes on

of the gland. The dry gland is much less responsive to

other parts of the molecule has been undertaken in an

endotoxin than the lactating gland and mild histopatho-

effort to find an antigen that could be used for active

logical changes are noted following infusion. E. coli is immunization. Gram-negative core antigens have

incapable of establishing itself permanently in the gland

immunological homology across bacterial species, but

in the first half of the dry period and this may be

are typically masked by the immunodominant O

due to lactoferrin (Bramley, 1976). One experiment

polysaccharide.

revealed that in the 30 days before parturition bacteria

In contrast to smooth organisms, rough mutants,

maintained infection in 14 of 37 inoculated quarters and

called so because of their colonial morphology, have

incomplete synthesis of O polysaccharide side chains

and dry matter intake was higher in vaccinates. In a sep-

and consequently varying amounts of the core gly-

arate trial of similar design, cows were challenged one

colopid are exposed. The E. coli J5 strain is an Rc

month after calving with a field strain known to cause

mutant of E. coli O11 : B4 and has an LPS devoid of O

mild clinical mastitis. No differences in temperature,

antigen (see p. 1016). Animals immunized with killed J5

milk production and systemic signs were observed

bacteria are able to make antibodies to the core region

between groups, but vaccination reduced the duration

and are protected from challenge with heterologous

of both infection and local clinical signs.

live organisms. Antibody to J5 cross-reacts with LPS

It is known that cows which succumb to natural clin-

extracted from other Gram-negative bacteria which

ical coliform mastitis are in a complex physiological

cause mastitis, in particular Klebsiella spp. The protec-state with alterations in neutrophil function, including

tive factor induced by vaccination is considered to be

receptor expression, rate of diapedesis and phagocytic

antibody to core glycolipid which binds to invading bac-

capacity. Measurement of these parameters can

teria at a time when the core antigens are most exposed,

predict which cows will suffer severe clinical mastitis in

that is, early in their growth phase. This antibody pro-

response to experimental challenge. These animals may

motes opsonization of Gram-negative bacteria and may

receive greatest benefit from vaccination and field trials

also be bactericidal or reduce growth of the organism.

would more accurately reflect this benefit. For immuno-

The protective ability of antibodies to core glycolipid

logical prevention of Gram-negative infection to be a

may also reflect their ability to bind to released LPS,

possibility three requirements must be met. A common

neutralize the toxic effects of lipid A and thereby dimin-

antigenic structure must exist; this must function as an

ish systemic signs. Such release would occur during bac-

immunogen and the response to this immunogen must

terial growth or after antibiotic therapy, phagocytic

generate protective antibodies. Large field trials indi-

destruction or complement mediated lysis.

cate that the J5 bacterin achieves this goal. Cows vac-

Initial studies of IgG1 antibody titres to the core anti-

cinated in the dry period and at calving have a lower

gens of J5 showed that titres of less than 1 : 240 were

incidence of clinical coliform mastitis in early lactation.

associated with 5.33 times the risk of clinical coliform

The vaccine does not reduce the incidence of intra-

mastitis (Tyler et al. , 1988). This vaccine has been the mammary infection with coliforms at calving, but

subject of several field trials. In one trial, 246 cows

reduces the number of infected quarters which display

received three doses of J5 killed cells (7.5 billion bac-

clinical signs. Two new areas of research include the use

teria per dose) in Freund's incomplete adjuvant, twice

of a Salmonella typhimurium Re17 bacterin to prevent *in the dry period and once after calving, while 240*

coliform mastitis and the effect on E. coli of antibodies unvaccinated cows served as controls. Six cases of clin-specific for membrane proteins involved in iron

ical coliform mastitis occurred in vaccinates with 29

transport.

occurring in control cows (Gonzalez et al. , 1989). In a separate trial which lasted 30 months, cows received

Klebsiella spp. *(see also Chapter 23)*

either vaccine or placebo at dry-off, 30 days later and

at calving. There was no difference between groups in

Klebsiella pneumoniae (K. pneumoniae) and K. oxytoca the percentage of quarters infected with Gram-negative

are environmental pathogens and opportunist invaders

bacteria at calving. In the control group, 67 per cent of

of the bovine mammary gland. Within the genus Kleb-

these infections became clinical in the first 90 days of

siella there are over 70 capsular types and eight somatic lactation compared to 20% in the vaccinated group

types or O groups. Thirty-three capsular types of K.

(Hogan et al. , 1992a).

pneumoniae were isolated from cows belonging to 12

Cows directly challenged with coliform bacteria via

herds and within individual herds up to 13 types could
the intramammary route have provided data which are
be found. The primary feature of pathogenic strains
less supportive of the efficacy of the J5 vaccine. One
is their ability to withstand the bactericidal effects of
experiment found no difference between vaccinates
normal serum. Some are also adapted to grow in the
and control cows subsequent to challenge with 150
secretion of non-lactating glands. Following infusion of
CFU of a serum-resistant strain (Hill, 1991). Both
small numbers of serum-resistant bacteria into normal
groups displayed acute clinical mastitis with systemic
mammary glands a severe mastitis is evident. This mas-
signs, a decrease in milk production and large numbers
titis is prevented by a pre-existing leukocytosis or by the
of bacteria in the milk. In an American study, cows
presence of specific antibody.
immunized at drying off, 30 days later and at calving
Cell wall O antigens are responsible for resistance to
were challenged with a virulent field strain 30 days into
serum bactericidal activity. The capsule confers resist-

lactation (Hogan et al. , 1992b). Lower milk bacteria

ance to phagocytosis in the absence of specific antibody.

counts were observed in vaccinates but SCC and local

Although type-specific protection can be achieved by

clinical signs did not differ between groups. Milk yield

vaccination with the homologous capsular polysaccha-

ride, the numerous capsule types recovered from lacteal

A. pyogenes does not adhere to mammary epithelial

secretions preclude the use of a polyvalent capsular

cells and this may explain why summer mastitis is typi-

vaccine. Antibody specific for core glycolipid of E. coli

cally associated with the non-lactating gland. This bac-

J5 strain cross-reacts with endotoxin extracted from K.

terium grows best in lacteal secretion when the pH is

pneumoniae. This antibody is reputed to bind to these

greater than 7, as in the dry gland, and secretes

core antigens during the log phase of bacterial growth

haemolysin and proteases. P. indolicus stimulates the and in this manner afford protection.

growth and haemolysin production of A. pyogenes. High *titres of protease antibodies are found in the serum of*

infected cows. P. indolicus and the microaerophilic

Mycoplasma spp. *(see also Chapter 23)*

coccus produce enzymes which can damage tissue.

Mycoplasmas lack a cell wall and are surrounded by a

Early vaccines were composed without regard to the

membrane which is similar to the cytoplasmic mem-

complex nature of the aetiology, typically containing A.

brane of bacteria. Several species of mycoplasma cause

pyogenes with or without hemolysin, and the results

mastitis but Mycoplasma bovis (M. bovis) is most were poor. Sorensen showed that A. pyogenes alone

prevalent. Cows in all stages of lactation are suscepti-

had no protective effect but that a triple bacterin prepa-

ble but those in early lactation suffer more severely.

ration composed of A. pyogenes, P. indolicus and the Antibiotics have little success but after a prolonged

microaerophilic coccus gave encouraging results and

time cows may recover. Resistance to killing by serum

merited further study (Sorensen, 1972). There is a

is a virulence determinant and a pre-existing leukocy-

marked lack of data on the immune response of the cow *tosis does not prevent cows from challenge. Neutrophils*

to these pathogens and approaches to vaccination will

are not capable of killing M. bovis unless specific anti-remain empirical for some time.

body is present.

Udders with a quarter which had resolved infection

***Staphylococcus aureus** (see also Chapter 23)*

were examined and it was found all quarters of the

udder were resistant to challenge. Quarters recovered

Staphylococcus aureus has been described as a persist-from infection were immune for up to six months, but

ent pathogen of the gland due to the failure of therapy

over one year postinfection all quarters were suscepti-

during the lactating period to achieve bacteriological

ble to reinfection. Studies of the immune response to

cures. It is a contagious pathogen and infusion of 10

M. bovis have failed to differentiate between resistant CFU into the teat sinus can cause mastitis. Much

and susceptible animals. Systemic antibody does not

research has been performed to ascertain the benefit

appear to protect from infection and the immunity may

of immunization with staphylococcal antigens. Early *be based on locally produced IgA and IgG and the*

attempts at vaccination were unsuccessful and these

action of T lymphocytes. Immunization with protein

failures can be explained to a degree by the low

extracts assists cows in eliminating infection. No atten-

numbers of bacteria used and by the culture of these

uated strains have been identified.

bacteria in conventional media which does not support

the expression of certain surface polysaccharide viru-

lence factors. Later work demonstrated limited protec-

The summer mastitis complex

tion against homologous strains, a reduction in the

(see also Chapter 24)

severity of clinical infection and a reduction in spread

There are conflicting views on what are the causative

of Staph. aureus mastitis in vaccinated herds.

organisms of summer mastitis and how these organisms

The cell wall is composed of peptidoglycan, teichoic

spread and invade the gland. Summer mastitis typically

acid and protein A. Protein A can bind to the Fc portion

affects the non-lactating gland of heifers or dry cows and *of IgG molecules. Peptidoglycan was once considered*

involves mixed bacterial infections. Arcanobacterium

to be the key cell surface component involved in

pyogenes (A. pyogenes), Peptostreptococcus indolicus promoting opsonization of Staph. aureus. Most bovine

(P. indolicus), a microaerophilic coccus and Streptococ-mammary isolates of staphylococci produce additional

cus dysgalactiae are the pathogens believed to have a surface polysaccharides which are located outside the

role in this condition. Fusobacterium necrophorum and peptidoglycan layer. These polysaccharides may block

Bacteroides melaninogenicus have also been recovered

antibody binding to peptidoglycan or prevent bound

from the secretion of affected glands. Sorensen (1972)

antibody interacting with phagocytic receptors. Their

could induce summer mastitis in heifers with A. pyo-

precise composition remains obscure and they have

genes and P. indolicus or with these two organisms and been described as exopolysaccharides, pseudocapsules

a microaerophilic coccus. Cultures were more virulent if

and slime. Their production is typically associated with

grown together and infused rather than grown sepa-

growth in milk. Such growth increases the virulence rately and then mixed for infusion.

of a strain, induces anti-phagocytic properties and

increases adherence to epithelial cells. A typing scheme

was not statistically significant (Nordhaug et al. , 1994).

based on chemically characterized capsular polysac-

Isolated exopolysaccharide in liposomes afforded

charides has been described for staphylococci. Serotyp-

sheep protection from infection.

ing of bovine isolates for capsular polysaccharides 5 and

Studies performed in Australia found vaccination

8 typically found 50 to 70 per cent of isolates possessed

with live bacteria protected the gland from infection.

one of these microcapsules, though in some countries

The protection afforded by vaccination with live bacte-

non-typeable isolates predominated.

ria is due to the generation of specific IgG2 which is

Staphylococcus aureus produces around 30 extracel-

cytophilic for PMN. The use of live bacteria has signif-

lular proteins, some of which have been shown to be

icant disadvantages and consequently bacteria grown in *virulence factors (Sutra & Poutrel, 1994). Alpha-toxin*

a medium containing milk whey and then killed have

is believed to be responsible for much of the tissue

been used. Killed bacteria stimulate IgG2 when admin-

damage seen in staphylococcal mastitis and beta-toxin

istered with the adjuvant dextran sulphate. In normal

has been shown to cause inflammation of the gland.

glands there is a 24 hour lapse between entry of

Following experimental infection ulcerative and erosive

bacteria into the gland and the accumulation of 500 000

lesions in the epithelial layer are evident throughout

PMNs per millilitre and this delay allows infection to

the ductal system. Toxins can also damage PMNs whose

become established. Vaccination can decrease this lag

role in defence against Staph. aureus became apparent period to 6 hours and PMNs may enter the gland, car-when anti-bovine leukocyte serum converted a chronic

rying IgG2 on their membrane.

staphylococcal mastitis to an acute gangrenous type.

Australian workers developed a vaccine containing

Neutralizing antibodies can be induced through vacci-

killed bacteria, alpha-toxoid and beta-toxoid, emulsi-

nation and these lessen the damage to secretory tissue.

fied in an adjuvant of mineral oil and dextran. Experi-

The surface of staphylococci contains proteins which

ments have been performed to establish the efficacy of

can bind the host tissue proteins fibronectin, fibrinogen

this Australian vaccine (Watson et al. , 1996). In chaland collagen. Attachment to ductal epithelial cells is an

lenge studies in sheep the incidence of peracute gan-

important step in colonization and is thought to be

grenous and acute clinical mastitis and the decrease in

mediated by fibronectin binding protein. Specific anti-

milk yield was lower in the vaccinates. Heifers which

body has been shown to prevent this adherence. During

received the vaccine had lower SCC and greater milk

infection toxins may expose subepithelial connective

production after challenge, compared to controls. A

tissue components to which the organism can bind in a

field trial conducted on seven herds and over 1800 cows

specific manner.

found 45 clinical cases of Staph. aureus mastitis in vac-Staphylococcal enterotoxins were originally

cinates and 67 cases in controls. This difference was not *described for their ability to cause food poisoning or*

statistically significant. One of the herds had a high inci-

toxic shock syndrome in humans. There is variation

dence of Staph. aureus mastitis and in this herd clinical between countries in the proportion of bovine Staph.

and subclinical cases of mastitis were significantly lower

aureus isolates secreting these molecules. Recent

in vaccinates compared to controls.

research suggests they may have a role to play in

A better understanding of Staph. aureus suggests that staphylococcal mastitis by causing immunosuppression.

protection depends on antibodies being generated to

Enterotoxins may activate CD8+ T lymphocytes and

several virulence factors. Vaccines should generate anti-

decrease the response of CD4+ T lymphocytes to

bodies specific for matrix binding proteins to prevent

staphylococcal antigens. As superantigens, enterotoxins

adherence and to the surface polysaccharides to

may also contribute to inflammation by activating cells

promote opsonization. Neutralizing antibodies specific

in a non-specific manner and causing the release of

for alpha- and beta-toxins would lessen clinical damage *inflammatory cytokines. Bovine mononuclear cells pro-*

and protect the cellular defences of the gland. The

liferate in response to enterotoxin and secrete IL-2,

results of trials with experimental vaccines based on

gamma-interferon and TNF. It is difficult to stimulate

these three components will clarify whether vaccination

neutralizing antibodies to these molecules.

has a role in preventing staphylococcal mastitis. When

In a field trial with a staphylococcal bacterin–toxoid

attenuated strains are administered by the intramam-

preparation, fewer new infections, less culling and lower

mary route, they replicate but are eliminated by the

somatic cell counts were evident in vaccinated cows as

gland. The capacity of such strains to stimulate protec-

opposed to controls. Each dose of bacterin contained

tive immunity is being examined.

10 billion CFU of each of two strains of Staph. aureus, whose exopolysaccharide cross-reacted with most field

Streptococcus spp.

isolates. The toxoid component contained alpha- and

beta-hemolysins. A second trial found fewer clinical

There are no cross-reactive protective epitopes shared

and subclinical cases in vaccinates but this difference

by the streptococci which cause mastitis.

Streptococcus agalactiae (see also Chapter 23)

found in the alveolar exudate with just a small number

associated with damaged epithelial cells. After infection

Streptococcus agalactiae (Strep. agalactiae) is a Group B

there are many neutrophils in gland secretions but few

streptococcus and is an obligate parasite of the bovine

contain Strep. uberis. The role of this cell in defence mammary gland where it colonizes the milk ducts. It

against Strep. uberis is unclear because isolates poscan be eliminated from a herd through culture and ther-

sessing a hyaluronic acid capsule resist uptake by neu-

apeutic means. This easy step should take precedence

trophils and capsular material can damage PMNs.

over the task of generating protective antibody. The

Macrophages may be the key defence cell since they

group-specific polysaccharide is common to all strains

can ingest isolates which have been opsonized by IgG *and Strep. agalactiae can be divided into five distinct 1*

and IgG

serotypes based on the presence of type-specific surface

2.

Quarters previously infected with Strep. uberis are

antigens. A protein antigen designated X is frequently

significantly protected from subsequent infection by the

associated with bovine mastitis isolates. Attachment to

same bacteria. Immunization with killed bacteria via

epithelia is a prerequisite for colonization and surface

the intramammary or subcutaneous route offered pro-

lipoteichoic acid may aid in this attachment. Strep.

tection from challenge with the immunizing strain and

agalactiae produces CAMP factor which is lethal for

a strong inflammatory reaction was present in the

mice and rabbits.

gland. The bacterin did not afford protection from

The bactericidal activity of neutrophils for Strep.

infection with wild-type strains. When live bacteria

agalactiae is dependent on antibody and complement.

were administered subcutaneously and bacterial

Most opsonizing antibody is directed to the weakly extracts by the intramammary route, a degree of pro- immunogenic, type-specific polysaccharide and such tection was again noted. This protection did not extend antibody is a more efficient opsonin when it binds com- to strains not included in the vaccine. As there was only plement. The sera of cows contain low levels of natural a mild inflammation in the gland it was proposed that opsonin. Mackie et al. (1986) found heifers became live vaccine affected the ability of the organism to repli- hyperimmune following systemic vaccination by the cate and a neutrophil response was not critical for pro- subcutaneous and intravenous routes. Despite high tection from infection (Leigh, 1999).

titres there was little real difference between the hyper- Streptococcus uberis is unable to produce certain immune and non-vaccinated heifers following chal- amino acids and must find them in its environment. lenge with around 40 million bacteria and it was Studies using chemically defined media found all strains concluded that locally produced antibody may be *require eight amino acids for growth, with some requir-*

required for protection. Antibodies to protein X

ing 13 amino acids. The organism is incapable of

increase the ingestion of bacteria by PMNs but do not

hydrolysing proteins directly, but is able to convert

increase the number of bacteria killed by PMN.

bovine plasminogen to plasmin, a protease which can

break down casein into peptides. The plasminogen acti-

vator of Strep. uberis is a protein of 30 kD; it is secreted Streptococcus uberis (see also Chapter 23)

by almost all isolates and specific neutralizing antibod-

Streptococcus uberis (Strep. uberis) has been examined ies are stimulated following immunization.

serologically, biochemically and by molecular biological

In an experimental challenge trial, vaccination with

techniques. It does not fit into the Lancefield classifica-

plasminogen activator gave a significant degree of

tion with 25 per cent of strains typing as group E and

protection from clinical disease and greatly reduced

smaller numbers belonging to other serogroups. A

bacterial numbers in milk (Leigh, 1999). Both of these

similar percentage of strains is CAMP positive. Sensi-

protection indices were achieved in the presence of a

tive molecular typing methods indicate most isolates

mild inflammatory response and protection was corre-

are genetically dissimilar. This organism can be recov-

lated with the titre of neutralizing antibody specific for

ered from several body sites of the cow and from

plasminogen activator. The studies conducted with

manure and soil. It has become a significant cause of

Strep. uberis could be highly relevant to other mastitis mastitis and as an environmental pathogen is less

pathogens and have underlined the importance of in

affected by conventional control methods.

vivo rather than in vitro studies.

The susceptibility of the dry mammary gland to

infection with Strep. uberis increases with time and in Streptococcus dysgalactiae (see also Chapter 23)

the second half of the dry period all quarters are

susceptible. This bacterium binds low amounts of fi-

Streptococcus dysgalactiae (Strep. dysgalactiae) is a bronectin, fibrinogen and type II collagen. Adherence

group C streptococcus and possesses a hyaluronic acid

to mammary epithelial cells has been described in vitro, capsule. The group C antigen is a carbohydrate and *but in experimental infections most bacteria were*

three type-specific antigens have been identified. This

bacterium is able to cause mastitis on its own and is one

entation to CD4+ T cells and to B cells. These CD4+ cells

of a number of pathogens involved in the summer

release cytokines that stimulate the B cells to divide and

mastitis complex. Strains of highest infectivity are those

produce antibodies. A small proportion of B cells

which adhere well to mammary epithelial cells. Strep.

become memory cells and if subsequently presented

dysgalactiae binds well to fibronectin, moderately to fib-with their specific antigen they will proliferate rapidly

rinogen and poorly to collagen. Protein G is present in

and produce large amounts of antibody. Macrophages,

the cell walls of some Strep. dysgalactiae and can bind T cells and B cells are present in the mammary gland

bovine IgG. Such non-specific binding of immunoglob-

and administration of antigen to the dry gland stimu-

ulin may protect the bacteria from gland defences.

lates local synthesis of IgA and IgG1. Such production

Cows develop protective antibody following immu-

persists well into lactation and is associated with the

nization and hyperimmunized cows showed a degree of

development of plasma cells in periductal connective

resistance to challenge exposure of the homologous

tissue and interalveolar areas. The response is much less

strain.

when antigen is administered to the lactating gland.

Intraperitoneal administration of antigen followed

by local infusion recruits cells from systemic lymphoid

Mucosal immune system

tissues which have been primed by intraperitoneal

immunization. Vaccination in the region of the draining

The concept of a common mucosal immune system was

lymph node of the mammary gland stimulates serum

proposed following the observation that subsequent to

antibody and promotes production of local antibody.

intestinal exposure to antigen, specific immunity was

This may be due to the trafficking of lymphocytes. The

evident at distant mucosal sites. Immunocompetent

J5 coliform mastitis was efficacious when administered

cells (specific lymphocytes) can migrate from Peyer's *subcutaneously or in the area of the supramammary*

patch or mesenteric lymph nodes to distant sites,

lymph node. The administration of antigen in the region

become resident and respond to sensitizing antigen.

of the draining lymph node accompanied by local infu-

This does not seem to be true for ruminants since there

sion is likely to have the greatest impact on the gener-

is no selective migration of lymphocytes between the

ation of antibodies in lacteal secretions.

mammary gland and the gut of the cow. There are two

The time of vaccination is another important factor

major groups of recirculating lymphocytes in the cow:

since most infections occur at drying off, during the dry

a peripheral and an intestinal pool. Labelled lympho-

period and in the periparturient period. Almost 100 per

cytes from the supramammary lymph node recirculated

cent of clinical mastitis occurs during lactation, with 60

to the prescapular and supramammary lymph node

per cent taking place in the first 40 days. Vaccination

whereas labelled ileac mesenteric lymphocytes were

should be designed to offer maximum protection at *recovered from intestinal mesenteric lymph nodes.*

these times. If systemic immunization is carried out at

Local administration of antigen to the mammary gland

drying off, a booster given shortly before parturition by

would stimulate lymphocytes in the lamina propria to

the intramammary route allows the gland to give a

expand clonally and some of these cells would traffic to

heightened and prolonged response through the next

the supramammary lymph node.

lactation (Watson & Lascelles, 1975).

Two components of a successful vaccine are the

antigen and the adjuvant. As knowledge of the protec-

Generation of immune response

tive antigens of mastitis causing bacteria has grown, it

is now appreciated the amount of antigen in a vaccine

Immune responses designed to protect the bovine

dose is critical and that the numbers of bacteria used in

mammary gland from infection can be generated by

early studies were too low. Growth of Gram-positive

administration of antigen by various routes. Systemic

cocci on conventional laboratory media can result in *immunization performed by the intramuscular, subcu-*

decreased expression of key bacterial antigens which

taneous or intravenous route generates serum antibody.

are expressed during in vivo replication. Adjuvants

When mammary epithelium becomes inflammed size-

are substances which act in a non-specific manner to

able amounts of circulating antibody pass into the

augment the immune response to an antigen. Mineral

lacteal secretions from the serum by transudation. Anti-

oil, saponin and aluminium hydroxide are examples of

body has its greatest effect when present in lacteal

adjuvants employed in veterinary vaccines. They can

secretions before infection is established. Direct injec-

affect the magnitude, duration and isotypic composition

tion of antigens into the udder stimulates both a local

of the immune response. The mechanism of action of

and a systemic response.

adjuvants is not fully understood but includes slow

The primary course of events for humoral immunity

release of antigen from a depot, alteration of lympho-

involves antigen processing by macrophages and pres-

cyte circulation and release of cytokines.

Limitations of vaccination

To maintain levels of antibody in this volume of secre-

tion requires an enormous synthetic rate. Immunization

does not confer absolute protection and at best will

The scientific literature contains numerous reports doc-

complement good husbandry and other mastitis control

umenting the failure of vaccination to protect against

procedures. Vaccines for coliform mastitis will continue

intramammary challenge with a pathogen. There are

to be used widely while products to prevent Staph.

fewer reports of protective products. These studies

aureus and Strep. uberis should become available in the account for the two opposing views concerning the role

near future. For other mammary pathogens there is

of vaccination in mastitis control programmes. Chal-

little prospect of vaccines becoming available.

lenge studies often have consisted of placing thousands

of bacteria into the teat sinus, which is not an accurate

reflection of natural infections in which only a few

References

organisms will traverse the teat duct and reach the

cistern to multiply. A better method to establish the effi-

cacy of a vaccine is to perform field trials in herds where

Bramley, A.J. (1976) Variations in the susceptibility of lactating and non-lactating bovine udders to infections when

natural exposure to the pathogen will occur, with one

infused with Escherichia coli. Journal of Dairy Research, **43**, half of the herd receiving vaccine and the remaining

205–11.

half receiving placebo. The evaluation of infection, clin-

Butler, J.E. (1986) Biochemistry and biology of ruminant

ical inflammation, persistence of leukocytosis, bacterial

immunoglobulins. Progress in Veterinary Microbiology and

shedding and the effect on milk production will help

Immunology, **2**, 1–53.

determine vaccine efficacy.

Colditz, I.G. & Watson, D.L. (1985) Immunophysiological

The dairy cow undergoes periods of severe stress in

basis for vaccinating ruminants against mastitis. Australian each lactation cycle and immune dysfunction occurs at

Veterinary Journal, **62**, 145–52.

certain times. Immunosuppression can occur during

Gonzalez, R.N., Cullor, J.S., Jasper, D.E., Farver, T.B., Bushnell, pregnancy, lactation and parturition. Much interest has

R.B. & Oliver, M.N. (1989) Prevention of clinical col-

been directed to the four-day period prior to and sub-

iform mastitis in dairy cattle by a mutant Escherichia coli vaccine. Canadian Journal of Veterinary Research, ***53****, sequent to parturition, the so-called periparturient*

301–305.

immunosuppression. Secretion taken just after drying

Hill, A.W.

(1979) The pathogenesis of experimental

off and at parturition has an inhibitory effect on blas-

Escherichia coli mastitis in newly calved dairy cows.

togenic responses to mitogens. Proliferative responses

Research in Veterinary Science, ***26****, 97–101.*

to mitogens by blood and milk lymphocytes are low for

Hill, A.W. (1991) Vaccination of cows with rough Escherichia one week before parturition and lowest on the day

coli mutants fails to protect against experimental intra-before calving (Kehrli et al. , 1989). This may relate to mammary bacterial challenge. Veterinary Research Com-the high incidence of clinical mastitis and intramam-

munications, ***15****, 7–16.*

mary infection which occur at calving and up to 30 days

Hogan, J.S., Smith, K.L., Todhunter, D.A. & Schoenberger, P.S.

past calving. Certain indices of neutrophil function

(1992a) Field trial to determine efficacy of an Escherichia increased two weeks before parturition and decreased

*coli J5 mastitis vaccine. Journal of Dairy Science, **75**, 78–*

84.

dramatically by the first week after parturition.

Hogan, J.S., Weiss, W.P., Todhunter, D.A., Smith, K.L. &

Because the concentration of PMNs is used to assess

Schoenberger, P.S. (1992b) Efficacy of an Escherichia coli J5

milk quality and a major defence component of the

mastitis vaccine in an experimental challenge trial. Journal gland involves a leukocytosis with specific antibody,

*of Dairy Science, **75**, 415–22.*

some authors argue that protection afforded by such a

Kehrli, M.E., Nonnecke, B.J. & Roth, J.A. (1989) Alterations leukocytosis is, by definition, mastitis. Such a protective

in bovine lymphocyte function during the periparturient

response can be interpreted in this manner. There

*period. American Journal of Veterinary Research, **50**, 215–20.*

is mounting evidence indicating that for certain

Leigh, J.A. (1999) Streptococcus uberis, a permanent barrier pathogens, appropriate immunization strategies can to the control of bovine mastitis? The Veterinary Journal, reduce the number of clinical cases, reduce the number

157, 225–38.

of new infections, improve the response to therapy and

Linton, A.H. & Robinson, T.C. (1984) Studies on the association of Escherichia coli with bovine mastitis. British Veteri-decrease the severity of clinical mastitis. If this involves

nary Journal, **40**, 368–73.

a transient leukocytosis, it is likely farmers will accept

Mackie, D.P., Meneely, P.J., Pollack, D.A. & Logan, E.F.

the benefits.

(1986) The loss of opsonic activity of bovine milk whey fol-

The mammary gland of the cow has limited defensive

lowing depletion of IgA. Veterinary Immunology and

capabilities with regard to PMN function and level of

Immunopathology **11**, 193–8.

opsonins. In North America, good dairy cows yield on

Mellenberger, R.W. (1977) Vaccination against mastitis.

average 30 litres of milk for each day of their lactation.

Journal of Dairy Science, **60**, 1016–21.

Nordhaug, M.L., Nesse, L.L., Norcross, N.L. & Gudding, R.

Tyler, J.W., Cullor, J.S., Osburn, B.I., Bushnell, R.B. & Fenwick, (1994) A field trial with an experimental vaccine against

B.W. (1988) Relationship between serologic recognition of

*Staphylococcus aureus mastitis in cattle. 1. Clinical param-Escherichia coli O111, B4 (J5) and clinical coliform masti-eters. Journal of Dairy Science, **77**, 1267–75.*

*tis in cattle. American Journal of Veterinary Research, **49**, Outteridge, P.M. & Lee, C.S. (1988) The defence mechanisms 1950–4.*

of the mammary gland of ruminants. Progress in Veterinary

*Watson, D.L. & Lascelles, A.K. (1975) The influence of sys-Microbiology and Immunology, **2**, 1–53.*

temic immunization during mammary involution on subse-

Sorensen, G.H. (1972) Sommer mastitis. Den mulige

quent antibody production in the mammary gland. Research

beskyttende virkning af to forskellige vacciner overfor

*in Veterinary Science, **18**, 182–5.*

*eksperimentelle infektioner. Nordisk Veterinar Medecin, **24**, Watson, D.L., McColl, M.L. & Davies, H.I. (1996) Field trial 259–71.*

of a staphylococcal mastitis vaccine in dairy herds, clinical, Sutra, L. & Poutrel, B. (1994) Virulence factors involved in the subclinical and microbiological assessments. Australian

pathogenesis of bovine intramammary infections due to

*Veterinary Journal, **74**, 447–50.*

*Staphylococcus aureus. Journal of Medical Microbiology, **40**, 79–89.*

Chapter 30

Antimicrobial Therapy of Mastitis

D.J. O'Rourke and J.D. Baggot

General considerations

391

Mycoplasma sp. (see Chapters 23 and 24). Differences

Antimicrobial resistance

391

in climate, management and national or regional regu-

Pharmacology of the mammary gland

392

latory efforts result in patterns of disease that vary

Intramammary preparations

393

markedly. The arid south-western regions of North

Parenteral preparations

395

America have repeatedly identified prevalences of

Selection of antimicrobial agent

396

intramammary Mycoplasma sp. infection exceeding

Response to therapy

397

those observed in other parts of the world (Jasper et al., Therapy of mastitis

397

During lactation

397

1966; Jasper, 1980). In a survey of 50 California dairy

During the dry period

399

herds (23 138 cows) potential mastitis pathogens were

Benefits of antimicrobial therapy for mastitis

402

isolated from 22 per cent of cows (Gonzalez et al., 1988).

Improved milk quality

402

Staphylococcus aureus was isolated from all 50 herds, Increased milk production

402

Strep. agalactiae from 47 herds and Mycoplasma sp.

Effective microbiological cures, eliminating reservoirs

from 24 herds. The prevalence of mastitis pathogens

of infection

403

(per cent cows) was Staph. aureus (9.1 per cent), Strep.

Costs associated with antimicrobial therapy

403

agalactiae (9.3 per cent), Mycoplasma sp. (0.9 per cent), Drug and veterinary costs

403

coliform bacteria (1.2 per cent) and other streptococci

Discarded milk

403

(0.9 per cent).

Slaughter withdrawal periods

403

Laboratory testing is an integral part of treatment

Risks of new infections/altered host defences

403

and control programmes and identification of the causal

agents will have a direct bearing on subsequent therapy

decisions. Several handbooks (International Dairy

General considerations

Federation, 1981; National Mastitis Council, 1999) and

articles (Higgs & Bramley, 1981; Buswell, 1995) are

Mastitis is the single most common disease of the adult

available to assist in the identification of mastitis

dairy cow, accounting for 30 per cent of all morbidity

pathogens.

(Gardner et al., 1990) and 38 per cent of health costs (Kossaibati & Esslemont, 1997). Additionally, in herds

where the average culling rate was 23.8 per cent, mas-

Antimicrobial resistance

titis was cited as the reason for culling in 10.1 per cent

of cases and was the most common cause of death (8.9

Although useful as a guideline for antimicrobial selec-

per cent) (Esslemont & Kossaibati, 1997). Failure to

tion, antibiotic sensitivity testing does not guarantee the

achieve expected lactation yield as a consequence of

efficacy of an antibiotic. Generally, the major strepto-

clinical mastitis (Lucey & Rowlands, 1984; Rajala-

coccal pathogens of the bovine mammary gland are

Schultz et al. , 1999) and a reduction in milk yield caused sensitive (>90 per cent) to penicillin, ampicillin and

by subclinical mastitis are responsible for even greater

erythromycin (Prescott & Baggot, 1988). Actual cure

economic losses (Hortet & Seegers, 1998; Hortet et al., rates vary with clinical *and lactation status.*

1999). Efficacious, economical treatment of mastitis

There appears to have been no significant increase in

is therefore an important component of livestock

bacterial resistance of mastitis-causing bacteria in the

medicine.

UK over the past 25 years. Craven et al. (1986) found a The most frequent causes of mastitis are Staphylo-high incidence (69.8 per cent) of b-lactamase produc-

coccus aureus, Streptococcus agalactiae, Strep. uberis, tion which was similar to that (66.1 per cent) reported

Strep. dysgalactiae, Escherichia coli, Enterobacter sp., by Jones and Heath (1985). These studies indicated

Pseudomonas sp., Klebsiella sp., Arcanobacterium little change from the 70.6 per cent of penicillin-

(Actinomyces;

Corynebacterium) pyogenes

and

resistant strains reported by Wilson (1961). Recent

surveys have indicated little change (Buswell, pers.

antimicrobial agent to which the causative pathogenic *comm.). It should also be noted that no staphylococci*

micro-organisms are susceptible at the drug concentra-

of bovine origin that are resistant to cloxacillin have

tion attained at the site of infection in the udder. The

been identified (Jones, 2000), despite its widespread use

administration of an intramammary preparation in con-

in both lactating and dry-cow intramammary prepara-

junction with systemic therapy is highly desirable, but

tion syringes for over 30 years.

the effectiveness of an infused antimicrobial is limited

Sensitivity patterns for the two most common Gram-

negative intramammary pathogens, E. coli and Klebsiella sp., are reported in Table 30.1 and may be used to ***Table 30.1***

Antibiotic sensitivities of selected Gram-negative

guide the choice of antibiotic when treating peracute

bacteria isolated from cattle with clinical mastitis (reported as per mastitis (Mackie et al., 1988; Prescott & Baggot, 1988).

cent of isolates sensitive).

One should be cautioned that sensitivity patterns will

vary locally according to antibiotic use. Historical sus-

Antibiotic

Prescott & Baggot

Mackie

ceptibility information drawn from individual farms will

(1988)*a*

et al. (1988)

likely prove more useful. Table 30.2 reports in vitro sensitivity (Mackie et al., 1988) and in vivo cure rates (Le

E. coli

Klebsiella

Coliforms

Loudec, 1978) with respect to Staph. aureus for several Amoxycillin

–

–

51–65

commonly used antimicrobial agents. It should be

Ampicillin

35

0

3–41

noted that the percentage of sensitive isolates consis-

Cephalothin

60–73

82–93

–

tently exceeds cure rates. The absence of in vitro activ-Erythromycin

39

25

–

ity indicates bacterial resistance while sensitivity infers,

Framycetin

–

–

83–97

but does not guarantee, clinical efficacy.

Furazolidone

92–98

25–92

88–99

Gentamicin

99–100

100

–

Lincomycin

29

17

–

Pharmacology of the mammary gland

Neomycin

56–70

33–90

19–93

Penicillin

0

0

–

Antimicrobial therapy is applied in the treatment of

Polymyxin

100

100

–

Spectinomycin

–

–

30–59

clinical mastitis during lactation and in treating sub-

Streptomycin

73

77

49–61

clinical mastitis at the end of lactation, while the imple-

Tetracycline

23

42–54

54–88b

mentation of preventive measures is essential for

Trimeth-sulfa

81

100

62–95

decreasing the incidence of infection in the dairy herd.

Clinical mastitis is often treated systemically which

a Compiled from several sources.

entails the repeated parenteral administration of an

b Oxytetracycline.

Table 30.2

Antibiotic sensitivities and bacteriological cure rates following treatment for Staphylococcus aureus after intramammary treatment with various antibiotics (adapted from Mackie et al. (1988) & Le Loudec (1978).

Antibiotic

% sensitive

Staph. aureus

No. of reports

Mean % cure

Range

Penicillin

19–62

32

0–87

12

Cloxacillin

100

41

21–84

14

Cephalosporins

100

72

1

Neomycin

72–98

27

25–36

2

Tetracycline

84–92

54

17–96

8

Tylosin

55

48–59

1

Erythromycin

72–98

63

51–76

2

Spiramycin

70

45–82

2

Rifamycin

66

65–66

2

Penicillin-streptomycin

39

21–78

2

Penicillin-neomycin

96

95–100

2

Ampicillin-cloxacillin

27

27–29

1

by decreased ability of the drug to ascend partially *respectively; weak organic bases, apart from aminogly-*

occluded milk ducts and by frequent stripping of the

cosides, spectionmycin and polymyxin B (drugs with

infected quarter.

low solubility in lipid), attain milk ultrafiltrate-to-

Antimicrobial agents, like other drugs, cross the

plasma ultrafiltrate equilibrium concentration ratios

blood–milk barrier, which is a somewhat restrictive

greater than 1 (Baggot, 2000). The high concentration

functional rather than an anatomical barrier, mainly by

ratios attained by lipophilic organic bases (macro-

passive diffusion. Both non-polar lipid-soluble com-

lides, lincosamides and trimethoprim) are attributed

pounds and polar substances with sufficient lipid solu-

to the ion-trapping effect in acidic milk. Enrofloxacin

bility passively diffuse through the predominately

and its active metabolite ciprofloxacin, formed by

lipoidal barrier (Baggot, 1977). At a moderate level of

N-de-ethylation (a microsomal-mediated oxidative

milk production the ratio of the volume of blood circu-

reaction) in the liver, would be expected to attain *lating through the mammary gland to the volume of*

concentrations in milk that would be effective against

milk produced has been estimated to be 670:1; this pro-

Gram-negative aerobic bacteria,

in particular

vides ample opportunity for drugs to passively diffuse

Escherichia coli.

from the general circulation into milk. The rate of trans-

In the presence of mastitis, the pH of milk increases

fer is directly proportional to the concentration gradi-

to within the range 6.9 to 7.2. As a consequence the ion-

ent across the blood–milk barrier and the lipid

trapping effect on lipophilic organic bases is reduced

solubility of the drug. The milk-to-plasma equilibrium

while the concentrations attained by weak organic acids

concentration ratio of total (non-ionized plus ionized)

are somewhat increased. The inflammatory reaction in

drug is determined by (i) the degree of ionization of the

udder tissues enhances the passage of penicillins into

drug, which is pKa/pH-dependent, in blood and milk, (ii)

milk. The increased pH of milk does not affect the

the charge on the ionized moiety and (iii) the extent of

concentrations attained by amphoteric drugs (fluoro-

binding of plasma proteins and milk macromolecules. It

quinolones, tetracyclines, rifampicin), but antimicrobial

has been shown that only the lipid-soluble, non-ionized

activity of these drugs is lower in milk than in extracel-

moiety of a weak organic acid or base that is free (not

lular fluid or in vitro determination would predict.

bound to proteins) in the plasma can diffuse through

the cellular barriers and enter the milk (Rasmussen,

1966). In normal lactating cows (milk pH range

***Intramammary preparations** (Table 30.3)*

6.5–6.8), weak organic acids attain milk ultrafiltrate-to-

plasma ultrafiltrate equilibrium concentration ratios

Intramammary preparations are used, often in con-

less than 1; oxytetracycline and rifampin, amphoteric

junction with parenteral preparations (depending on

drug molecules with moderate and high lipid solubility,

severity of infection), to treat clinical mastitis and at

attain equilibrium concentration ratios of 0.75 and ca 1, the end of lactation to treat subclinical infection and

Table 30.3

Distribution of antibiotics throughout the udder after intramammary administration (adapted from Ziv, 1980).

Good

Moderate

Poor

Amoxycillin

Penicillin G

Bacitracin

Ampicillin

Cloxacillin

(Dihydro)streptomycin

Cephalexin

Cephalonium

Gentamicin

Erythomycin

Cephapirin

Neomycin

Novobiocin

Cephacetrile

Polymyxins

Penethamate

Cefquinome

Framycetin

Quinolones

Tetracyclines

Spiramycin

Other sulphonamides

Sulphanilamide

Tylosin

Trimethoprim

Rifamycin

Amoxycillin-clavulanic acid

Lincomycin

Pirlimycin

prevent the establishment of new infections during the

ping of the infected quarter(s) is recommended in cows

dry period. The various preparations differ in nature,

with clinical mastitis, it follows that only quick-release

content and release pattern of the active ingredient(s)

intramammary preparations are suitable for use in lac-

and in the length of the withdrawal periods (slaughter

tating cows.

and milk withholding) but all preparations must be rea-

Intramammary preparations for use in lactating cows

sonably non-irritating to the udder. Intramammary

should contain a readily available form, usually water-

preparations are formulated either to provide quick

soluble salt, of an antimicrobial agent with a low degree

release of the antimicrobial agent or slow release of the

of binding to milk and mammary tissue proteins. The

antimicrobial over an extended period. The former are

vehicle used and viscosity of the formulation should

used mainly in lactating cows while the latter are used

allow rapid release of the drug and ensure that effective

at the end of lactation (after the last milking) and

concentrations are maintained throughout the recom-

in non-lactating cows. While the formulation of an

mended dosage interval. Examples of intramammary

intramammary preparation determines the pattern of

preparations that are formulated as suspensions and

antimicrobial release and may influence the withdrawal

have a recommended dosage interval of 12 hours
periods, the chemical nature and physico-chemical
include cloxacillin sodium, oxytetracycline hydrochlo-
properties (in particular lipid solubility) of the drug
ride, ampicillin sodium–cloxacillin sodium combination
govern its uptake and distribution in mammary tissue
and trimethoprim–sulfadiazine combination. Cefurox-
and its absorption into the blood. Drug transfer from
ime sodium and cefoperazone sodium (second- and
treated to untreated quarters of the udder takes place
third-generation cephalosporins, respectively) are for-
via the bloodstream.
mulated as an oily paste and oily suspension, respec-
Following intramammary infusion antimicrobials
tively. While a 12-hour dosage interval is recommended
with high lipid solubility (macrolides, trimethoprim,
for cefuroxime, a single dose of the cefoperazone prepa-
fluroquinolones, rifampicin) are readily taken up by and
ration is considered to be usually sufficient for treat-
distributed widely in mammary tissue. Oxytetracycline
ment. Quick-release intramammary preparations have

is moderately lipid-soluble and the fraction that is not

short withdrawal periods, typically slaughter times of 7

chelated with calcium in milk enters mammary tissue

days and milk withholding times of 3.5 days, or either

and distributes evenly in a manner that is not subject to

may be less depending on the preparation.

the pKa/pH-dependent ion-trapping effect. However,

Slow-release intramammary preparations may

the antimicrobial effect, which is exerted mainly on

contain an antimicrobial agent with a high degree of

streptococcal spp. and coagulase-negative staphylo-

binding to the secretions and mammary tissue proteins.

cocci, is bacteriostatic. The susceptibility of coagulase-

Either a poorly soluble salt of an antimicrobial agent

positive Staph. aureus, E. coli and Klebsiella spp. to may be used or the formulation of the preparation be

oxytetracycline is variable and unpredictable. The

such that the rate of antimicrobial release is relatively

uptake and distribution of sulfadiazine (pKa 6.4) and

constant, approaching zero order (Baggot & Brown,

sulphamethoxazole (pKa 6.0), which are moderately

1998). The formulation of slow-release preparations lipid-soluble organic acids, are influenced by the degree determines the antimicrobial concentration–time of ionization in their local environment. Since profile in the mammary gland to a greater extent than sulphonamides are combined with trimethoprim in quick-release preparations. Since only a single dose of intramammary preparations the broad-spectrum anti- a slow-release preparation is infused, the antimicrobial bacterial effect produced is bactericidal. The beta- content is generally higher than in quick-release pre- lactam antibiotics (penicillins and cephalosporins), parations. The antimicrobial must remain active (be although they exist mainly in an ionized form in milk, stable) throughout the extended duration in the udder are taken up by mammary tissue and distribute rea- and the preparation must not cause irritation. Exam- sonably well but do not readily enter epithelial cells or ples of slow-release intramammary preparations kill bacteria within phagocytic cells (neutrophils and include cloxacillin (as benzathine salt) with aluminium

macrophages). The uptake of hydrophilic antimicrobial
monostearate (suspension), ampicillin (as trihydrate)–
agents (aminoglycosides and polymixin B) from milk is
cloxacillin (as benzathine salt) formulated as an oily
low and their distribution is very limited and uneven
suspension, procaine benzlypenicillin (oily paste) and
because of selective binding to mammary tissue com-
dihydrostreptomycin sulphate-procaine benzylpeni-
ponents. Antimicrobials that avidly bind to mammary
cillin (oily paste). The long withdrawal periods for these
tissue (polymyxin B, neomycin, streptomycin, spi-
preparations preclude their intramammary infusion in
ramycin) have long withdrawal periods.
lactating cows.
The frequency of milking and the efficiency of milk-
Intramammary administration permits delivery of
out greatly influence the concentration of antimicrobial
the antibiotic directly to the mammary gland. Peni-
that could be attained in the udder. Since frequent strip-
cillin derivatives have demonstrated efficacy in

intramammary treatment of Strep. agalactiae. Intra-

Parenteral preparations with pharmacokinetic prop-

mammary preparations for infusion are available as

erties that meet most of these criteria include procaine

single-use syringes for a course of treatment of one, two

benzylpencillin,

amoxicillin trihydrate–clavulanate

or three syringes at 12- or 24-hour intervals depending

potassium combination, trimethoprim–sulfadiazine (or

on the product. Lactating cow (quick-release) products

sulphamethoxazole) combination and enrofloxacin. In

are generally designed for rapid clearance and, conse-

order to obtain effective concentrations in milk oxytet-

quently, have shorter milk withholding periods. Anti-

racycline hydrochloride (conventional preparation)

biotics with extensive tissue binding (polymixin B and

should be administered by slow intravenous injection.

aminoglycosides) have extended milk withholding

Long-acting parenteral preparations of oxytetracycline

periods (Baggot, 2000). Dry-cow formulations, for the

are not indicated in the treatment of mastitis. Macrolide *treatment of subclinical mastitis, are designed to antibiotics have good tissue penetrative capacity and produce extended duration of effective drug concen- the ion-trapping effect favours the concentrations trations. This is achieved by using a higher concentra- attained in milk. An undesirable feature of their distri- tion of the active drug or the benzathine salt of the bution is diffusion from the systemic circulation into active drug in oil or a repository vehicle.*

ruminal fluid (pH 5.5 to 6.5) where the ion-trapping For antimicrobial therapy with either a parenteral or effect also applies. Because of their wide distribution in intramammary preparation, or the concurrent use of tissues and passage into ruminal fluid, high doses are both types of preparation, to be effective an antimicro- required to attain effective concentrations in milk. In bial concentration exceeding the MIC for the causative the case of spiramycin, the persistence of tissue residues pathogenic micro-organism must be maintained at the is a major disadvantage. Since parenteral preparations site of infection for an adequate duration. Provided the *of erythromycin and spiramycin cause tissue irritation*

appropriate antimicrobial is selected, the intramam-

at intramuscular injection sites, slow intravenous injec-

mary infusion of a slow-release preparation at the end

tion is the preferred route of administration.

of lactation may adequately meet this requirement.

Drugs are transferred from the general circulation to

However, in the case of Staph. aureus infection, the

the mammary gland by passive diffusion (Baggot, 1977;

administration of a parenteral preparation in conjunc-

Ziv, 1980). Consequently, non-ionized lipid-soluble

tion with a slow-release intramammary preparation

agents that are not extensively bound to plasma pro-

containing an antimicrobial, which is active against all

teins more readily reach the mammary gland (Table

strains of the bacterium, increases the effectiveness of

30.4). Because milk is weakly acidic (pH 6.5–6.8), drugs

therapy and consequently the recovery rate.

that are weak bases (trimethoprim, macrolides, lin-

cosamides) are preferentially concentrated by ion trap-

ping (Ziv, 1980; Baggot, 2000). Of the antimicrobials

Parenteral preparations

that distribute well in the mammary gland following

parenteral administration, only fluoroquinolones have

broad-spectrum activity against Gram-negative

Severe mastitis is usually treated systemically, although

pathogens. Because of bacterial resistance concerns for

intramammary therapy will often be used adjunctively.

humans, the use of this class of antimicrobial in dairy

An 'ideal' antimicrobial for systemic therapy of masti-

cows is not approved. The low degree of lipid solubility

tis should have the following properties (adapted from

of aminoglycosides and polymyxin B limits their

Ziv, 1980):

passage into milk.

• Low minimum inhibitory concentration (MIC) for

the majority of mastitis-causing pathogenic micro-

organisms.

• High biovailability following intramuscular ***Table 30.4*** *Distribution of antibiotics throughout the udder after injection.*

parenteral administration (adapted from Ziv, 1980).

• Lipid-soluble and predominately non-ionized in the

blood, and have a low degree of binding to plasma

Good

Moderate

Poor

proteins.

• *A long apparent half-life to ensure that concentra-*

Erythromycin

Amoxycillin

(Dihydro)streptomycin

tions above (preferably several-fold) the MIC are

Spiramycin

Ampicillin

Gentamicin

maintained at the site of infection throughout the

Tylosin

Cephalosporins

Neomycin

Trimethoprim

Penicillin G

Polymyxins

dosage interval (12 or 24 hours).

Baquiloprim

Rifamycin

Spectinomycin

• Minimal adverse effects in cows.

Fluoroquinolones

Sulphonamides

• Short withdrawal periods (milk withholding and

Tetracyclines

slaughter).

In the presence of clinical mastitis, the pH of the milk

adequate duration in order to achieve a bacteriological

increases (6.9–7.2), approaching that of plasma. Under

cure. Apart from preparations containing fixed com-

these circumstances weak acids (sulphonamides,

binations (trimethoprim–sulphonamide,

amoxillin–

penicillins, amoxycillin–clavulanic acid, cephalosporins,

clavulanate), the use of combination preparations

rifampin), although typically not concentrated in milk,

should generally be avoided.

may reach effective concentrations (Ziv,

1980;

Having made a (tentative) clinical diagnosis of the

Durnford, pers. comm.; Baggot, 2000). Lipophilic drugs

nature of the mastitis and established the history of

of various pharmacological classes will also be concen-

infection in the affected cow and incidence of infection

trated in milk in spite of the decreased ion-trapping.

in the herd, a pretreatment milk sample for bacterial

The site of infection within the udder varies with the

culture should be properly (aseptically) collected.

causative pathogenic micro-organisms and, in addition

Immediate examination of a milk sample is a particu-

to bacterial susceptibility, influences the choice of

larly useful aid in selecting an antimicrobial for em-

antimicrobial agent. Since streptococcal mastitis is

pirical treatment, which should commence at this time.

usually an infection of the milk compartment of the

A parenteral and quick-release intramammary prepa-

udder, antimicrobial agents that have limited mem-

ration may be used concurrently. The latter should be

brane penetrative capacity and produce a bactericidal
infused after stripping milk and other products (cellu-
effect, such as penicillins (benzylpenicillin), may be
lar debris, pus) from the infected quarter(s). Oxytocin,
selected for therapy. Even though coliform mastitis is
5 to 10 units of diluted solution (10 units/ml), can be
an infection of the milk compartment, the choice of
administered by slow intravenous injection to facili-
antimicrobial for systemic therapy is largely limited to
tate the completeness of stripping. The half-life of oxy-
enrofloxacin or trimethoprim–sulphonamide since the
tocin is approximately 2 minutes. In addition to anti-
long withdrawal period for aminoglycosides precludes
microbial administration, supportive therapy should be
their use. Staphylococcal aureus, the principal causative provided.
micro-organism of subclinical mastitis, may reside in the
Results obtained from the microbiology laboratory,
intracellular space and within epithelial and phagocytic
interpreted in conjunction with the tentative clinical
cells (Pyorala, 1995). The treatment of staphylococcal
diagnosis and knowledge of the distribution of anti-

mastitis requires the administration (parenteral and

microbial agents in the udder, facilitate selection of

intramammary) of an antimicrobial agent which can

the appropriate drug. Mastitis, with the exception of

penetrate epithelial cells and tissues of the udder and

summer mastitis, is usually caused by a single bacterial

is active against staphylococcal beta-lactamase.

species. When Staph. aureus is the causative pathogenic Amoxicillin–clavulanic acid combination and

micro-organism, it can be rapidly determined whether

macrolide antibiotics (erythromycin and spiramycin)

the strain isolated produces beta-lactamase (70 per cent

meet these requirements. The bacteriostatic effect pro-

of strains), although it should be recognized that milk

duced by macrolides and their reduced antibacterial

induces production of the enzyme. The susceptibility of

activity in milk could be disadvantageous.

streptococci can be predicted, but it is necessary to

determine quantitative susceptibility, using the broth

dilution method (which measures MIC), of coagulase-

Selection of antimicrobial agent

positive staphylococci and enteric bacteria (E. coli,

Klebsiella spp.). Knowledge of the susceptibility (pre-There are several factors to consider when selecting an

dicted or measured in vitro) of the causative bacterial antimicrobial agent, and the preparations (parenteral,

pathogen and of the pharmacokinetic properties of

intramammary) to use, for the treatment of mastitis.

the antimicrobial agent of choice provides the infor-

They include the nature and severity of the infection,

mation required for calculating the dose and selecting

the stage of lactation, the causative pathogenic micro-

the dosage interval for the parenteral preparation.

organism and its susceptibility, the relative cost of the

Dosage calculations are based on MIC which is

various antimicrobial preparations, the incidence of

assumed to be related to the concentration attained

mastitis in the herd and the usage pattern of intra-

at the site of infection in the udder. An intramam-

mammary preparations. Early diagnosis and the

mary preparation containing an antimicrobial that will

prompt application of appropriate treatment will

reach the site of infection and complement the activity *reduce the extent of mammary tissue damage and will*

of the antimicrobial in the parenteral preparation

increase the rate of recovery and the return of milk

should be chosen and administered by intramammary

production to or approaching the original level. It is

infusion (after stripping the inflamed quarter) at the

desirable to select an antimicrobial that produces a

recommended dosage interval, which is usually 12 or 24

bactericidal effect and has a narrow spectrum of activ-

hours, for preparations intended for use in lactating

ity and essential that treatment should continue for an

cows.

Response to therapy

infusion mainly in lactating cows.

Amoxycillin

trihydrate–clavulanate potassium and prednisolone are

A combination of methods, applied two to three weeks

combined in a compound intramammary preparation

after the end of treatment, should be used to assess the

(oily suspension) which provides greatly enhanced

effectiveness of antimicrobial therapy. They include

activity of amoxycillin against beta-lactamase produc-

clinical examination, bacterial culture of an aseptically

ing Staph. aureus and has short withdrawal periods.

collected milk sample, tests based on changes in somatic

Steroids (prednisolone) are present in low dose and

cell count, protein, enzyme and electrolyte contents of

their activity is of short duration. There has been no

milk (indication of inflammation) and return to the

convincing evidence of depressed antibody production

expected level of milk production (Pyorala, 1995). Dis-

or cell-mediated responses as a result of the inclusion

crepancy between the expected and obtained response

of prednisolone in an intramammary formulation. In

to therapy may be attributed to inadequacy of the host

fact, it could be argued that the inclusion of pred-

defence mechanisms, acquired bacterial resistance,

nisolone is supportable on grounds of cow welfare.

altered pharmacokinetic behaviour of the antimicrobial

Farmers will claim that the inclusion of the steroid will

in the diseased animal or poor distribution in the udder *lead to a reduction in size of the inflamed quarter. Trials*

with limited access to the site of infection. In the case

carried out with an amoxycillin–clavulanic acid formu-

of infection caused by Staph. aureus bacteria located in lation containing prednisolone confirm this observation

microabscesses, macrophages and fibrotic tissue, the

(O'Rourke, 1994) (Fig. 30.1).

bacterial pathogen may be virtually inaccessible to

Most compound preparations contain antimicrobial

antimicrobial agents or may be in a state of dormancy.

agents that are selected on the basis of broadening the

The bacteriological cure rate of staphylococcal mastitis

spectrum of antimicrobial activity without extending

is low, particularly when treatment is applied during lac-

the withdrawal period. These compound preparations

tation, while the high self-cure rate of coliform mastitis

(more than one antibiotic) are of doubtful value and are

greatly influences the validity of attributing bacterio-

often not successful in eliminating infection. Moreover,

logical cure to antimicrobial therapy (Sandholm &

the concentration achieved by any one antibiotic in

Pyorala, 1995). A reasonably satisfactory response rate

such preparations is likely to be lower than the

to treatment of staphylococcal mastitis is obtained only

optimum required for treatment and could facilitate

when appropriate therapy with a parenteral prepara-

the development of resistance (Egan, 1984). Unless the

tion and a slow-release intramammary preparation

antimicrobials in a combination preparation act syner-

is applied at the end of lactation after the last milking.

gistically (Table 30.5) the use of compound prepara-

The longer the antimicrobial(s) persists in the udder,

tions should be avoided.

the greater the likelihood of at least a moderately

In recent years veterinary practitioners have been

favourable response to therapy. The bacteriological

debating the concurrent use of an injectable and intra-

cure rate can vary widely.

mammary preparation in the treatment of mastitis.

Therapy of mastitis

25

During lactation

20

Factors to take into account when choosing an intra-

mammary preparation include:

15

• Antibacterial spectrum

10

• Cost of the preparation for usual duration of

treatment

5

• With/without steroid

0

• Previous treatment history

0

2

4

Percentage increase in quarter size

6

24

• Availability of injectable 'partner' (parenteral

Time from treatment (hours)

preparation)

• Milk withholding time

Fig. 30.1

Reduction in quarter size, experimentally infected

• Personal preference

with Streptococcus uberis, after treatment with amoxycillin and clavulanic acid formulations with and without prednisolone

Compound preparations containing one or more

(O’Rourke, 1994). 糉 = Lactating low formulation containing

antimicrobial agents and a corticosteroid (hydrocorti-

amoxycillin, clavulanic acid and prednisolone. 粽 = Same formu-

sone or prednisolone) are available for intramammary

lation without prednisolone.

There have been a number of studies indicating a ben-

Serratia spp. Because of the severity of clinical signs the eficial effect in the treatment of Staph. aureus infections following therapeutic regimen is suggested:

from the concurrent use of an intramammary and an

(1)

Frequent stripping of the affected quarter follow-

injectable (Tables 30.6 and 30.7). However, the com-

ing the administration of oxytocin is probably the

patibility of the injectable and intramammary prepara-

most important, yet most often neglected, compo-

tions should be taken into account whenever this form

nent of therapy. Evacuation of the udder serves to

of treatment is being considered.

remove both bacterial endotoxins and inflamma-

tory host mediators, thus markedly reducing the

Peracute mastitis

severity of clinical signs.

(2)

Antibacterial therapy: gentamicin, polymyxin B

Toxic mastitis is most commonly caused by the coliform

and potentiated sulphonamides have minimal

organisms E. coli, Klebsiella spp., Enterobacter spp. and inhibitory concentrations (MIC) and distribution

properties suitable for the treatment of coliform

Table 30.5

Clinically useful antimicrobial drug combinations in

mastitis.

veterinary medicine (adapted from Prescott & Walker, 2000).

(3)

Intravenous fluids.

(4)

Non-steroidal anti-inflammatory drugs.

Indication

Drug combination

Comment

The non-steroidal anti-inflammatory drugs have a

Bovine Staph.

Penicillin–

Synergistic

more selective action than glucocorticoids in that they

aureus mastitis

streptomycin

combination

directly inhibit cyclo-oxygenase, although isoforms of

the enzyme are inhibited to a varying degree depend-

Amoxycillin–

Potentiated

ing on the drug. The consequence of cyclo-oxygenase

clavulanic acid

combination

inhibition is that the synthesis of prostaglandins

Table 30.6

Bacteriological cure rates for subclinical Staphylococcus aureus infections at 21 days post treatment with amoxycillin and penicillin G (Owens et al., 1988). Reproduced with permission of the American Dairy Science Association.

Route

Regime

Bacteriological

cure rate (%)

Intramammary

62.5 mg amoxycillin

25

(n = 40)

six times @ 12-hour

intervals

Intramammary +

62.5 mg amoxycillin

51.4

injection (n = 35)

six times @ 12-hour intervals

+9 000 000 iu procaine

penicillin daily for 3 days

Table 30.7

Bacteriological cure rates for chronic Staphylococcus aureus infections at 20 days post treatment with spiramycin (Ziv, 1980).

Route

Regime

Bacteriological cure rate

(%)

Injection (n = 18)

10 g spiramycin (IM) twice

16

@ 72-hour intervals

Intramammary (n = 40)

500 mg spiramycin three

40

times @ 24-hour intervals

Intramammary +

10 g spiramycin (IM) twice

68

injection (n = 35)

@ 72-hour intervals +

500 mg spiramycin three

times @ 24-hour intervals

involved in central pyresis and pain perception as well

sequent lactation when compared with control cows

as tissue inflammation is inhibited. Unlike glucocorti-

that received no therapy.

coids, the non-steroidal anti-inflammatory drugs do not

The efficacy of dry-cow therapy for subclinical

produce immunosuppression. The rate of elimination

mastitis is not invariably reliable, especially for chronic

(hepatic metabolism) of these drugs in cattle differs

cases of mastitis caused by Staph. aureus (Table 30.9).

widely. The half-life of salicylate is 0.8 hours (3.5 hours

There are, however, results indicating that an improved

when administered orally as aspirin, due to slow disso-

cure rate can be achieved when intramammary treat-

lution/absorption from ruminal fluid), ketoprofen (0.4

ment is accompanied by systemic treatment (Table

hours), flunixin (8.1 hours) and phenylbutazone (42–66

30.10).

hours). They distribute to a similar extent, mainly in

extracellular fluid, and enter milk by passive diffusion.

Strategies for dry period treatment

Of these drugs, flunixin meglumine (2.2 mg/kg, admin-

istered by intravenous injection at 24-hour dosage

With consistent application of dry-cow therapy (DCT)

intervals) may have a place in the treatment of acute E.

in conjunction with other mastitis control measures the

coli (endotoxin) mastitis. The withdrawal period is

prevalence of contagious mastitis pathogens has

slaughter 7 days, milk 12 hours. The antipyretic, anti-

declined to a low level in many herds (Kirk et al., 1994), inflammatory and analgesic effects produced by the

as is evidenced by bulk milk somatic cell counts

drug are largely dependent on the stage of the inflam-

(BMSCC) of <200 000 cells/ml. Some owners of herds

matory process at which treatment is commenced.

with a low prevalence of contagious mastitis pathogens

Early diagnosis of coliform mastitis would increase the

have stopped using dry-cow therapy and others are ques-

beneficial effect produced by flunixin administration.

tioning the practice because of concerns about residues

in the milk (Kirk et al., 1994). Macmillian et al. (1983) indicated that in herds with low cell counts selective dry-

During the dry period

cow therapy may be preferable to whole herd therapy.

Routine dry-cow therapy provides the following

A fact sheet entitled Dry Cow Therapy (Anderson &

advantages:

Cote, 1996) from the Ontario Ministry of Agriculture,

Food and Rural Affairs recommends that selective dry-

• Bacteriological cure of a higher proportion of

cow therapy should be used when the monthly bulk

Staph. aureus infections (Table 30.8).

milk cell count (BMCC) is below 200 000 and the

• No loss of milk production.

quarter infection rate is <15%. The following cows

• Prevention of new infections (including summer

should be treated:

mastitis commonly due to Arcanobacterium pyo-

genes), especially in the early dry period.

• Cows with peak somatic cell count (SCC) >

• Treatment of infections caused by streptococci and

250 000/ml.

other bacteria.

• Cows which have had a clinical case of mastitis.

• Cows from which a major mastitis pathogen(s) has

In herds with a high prevalence of contagious masti-

been cultured.

tis pathogens, the use of dry-cow therapy has been an

efficacious and economically effective method of reduc-

In New Zealand the SAMM (seasonal approach to

ing the frequency of intramammary infections (Heald

managing mastitis) plan was devised by the Dairy

et al., 1977). Berry et al. (1997) showed that cows treated Research Corporation. It was adopted by the NZ

with dry-cow therapy at the end of lactation produced

Mastitis Advisory Committee and launched in 1993.

179 kg more milk during the first 120 days of the sub-

The implementation of the plan contributed to a

Table 30.8

Bacteriological cure rates (percentages) for selected Gram-positive intramammary infections using cloxacillin (adapted from Griffin et al., 1982).

Bacterium

Lactation

At drying off

Clinical

Subclinical

Streptococcus agalactiae

85

100

99

Staphylococcus aureus

26

52

61

Streptococcus dysgalactiae

90

98

96

Streptococcus uberis

77

82

87

Table 30.9

The responses of previously untreated or unsuccessfully treated staphylococcal infections to cloxacillin therapy given in lactation or at drying off (adapted from Griffin et al., 1982).

Previous lactation treatments

Lactation therapy

0

1

2

>2

No previous drying-off treatments

% response

46

21

17

12

1 or more previous drying-off treatments

% response

25

15

13

7

Drying-off therapy

0

1

>1

% response

61

46

24

Previous drying-off treatments

% response

60

24

10

Table 30.10

Bacteriological cure rates for chronic subclinical Staphylococcus aureus infections at 15 days postcalving (Johansson et al., 1995). Reproduced with permission of the International Dairy Federation.

Route

Regime

Bacteriological

cure rate (%)

Intramammary (n = 42)

0.17 g penicillin benzathine

57

+0.4 g dihydrostreptomycin

in all 4 quarters

Intramammary +

20 mg/kg

79

injection (n = 38)

benzylpenicillin procaine for

5 days followed by 0.17 g

penicillinbenzatin +0.4 g

dihydrostreptomycin in all

4 quarters

substantial decline in somatic cell count levels in

tion in clinical mastitis during the dry period and a 3-

subsequent years (national average cell count is

fold reduction in infected cows at calving and clinical

178 000/ml). The criteria used for determining herd

mastitis in the first 21 days of lactation when compared

mastitis status and dry-cow therapy are show in Table

to herds where there was no treatment (Table 30.13).

30.11.

Hovi and Roderick (2000) found that the incidence

The effects of three selection strategies for dry-cow *of new infection during the dry period was three times*

therapy on prevention of new infections and rate of

higher in organic herds when compared to conventional

antibiotic usage were compared in a trial involving 1044

herds (28.9 cases per 100 cows versus 9.2 cases per 100

cows in 12 herds (Table 30.12) (Browning et al., 1984).

cows). The authors point out that most organic dairy

Selective cow treatment was identified as the preferred

farmers felt that it was impossible to maintain low SCCs

strategy. Blanket treatment resulted in increased antibi-

without using dry-cow therapy and culling healthy

otic usage: 15.5 versus 6.4 tubes per infection eliminated

young cows.

with no additional benefit and selective quarter treat-

Whilst we may implement selective dry-cow therapy,

ment resulted in a higher new infection rate (6.4 versus

the key question is: are these untreated quarters more

3.9 per cent) during the dry period.

susceptible to infection during the dry period? The

Berry et al. (1999) confirmed that this is still the case physiological process whereby the teat canal becomes *today in a study comparing dry-cow therapy versus no*

closed through the formation of a keratin plug after

treatment. Dry-cow therapy resulted in a 10-fold reduc-

drying off appears to be a major defence mechanism.

Table 30.11

Criteria used in the SAMM plan for determining herd mastitis status and dry-cow therapy strategy (Woolford et al., 1995). DCT, dry-cow therapy. Reproduced with permission of the International Dairy Federation.

Criteria

Herd mastitis classification

High

Medium

Low

Average BMSCC, Jan–Mar (000/ml)

>400

150–400

<150

or

% cows >150 000/ml over Jan–Mar

>50%

20–50%

<20%

or

% cows clinical in first month of lactation

>10%

3–10%

<3%

or

15% cows clinical first 3 weeks of last

Yes

No

No

dry period?

or

Late season outbreak of clinical cases?

Yes

No

No

Recommended DCT strategy

Total

Selective

Selective

herd

cow

cow

Table 30.12

Prevalence of infected quarters at drying off and calving plus the new infection rate during the dry period for three different dry-cow strategies (Browning et al., 1984, reproduced with permission of Australian Veterinary Journal). DCT, dry-cow therapy.

Strategy

Drying off

Calving

New infection rate

prevalence

prevalence

during dry period

(%)

(%)

(%)

DCT

13.2

6.8

2.6

Selective cow

13.0

7.9

3.9

Selective quarter

13.1

10.0

6.4a

a P £ 0.05.

Table 30.13

Prevalence of clinical mastitis during the dry period, infected cows at calving plus clinical mastitis during the first 21 days of lactation (Berry et al., 1999). DCT, dry-cow therapy.

Strategy

Clinical mastitis

Infections at calving

Mastitis in first 21

during the dry

(%)

days of lactation

period (%)

(%)

DCT

0.0

9.6

5.5

No treatment

10.5

32.8

16.4

Williamson et al. (1995), reporting on the observations during the dry period, 97 per cent occurred in teats that

of the dynamics of teat canal closure for a group of 657

had an 'open' canal.

quarters after drying off, noted that 50 per cent of teat

The dilemma is how to protect quarters that are not

canals were classified as 'closed' at 7 days after drying

treated with dry-cow therapy. In New Zealand a non-

off. A further 45 per cent became closed over the fol-

antibiotic preparation, TeatsealTM, is available (Orbe-

lowing 50–60 days and 5 per cent remained 'open' at 90

SealTM in the UK). Teatseal is a dense, viscous material,

days. During this study 83 per cent of all clinical infec-

which is infused hygienically into the teat as soon as

tions during the dry period occurred within the first 21

possible after the last milking of lactation. It physically

days. Of the 52 clinical infections that were diagnosed

plugs the teat canal immediately after infusion thus

Table 30.14

Numbers of new intramammary infections (IMIs)

lishment of infection, by the presence of a physical

over the dry period and at calving for the four treatment groups barrier from day one of the dry period, which remains

(Woolford et al., 1998).

in place until calving.

Experimental group

NC

PC

TS

TS + Ab

Total quarters allocated

528

528

505

505

Benefits of antimicrobial therapy

at drying off

for mastitis

New dry period clinical IMIs

18

2a

1a

2a

Improved milk quality

New IMIs at calving

Streptococcus spp.

50

5a

4a

4a

Subclinical mastitis affects the quality of dairy products.

Staphylococcus aureus

3

0

1

0

Milk from infected cattle is less palatable, has a shorter

Coagulase-negative

6

1

6

2

shelf-life and produces lower yields of processed dairy

staphylococci

products. Consequently, cooperatives, commercial con-

Coliforms

4

4

1

1

cerns and regulatory agencies impose penalties, based

Other organisms

2

2

0

1

Clinical – no growth

2

0

0

0

on cell count and bacterial counts of bulk milk. The

at culture

most severe penalty arises with milk that is deemed

Total non-streptococcal

17

7b

8c

4a

unfit for human consumption and discarded (BMCC >

IMIs

400 000 cells/ml in EU, see Chapter 25). Although treat-

ment of clinical mastitis may not result in a microbio-

Total new IMIs at calving

67

12a

12a

8a

logical cure, macroscopic milk quality will return to

Total new IMIs

85

14a

13a

10a

normal more quickly following treatment. The more

Overall incidence of new

16.1

2.7a

2.6a

2.0a

rapid return to the production of saleable milk is an

IMI rate (% quarters)

important benefit of treatment.

Superscripts denote significant differences within rows between treatment groups and the negative control.

a P < 0.01; b P ª 0.05; c P < 0.1

Increased milk production

NC, negative control; PC, positive control (cephalonium); TS, Teatseal; TS + Ab, Teatseal + cloxacillin.

The largest cost associated with mastitis is reduced milk

yield as a result of clinical and subclinical infection.

Lucey and Rowlands (1984) found that the mean reduc-

preventing bacteria from entering the teat. The teat

tion in milk yield where clinical mastitis occurred was

canal then becomes closed from day one of the dry

540 kg, the average lactation being 4830 kg. The reduc-

period and remains closed for the dry period.

tion was greatest when infection occurred before peak

A large-scale study has been carried (Woolford et al., yield, the proportional reduction being higher in higher-1998) utilizing a total of 1200 cows across seven herds.

yielding cows. Where clinical mastitis occurred before

Cows with late lactation SCCs of < 200 000/ml were

peak yield, both peak yield and length of lactation were

identified and sampled aseptically to establish the infec-

reduced, though the rate of decline from peak yield

tion status of every quarter at drying off. At drying off

was unaltered. Where infection occurred between peak

uninfected quarters were randomly allocated to a treat-

yield and 10 weeks after peak yield, lactation yield and

ment. The numbers of new intramammary infections

length were both affected. Clinical mastitis occurring

(IMIs) during the dry period and at calving are shown

after peak yield appeared to have little effect on lacta-

in Table 30.14. In the 1998 study all three infused treat-

tion yield. Results suggested that cows which contract

ments (Teatseal, cephalonium (Cepravin DC), and Teat-

mastitis are unlikely to achieve their full milk-yield

seal plus 600 mg cloxacillin (prior to infusion of the seal)

potential in the following lactation. In a survey of just

showed about a 10-fold reduction in new clinical IMIs

over 24 000 dairy cows the daily loss in milk yield during

($P < 0.01$) relative to the negative control (no treat-the first 2 weeks after the occurrence of mastitis varied

ment). The incidence of new IMI due to Strep. uberis at from 1.0 to 2.5 kg. Total loss over the entire lactation

calving was 10-fold lower ($P < 0.01$) for prophylactic varied from 110 to 552 kg and depended on parity and

treatments compared to the negative control. It is also

the time of mastitis occurrence. Regardless of the time

interesting to note that the prophylactic treatments *of occurrence during the lactation, mastitis had a long-*

reduced the incidence of postcalving clinical mastitis by

lasting effect on milk yield; cows with mastitis did not

approximately 50 per cent in the subsequent lactation

reach their premastitis milk yields during the remain-

compared to the negative control. This study indicated

der of the lactation after the onset of the disease

that use of Teatseal protects the gland against estab-

(Rajala-Schultz et al. , 1999).

Table 30.15

(a) Reduction in test day milk yield (kg) in rela-*

not obligate parasites of the mammary gland, are trans-

tion to somatic cell counts (SCCs) of Holstein cows without clini-mitted from cow to cow (Bramley & Dodd, 1984).

cal mastitis, and (b) for SCCs of 200 000 cells/ml the reduction Identification followed by treatment, isolation or

in test day milk yield (kg) at days 50, 150 and 250 postpartum eradication can markedly reduce the numbers of*

(Hortet et al., 1999, reproduced with permission from Elsevier new infections if coupled with appropriate hygienic

Science).

measures.

(a) Reduction in yield at various SCCs

Costs associated with

SCC (cells/ml)

antimicrobial therapy

100 000

200 000

600 000

Drug and veterinary costs

Primiparous 0.30

0.61

1.09

These costs will not be detailed, but should be con-

cows

sidered when evaluating the costs associated with

Calving 2

0.32

0.63

1.13

Calving ≥3

0.30

0.60

1.07

treatment.

(b) Reduction in yield at SCC of 200 000 cells/ml

Discarded milk

Day 50

Day 150

Day 250

Available intramammary antibiotic preparations rec-

postpartum

postpartum

postpartum

ommend milk withholding periods (discard times) that

vary from 36 to 120 hours after the last treatment .

Calving 2

0.63

0.92

1.77

Cattle with clinical mastitis are usually treated three

Calving ≥3

0.60

1.09

1.85

times at 12 to 24 hour intervals. The antibiotic-contam-

inated, and hence discarded, milk may total as much

*Reduction in yield was calculated as the deviation from a reference as 420 litres in a high-producing cow. The decision to

value set at 50 000 cells/ml.

undertake treatment cannot be taken lightly. Dry-cow

therapy is particularly cost-effective because it does not

Reduction in milk yield is also associated with sub-

require milk discarding.

clinical infection. Hortet and Seegers (1998) found in a

review of 19 papers that there was an average loss of

Slaughter withdrawal periods

80 kg of milk in primiparous and 120 kg in multiparous

cows for each two-fold increase of the geometric mean

Both systemic and local (intramammary) antibiotic

of somatic cell count (SCC) > 50 000 cells/ml. The reduc-

preparations have slaughter withdrawal periods.

tion in test day milk yield (kg) associated with SCC of

Treated individuals cannot be marketed for salvage

less than or equal to 600 000 cells/ml in cows without *purposes, regardless of the success of treatment, until*

clinical mastitis was assessed using monthly cow records

after the withdrawal period for the administrated

collected for a one year period in 105 Holstein herds in

preparation has ended.

France (Hortet et al., 1999). Results indicated that for 100 000, 200 000 and 600 000 cells/ml the reduction in

Risks of new infections/altered

daily milk yield was approximately 0.30 kg, 0.60 kg and

host defences

1.10 kg, respectively (Table 30.15).

Intramammary infusion of antibiotics is far from being

an innocuous procedure. The infusion procedure may

Effective microbiological cures,

remove the keratin lining of the streak canal, an impor-

eliminating reservoirs of infection

tant barrier to intramammary infections (see pp. 313,

A very real, but often overlooked, benefit of antimi-

400). Strict hygiene must be practised to prevent acci-

crobial therapy relates more to the overall herd health

dental introduction of micro-organisms at the time of *status than the infected cow. This is because the infected*

treatment. Only commercially available formulations of

cow is a reservoir of transmissible infection. Each

known efficacy and guaranteed safety are suitable for

infected cow may represent not only an individual with

intramammary therapy. Special care must be exercised

suboptimal health and production, but also a reservoir

when large numbers of cattle are being treated on a

of infection. Each infected cow thus poses a threat to

single occasion. Explosive outbreaks of peracute and

the productive capacity of non-infected cattle. Strep.

often fatal mastitis have been known to follow either

agalactiae is an obligate parasite of the mammary gland.

poor hygiene during infusion of an intrammamary

Staphylococcus aureus and Mycoplasma spp., although product or use of a contaminated product.

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Adult Cattle

Lameness

Chapter 31

Lameness in the Foot

R.W. Blowey

Introduction

approach to hoof trimming and the causes and control

Incidence and prevalence

409

of lameness.

Structure of the foot

411

Hoof

411

Corium

413

Incidence and prevalence

Bone and associated structures

413

Weight bearing surfaces, hoof overgrowth and wear

413

The incidence of lameness is defined as the number of

Hoof overgrowth

413

Hoof trimming

415

cases recorded over a given period, usually a year. It is

Lesions causing lameness

417

a longitudinal measure and is often expressed as the

Sole ulcers and white line defects

417

number of cases per 100 cows per annum. A single case

Sole ulcers

419

of lameness is defined as one lesion in one claw. A

Heel and toe ulcers

419

repeat or new case can be a different lesion in the same,

White line defects

419

or another, claw, although it may be a recurrence of the

Causes and control of coriosis (laminitis)

420

same lesion after a period of time. Prevalence is the

Other causes of foot lameness

425

number of cases of lameness present at a single point

Hoof disorders

425

in time, for example when the whole herd is examined

Foreign body penetration of the sole

425

on the same day, and is known as a cross-sectional

Slurry heel

425

measure.

Vertical fissures (sandcracks)

425

Hardship lines

426

A further distinction must be made between the inci-

Horizontal fissures (sandcracks)

426

dence or prevalence of lameness and the incidence or

Axial wall fissures

426

prevalence of lesions, and care must be taken when

Skin disorders

426

comparing data. The majority of studies record the

Interdigital necrobacillosis

426

prevalence of lesions, as this produces a larger number

Digital dermatitis

427

of observations. Very few studies have examined the

Interdigital dermatitis

429

proportion of lesions that eventually translate into

Interdigital skin hyperplasia

429

clinically detectable lameness, and yet this is an ex-

Mud fever

429

tremely important issue if we are to continue to use

Bone and joint disorders

429

lesion prevalence studies to investigate the causes of

Fracture of the pedal bone

429

lameness.

Apical necrosis of the pedal bone

429

Deep pedal infections

430

The results of studies of lameness incidence will

General treatment and control of foot lameness

430

depend on the person recording. Inevitably, studies by

Footbaths

430

veterinary surgeons will give lower figures than those

Nursing, dressings and footblocks

431

by farmers or stockmen, because rarely are all lame

cows on a farm dealt with by a veterinarian. It is diffi-

cult to provide an average figure for the proportion

Introduction

of lame cows seen by veterinary practitioners. For

example, the study of Clarkson et al. (1996) showed

Lameness remains a major problem for dairy herds

that 3 per cent of lame cows were examined by the *worldwide. There are few other problems which*

veterinarian in Cheshire, 20.4 per cent in the Wirral,

produce as much pain and distress to the cow and very

21.7 per cent in Wales and 77.3 per cent in Somerset.

few other problems where the herdsman spends so

An American study where observers went to each farm

much time and effort on routine prevention, namely

twice to record the number of lame cows showed that

hoof trimming. This chapter examines the incidence

their recorded prevalence was 2.5 times higher than

and costs of lameness, the anatomy of the digit, an

that estimated by the herd managers (Wells et al. , 1993).

Table 31.1

The incidence levels of lameness in several British Isles surveys.

Authors

Date

Recorders

Incidence (cases/100

cows per year)

Hedges et al.

2000

Veterinarians

68.9

Clarkson et al.

1996

Veterinarians and farmers

54.6

Esslemont & Spincer

1993

Veterinarians and farmers

36

Prentice & Neal

1972

Veterinarians

30

Booth

1989

Farmers

30

Arkins

1981

Farmers

28

Whitaker et al.

1983

Veterinarians and farmers

25

Esslemont & Kossaibati

1996

Veterinarians and farmers

24

Collick et al.

1989

Veterinarians

17

Bell & Miller

1977

Veterinarians

11

Eddy & Scott

1980

Veterinarians

7

Russell et al.

1982

Veterinarians

6

Leech et al.

1960

Veterinarians and farmers

4

Whitaker et al. (1983) estimated that in Britain veteri-An American study of 18 farms showed a median

nary surgeons saw only a quarter of the total lameness

prevalence of 11.8 per cent of lactating dairy cows were

cases, the remainder being treated by the farmer. This

clinically lame in the summer and 14.8 per cent in the

was based on a study of 185 herds where the veterinary

winter (Wells et al. , 1995). No overall prevalence was surgeon treated 25.2 per cent and the farmer 74.8 per

provided because of the management differences.

cent of all lamenesses. As herds increase in size, the

A two-and-a-half-year UK study of 37 farms where *stockman becomes more competent and the number*

both farmers and vets recorded lameness produced a

of lame cows seen routinely by the veterinary surgeon

mean annual incidence rate of 54.6 new lamenesses per

decreases.

100 cows, varying on individual farms from 10.7 to 170.1

The use of data produced by farmer recording

(Clarkson et al. , 1996). The mean incidence rates for the produces problems of terminology and there will be

winter and summer were 31.7 and 22.9 respectively, with

errors in recording the causes of lameness. Hence many

78.7 per cent of the total in the outer claw. The mean

studies refer to ‘under-run sole’ or ‘a foot abscess’, when

prevalence rate was 20.6 per cent, ranging from 2.0

in fact the primary lesion was a white line disorder or

per cent to 53.9 per cent, with winter and summer rates

a sole or heel ulcer. This produces further errors in our

being 25.0 per cent and 18.6 per cent, respectively

understanding of the incidence and causes of lameness.

(Clarkson et al. , 1996).

It is generally accepted that the incidence of lameness

The trial reported by Hedges et al. (2000) was an 18-

has increased over the past 40 years (Table 31.1) when

month intervention study involving only five farms in

a study provided by both veterinary surgeons and

one area (Gloucestershire) of the UK. All lame cows

farmers gave an incidence of 3.88 per cent (Leech et al. , were examined by veterinarians, so the study produced

1960). The last major British survey was in 1977 and

useful data on the incidence of lesions causing lame-

involved 48 veterinary practices which recorded 7526

ness. The incidence of lameness treated by both veteri-

cases of lameness in 1821 dairy herds (Russell et al. , nary surgeons and farmers in 90 well-recorded UK

1982). The average incidence amongst cattle was 5.5 per

dairy herds is shown in more detail in Table 31.2. The

cent, although this varied between the veterinary prac-

authors concluded that it should be a reasonable target

tices from 1.8 to 11.8 per cent. Most lesions (88.3 per

for farmers to reduce lameness incidence to second

cent) occurred in the feet and 84 per cent of foot lesions

quartile values, i.e. 11 per cent of the herd affected,

were in the hind feet. The remaining 11.7 per cent of *giving a target of 14 cases/100 cows per annum. From*

lameness occurred in the legs and trunk and the major-

other figures in Table 31.1 this would appear to be a

ity of these involved trauma (Russell et al. , 1982). A rather optimistic target.

New Zealand farmer-recorded study of three herds in

Although enormous research effort over the past 25

1989/90 showed variations in lameness incidences of 38

years has led to an increase in our understanding of

per cent, 22 per cent and 2 per cent (Tranter & Morris,

lameness, the incidence has not declined significantly.

1991).

One major reason for this is the advent of digital

Table 31.2

Incidence of lameness in 90 well recorded DAISY herds (Esslemont & Kossaibati, 1996).

Weighted average values

Overall

Lowest quartile

Second quartile

Third quartile

Fourth quartile

Number of herds

90

22

23

23

23

% of herd affected

17.4

4.4

11.1

18.3

33.8

by lameness

Cases per affected cow

1.4

1.0

1.2

1.4

1.8

Cases per 100 cows

24

4.7

14.1

24.6

47.4

dermatitis. First reported in the UK in the mid 1980s

Hoof

(Blowey & Sharp, 1988), digital dermatitis now ac-

The hoof, or horn capsule, is keratinized epidermis,

counts for around one third of all cases of lameness

similar to hair or finger nails. There are five distinct

seen. In a UK study of five UK dairy herds involving

parts to the hoof, namely the periople, the wall, the sole,

over 1100 cow lactations over 18 months, where all lame

the white line and the heel. The wall, sole and heel

cows were examined and recorded by a veterinarian,

consist of tubular horn, produced by the underlying

the incidence of digital dermatitis was 12.0 cases per

papillary corium (or dermis). Keratinization of the epi-

100 cows per annum, compared with sole ulcers at

dermal cells is a physiological process involving a high

13.9 cases/100 cows p.a. and white line disease at 12.7

rate of synthesis of keratin proteins inside the cell, plus

cases/100 cows p.a. (Hedges et al., 2000).

the production of intercellular cementing substances.

Several studies have attempted to record the fre-

This must be carried out entirely by diffusion, because

quency of lesions causing lameness, although results

the epidermis is avascular. The strength, or quality, of

must be interpreted with care. Studies which rely on

the horn is determined by three main factors:

veterinary records of cases for which the farmer has

requested attention for treatment will undoubtedly

underestimate the incidence of conditions such as

• The amount of keratin fibrils within the cell and the

strength of their cross-linking disulphide bonds to

digital dermatitis and foul in the foot, as many farmers

form keratin masses.

would treat these themselves. On the other hand,

studies involving farmer recording may use vague terms

• The amount and quality of the intercellular cement-

ing substances which cement the keratinized cells *such as 'under-run heel' or 'sole abscess', without defin-*

together.

ing the initial cause of the lesion (sole ulcer, white line,

foreign body penetration, etc.), and these studies would

• *The architecture of the horn itself, namely the ratio*

of tubular to non-tubular horn, which is effectively

lack accuracy. Table 31.3 summarizes five sets of data

the density of the horn tubules.

on lesions causing lameness.

Heel ulcers are a recently defined condition (Blowey

Horn tubule density is approximately 80 tubules/mm2

et al., 2000a) and may have been classified as under-run in the wall, decreasing to 20 tubules/mm2 in the central

heel or foreign body penetration in other surveys. Axial

sole area. There is no tubular horn in the white line. The

wall fissures also appear to be of increasing importance

wall is therefore the stronger part of the hoof, especially

worldwide (Vermunt, 1998) and may be a form of white

at the toe when it is more mature. As the number of

line lesion as many follow the line of the axial groove.

horn tubules is fixed at birth, enlargement of the hoof, *for example in older cows, is by an expansion of the*

Structure of the foot

intertubular cement. The very large flat foot of a

cow is generally softer and weaker than the small

compact foot of the heifer, because of its lower tubule

The bovine claw consists of three main components,

density.

namely (Fig. 31.1):

The periople is the hairless band of soft horn that sep-

• Hoof

arates the wall from the skin at the coronary band. It is

• Corium

continuous from one claw to the other and merges with

• Bone and associated structures

the bulbs of the heel to give the smooth, waxy coating

Table 31.3

Types of lesion recorded as causing lameness.

Study No.

1

2

3

4

5

% of

% of

% of

% of

Cases/100

lesions

lesions

lesions

lesions

cows per year

Sole ulcer

12.0

28

13.90

White line disease

18.0

39

16.8

22

12.70

Interdigital necrobacillosis

14.7

15.0

5

7.20

Foreign body penetration

12.3

3.10

Digital dermatitis

8

12.00

Interdigital dermatitis

Interdigital skin hyperplasia

4.2

5

1.20

Interdigital foreign body

2.0

5.6

5

Overworn sole/bruising

1.9

42

8

2.00

Vertical fissure (sandcrack)

1.1

0.54

Aseptic laminitis

4.7

Under-run heel

7.7

Deep sepsis

3.1

8.9

0.45

Heel ulcers

5.80

Axial wall fissures

1.07

Foot lesions

88.3

82.3

Leg lesions

11.7

Hind foot lesions

65.0

35.70

Key to study numbers:

(1) Russell et al. (1982), UK. Lameness reported by farmers and examined by veterinarians.

(2) Tranter & Morris (1991) New Zealand study of three dairy herds. All lame cows examined by veterinarians.

(3) McLennan (1988), Australia. Cases reported to veterinarians.

(4) Clarkson et al. (1996), UK. Lesions recorded by farmers and veterinarians
(5) Hedges et al. (2000), UK study of five dairy herds. All lame cows reported by farmers but examined by veterinarian.

Papillary corium

Laminar corium

Digital

cushion

Wall

Pedal bone

Heel

horn

Wall

Horn

Laminar

Intertubular

tubule

horn

Papillary corium

horn

leaflets

of the sole

Sole

Interdigitating

horn

White

Fig. 31.1

The structure of the hoof wall

line

and white line. (Diagram: Jane Upton.)

seen on good quality hooves. Its main function is to

The wall, produced by papillary corium beneath the

prevent dehydration of the horn. Deterioration with

coronary band (Plate 31.1), flows over the laminar

age or with hot, dry or windy conditions will predispose

corium at approximately 5 mm per month. As the length

to vertical fissures.

of the anterior wall, from the coronary band to the toe,

is approximately 75 mm, new horn takes 15 months (75

pedal bone, the corium is impregnated with fat,

∏ 5 = 15) to come into wear at the toe.

fibrous and elastic tissue, to form a shock absorber

The lamellae of the deeper layers of the epidermis

and vascular pump. Trauma to the digital cushion

(namely the hoof capsule) interdigitate with the

results in a permanent replacement of fat and

laminae of the dermis (the corium). This produces a

elastic tissue by scar tissue, with subsequent loss of

structure that is firmly attached to and protects the

function.

corium, but allows free movement for the horn wall and

• *On its internal aspect the corium provides nutrients*

acts as a shock absorber during locomotion.

and vascular support for the pedal and navicular

Sole horn is produced by the papillary corium of

bones. Arteriovenous shunts allow blood to bypass

the sole and therefore consists of tubular horn and

the foot during periods of weight bearing.

intertubular matrix (Fig. 31.1). The sole thickness varies

from 10 to 15 mm and thus sole horn comes into wear

Bone and associated structures

two or three months after formation.

The white line is the cemented junction between the

The third phalangeal (pedal) bone, the distal sesamoid

wall and the sole and runs from the heel, along the

(navicular) and the distal interphalangeal (pedal) joint

abaxial wall to the toe, caudally along the axial wall,

are all contained within the hoof capsule. The deep

then dorsally along the axial groove, to end in the inter-

digital flexor tendon is attached to the flexor tuberos-

digital cleft. The white line (Plate 31.2) consists of

ity of the pedal bone and within the heel is separated *laminar horn leaflet cells and interdigitating horn cells.*

from the distal sesamoid by the navicular bursa. Small

Both are produced from the adjacent corium at the toe,

fibrous strands of tendinous structure, sometimes

where the laminar corium of the wall joins the papillary

visible in the base of deep sole ulcers, are fragments of

corium of the sole. There is no tubular horn and hence

the deep flexor tendon. The suspensory apparatus of the

white line horn is less mature and considerably weaker

pedal bone (Fig. 31.8) supports the caudal edge of the

than the wall or the sole.

bone. It is firmly attached to the corium on the abaxial

The heel, or bulb of the hoof, is a continuation of the aspect and joins the suspensory ligaments of the leg

perioplic layer, with horn tubules running obliquely in

axially.

an anterior/ventral direction from the heel towards the

sole. The softer heel horn can expand and contract

during locomotion and, in conjunction with the under-

Weight bearing surfaces, hoof

lying digital cushion, acts as both a shock absorber and

overgrowth and wear

vascular pump preventing venous stasis. Consequently

heifers which remain stationary, standing for very long

As the primary objective of hoof trimming is to restore

periods, may develop anoxia of the corium with subse-

the foot to its 'normal' shape, it is important to under-

quent poor horn production.

stand the correct weight bearing surfaces of the foot

and the distortions that occur due to overgrowth. In a

correctly shaped hoof, weight is taken on the heel, on

Corium

the abaxial wall and, to a lesser extent, on the white line

The corium is the modified dermis providing nerve and

and 10–20 mm of adjacent sole, and on the axial wall

vascular supplies (and therefore nutrients) to the hoof

running from the toe caudally along the first third of the

horn externally and the bones and associated structures

axial space. The remainder of the axial surface of the

internally. Arteriovenous shunts across the top of the

claw should be non-weight bearing (Fig. 31.2). Other

foot enable blood to bypass capillaries during weight *dimensions of the claw are given in Fig. 31.3.*

bearing, although if the shunts remain open for too

long, for example as a result of laminitis/coriosis, anoxia

Hoof overgrowth

and consequently dyskeratotic horn formation result.

The corium is structurally modified, enabling it to per-

The size and shape of the hoof at any one time will be

form differing functions in various areas of the foot,

a balance between the rate of growth and the rate of

namely:

wear. As one might expect, there are a variety of factors

that influence both processes. For example, horn growth

• Papillae on the wall and sole extrude tubular horn.

is faster:

• The laminar corium is a support structure where it

interdigitates with lamellae on the hoof wall and in

• In young animals

its distal extremities it produces white line cement.

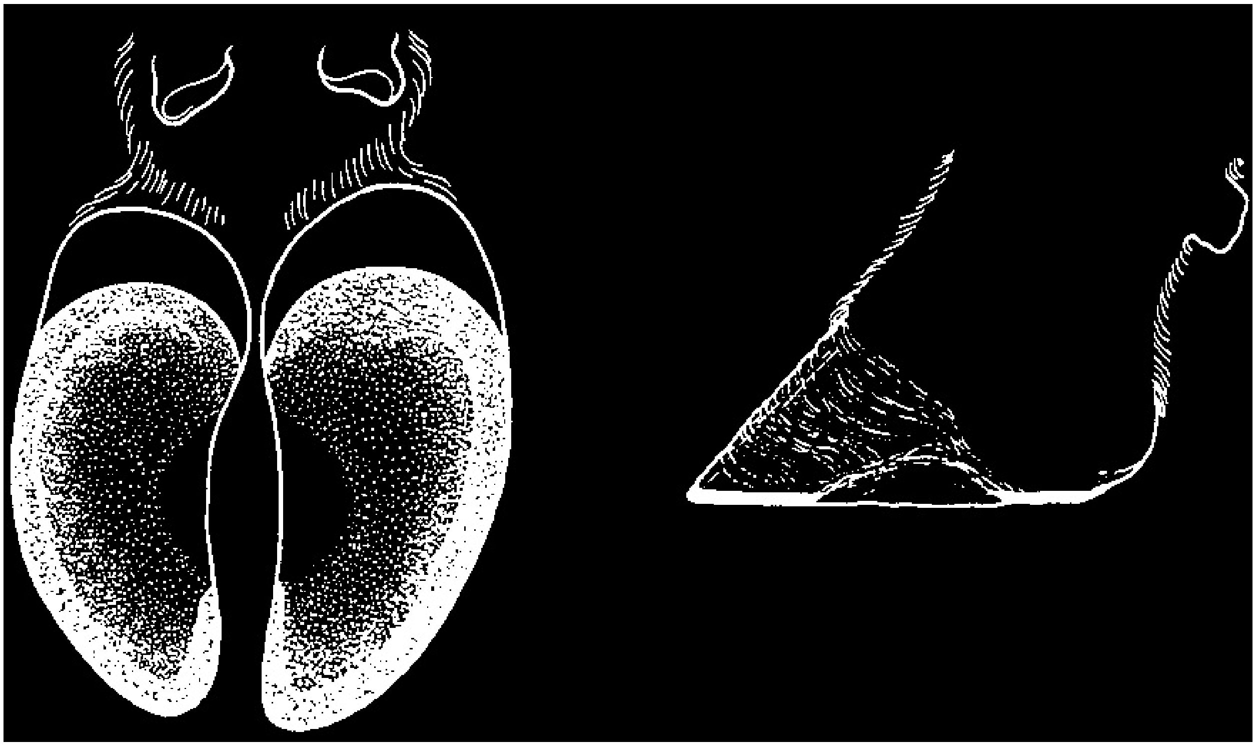
• With high concentrate feeding

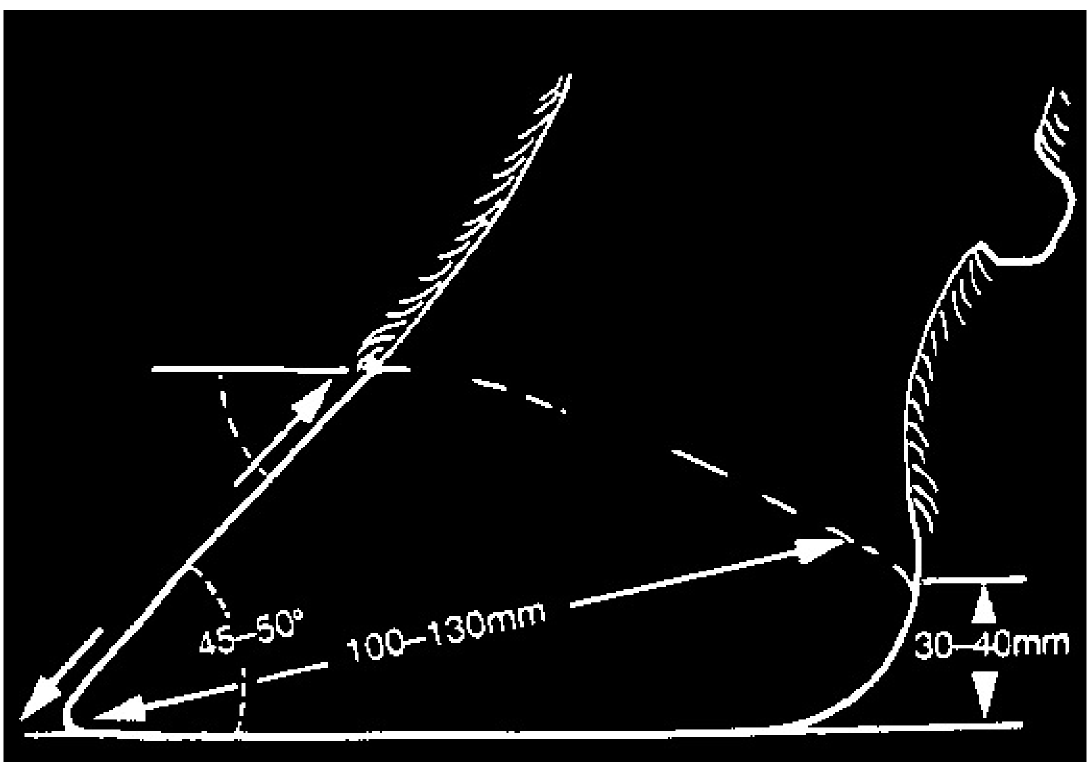
• The digital cushion: within the heel and extending

• With more exercise

forwards to a point beneath the caudal edge of the

• *On rough surfaces*





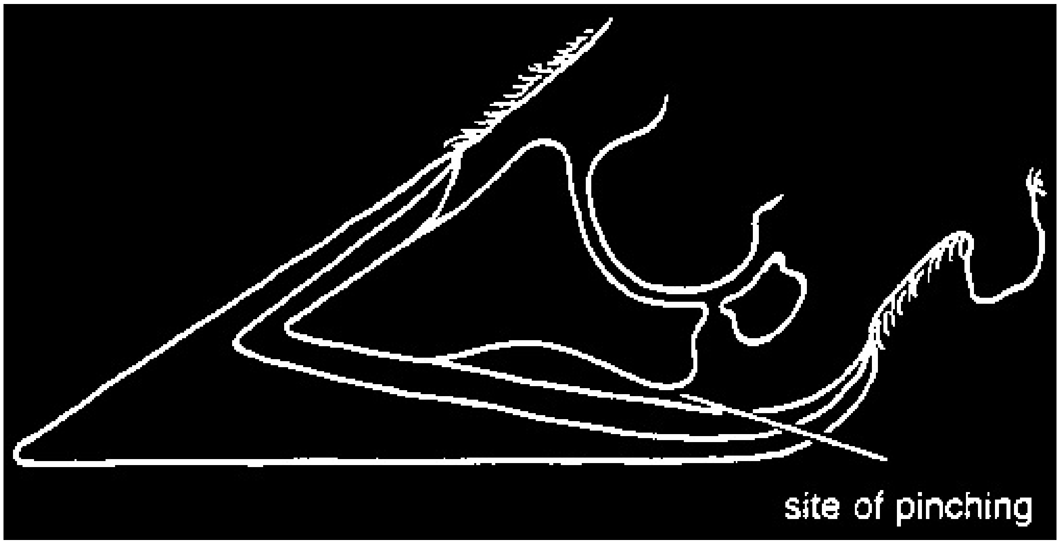


Fig. 31.2

The correct weight bearing sur-

faces of the foot.

60–80mm

Fig. 31.4

Overgrowth at the toe leads to a caudal rotation of

the pedal bone.

Fig. 31.3

Approximate dimensions and angles of a normal

claw.

the pedal bone remains the same size, irrespective of

the degree of overgrowth. In this respect the hoof is

The rate of wear is increased by factors such as:

very different from the cow's horn, where the cornual

• Wet conditions underfoot, leading to softer horn

bone lengthens with increasing length of the horn.

which wears faster

• Excessive standing and walking

Overgrowth of the lateral wall

• Hard and/or abrasive floor surfaces

In some animals the wall of one claw grows faster than

the other and starts to curl under the sole. This produces

Overgrowth at the toe

a corkscrew effect at the toe. Corkscrew claw may be a

The horn of the wall is generally harder than the horn

genetic trait or can be a result of coriosis/laminitis.

of the heel, so although both may grow at the same rate,

horn is worn away more slowly from the toe than from

Overgrowth of the sole

the heel. This results in overgrowth occurring primarily

at the toe. The additional horn at the toe lifts the front A ledge of horn is commonly seen growing from the

of the foot and the front wall then forms a more shallow

sole and extending into the axial space (Fig. 3.17, Plate *angle, decreasing from 45° to 30° or 20°, or even to the*

31.4). In some instances it may even overlap the adja-

horizontal. In extreme cases the front wall becomes

cent claw, and may be so pronounced that it becomes

concave and the toe is lifted off the ground (Plate 31.3).

the major weight bearing area of the foot. This has

These changes are shown in Fig. 31.4. Internally the

importance in the pathogenesis of sole ulcers, as the

pedal bone is rotated backwards, thereby putting even

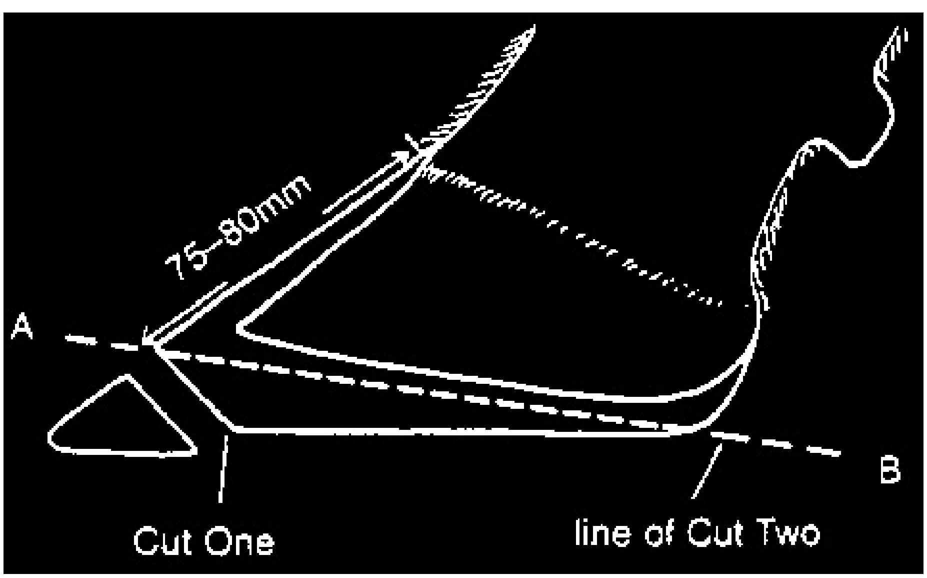
overgrowth of sole horn is immediately beneath the

more pressure on its rear edge (the flexor tuberosity)

flexor tuberosity of the pedal bone and in an area where

and further increasing the risk of sole ulcers. However,

weight bearing should be minimized.



Disparity of claw size

of the abaxial wall, across the dorsal wall to the sole

surface of the axial wall. 'Hardship lines' can be used

The lateral claw of the hind foot is often considerably

to establish the chronology of previous episodes of

larger than the medial claw. There is no single reason

coriosis/laminitis, and therefore the potential causes of

for this and suggested causes include:

current hoof problems.

• The lateral claw is naturally slightly larger than the

medial (Paulus & Nuss, 2002).

Hoof trimming

• Poorer suspension of the pedal bone within the

lateral claw, leading to pinching of the corium and

A variety of methods have been described, but all have

stimulating the growth of horn. The caudal edge of

one common aim, namely to restore the foot to its

the pedal bone is suspended within a 'hammock',

correct shape and weight bearing surface. The manner

known as the pedal suspensory apparatus (fig. 31.8).

in which this is achieved is less important and the fol-

This is connected to the laminae on the abaxial wall,

lowing text simply describes one approach (Blowey,

and axially to the suspensory ligaments of the leg.

1998), with emphasis being placed on the anatomical

• A greater variation in load bearing on the lateral

corrective stages, rather than the precise method used.

claw compared with the medial claw when the cow

Other approaches are described elsewhere (Toussaint-

is walking (Toussaint-Raven, 1985).

Raven, 1985). Although described as a four-stage pro-

• A leg conformation in which the hocks point in-

cess, in reality one part of the trimming process merges

wards and the toes outwards.

with the next.

• Excessive engorgement of the udder at calving,

forcing the legs apart.

Cut one

• The hind feet are the major propelling force of

the cow during locomotion, pushing her forwards,

The overgrown toe should be cut to its correct length, *whereas the front feet are the major weightbearing*

which is approximately 75–80 mm from the coronary

structures.

band to the toe, or one handspan. Most experienced

hoof trimmers would simply estimate this distance but,

In the front feet the position is reversed: the medial

when learning, it would be better to measure specifi-

claw is commonly larger than the lateral claw.

cally. After cut one the cow is left with a 'square-ended

toe'. In Plate 31.5 it can be seen that the white line now

Negative net growth

passes across the end of the toe and clearly the wall,

At housing, and especially when housing and calving

which should be the correct weight bearing surface, is

coincide, heifers invariably undergo a period of negative

no longer weight bearing at this point. Although the

net growth. The rate of hoof horn growth is reduced but anterior wall may now be the correct length, the toe is

at the same time there is a rapid increase in wear, espe-

still too high and this means that the front angle of the

cially at the toe. This leads to a shortening and increased *anterior wall is too shallow. This is demonstrated in Fig.*

angle in the dorsal wall, plus a thinning of the sole. In

31.5.

some heifers the changes may be sufficiently extreme

for the horn at the toe to become totally eroded, expos-

Cut two

ing the corium. Such heifers are said to have 'soft soles'

or 'toe ulcers'. The syndrome is seen especially in heifers

The next stage is to remove the excess horn from the

that have to walk long distances to and from pasture, for

sole surface of the toe, thus dropping the toe relative to

example in New Zealand and Uruguay, and also in

the heel and bringing the front wall back to a more

young bulls introduced into a dairy herd. It may be occa-

sionally seen in maiden heifers when they are housed at

the end of their first grazing season.

Hardship lines

Temporary disruptions of hoof formation in the ante-

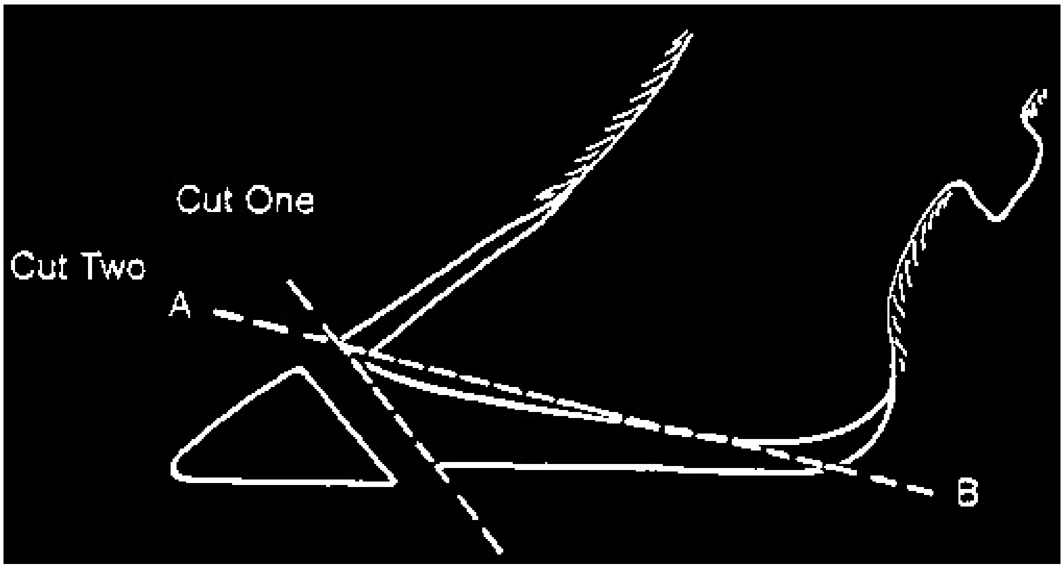
rior wall lead to circumferential rings of variable thick-

ness known an 'hardship lines'. When horn production

is poor, a groove is formed and in extreme cases results *in total cessation of horn formation, leading to a horizontal fissure. Because the dorsal wall is longer than the heel, the hardship lines often run from the sole surface*

Fig. 31.5

Hoof trimming cuts one and two.



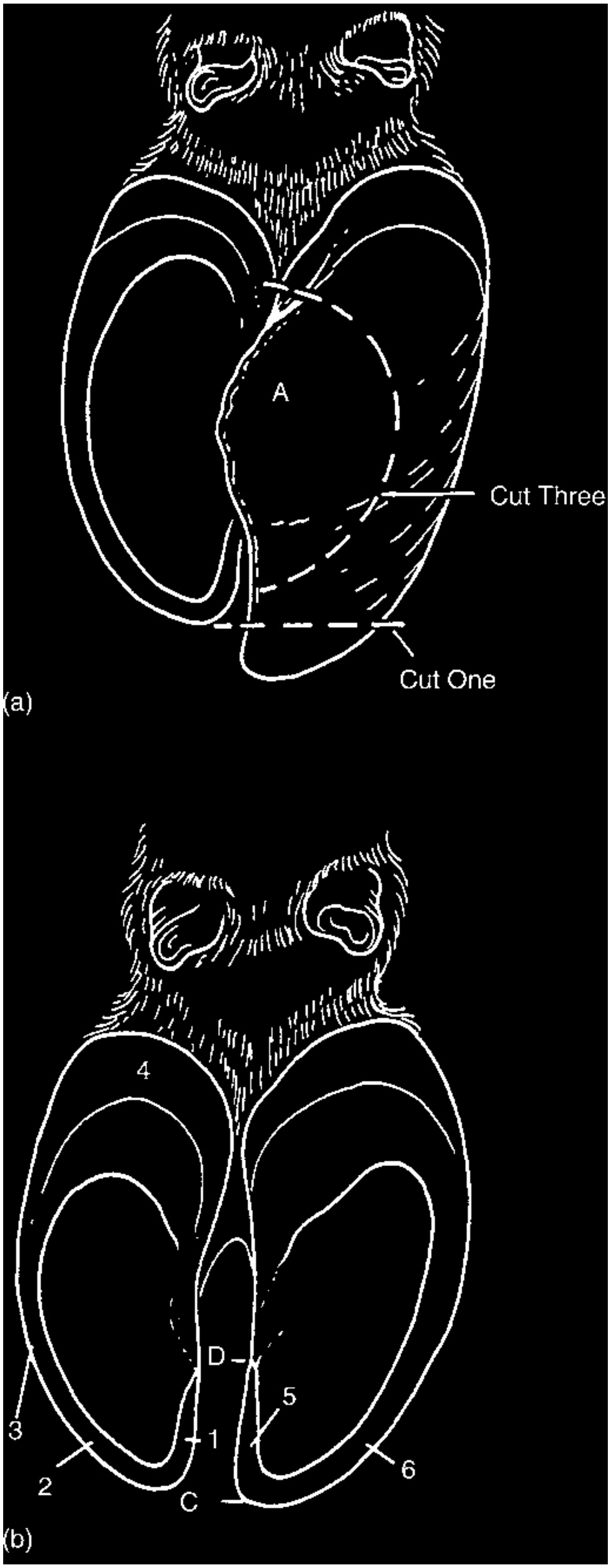

A
Cut Three
Cut One
(a)
4
D
5
3
1
2
6
C
(b)

Fig. 31.6

Hoof trimming. Cut one should not be made too short.

upright position. The horn to be removed in cut two lies beneath the line AB (Fig. 31.5), which is a line joining cut one to the base of the heel. The first part of cut two can be performed by removing part of the wall using hoof clippers, but later stages should be carried out with a hoof knife, using thumb pressure to check this area of the sole regularly for signs of softening. A softening of the horn should not occur, but if it does then trimming must stop. There will only be a few millimetres of horn before the corium is penetrated and exposure of the corium in this area of the foot can lead to quite severe and protracted lameness.

If cut one was in the correct position it should be possible to remove horn from the sole surface of the toe until the white line and adjacent wall are once again clearly visible at the toe. The wall is now the weight *bearing surface. It is important that this is achieved, otherwise the weaker white line structure would become weight bearing, with obvious adverse consequences.*

It is vital that cut one does not make the hoof too short; this scenario is shown in Fig. 31.6. Because cut one was too short, a line drawn from the top of cut one to the bottom of the heel (AB in Fig. 31.6) would lead to exposure of the corium at the toe and this can produce severe lameness.

Cut three

Fig. 31.7

Hoof trimming. Cut three and the finished foot.

Cut three consists of removing any axial overgrowth of the sole, followed by dishing the axial sole surface of both claws (Fig. 31.7a), so that weight bearing beneath the flexor tuberosity of the pedal bone is minimized.

Cut three also slightly increases the space between the longer. This usually means removing additional horn digits. This makes impaction by dirt and foreign bodies from the outer claw of hind feet and the inner claw of less likely, decreasing the incidence of diseases such as front feet, bringing the legs back to the upright position.

foul, interdigital dermatitis and interdigital skin hyper-

This produces more even weight bearing.

plasia (‘corns’).

General points

Cut four

When trimming is complete, points 1, 2, 3 and 4 on Fig.

The final stage is to trim the two claws back to ap-

31.7b should all be on the same longitudinal horizontal

proximately the same size with the lateral claw 4–5 mm

plane, to provide adequate weight bearing. The two

claws should also be of equal size and their two sole sur-

• Conditions of the skin: digital dermatitis, inter-

faces on the same transverse horizontal plane. Removal

digital necrobacillosis, interdigital skin hyperplasia

of the axial (inner) wall CD (Fig. 31.7b) is a common

and mud fever.

mistake made by some herdsmen who feel that the toes

• Disorders of the pedal and navicular bones.

should not be touching once trimming is complete. This *is a fallacy. If the wall CD was lowered the claw would*

be seriously destabilized, causing it to rotate inwards

Sole ulcers and white line defects

and allowing overgrowth of the lateral wall. In the

Pathogenesis

worst case excessive removal of the axial wall might

expose the corium, leading to severe lameness.

The horn of the white line and sole is produced by the

It is preferable not to remove any heel horn unless it

corium. Damage or disruption of the corium will there-

is badly under-run, other than as part of cut four. If the

fore be the primary change that later leads to the for-

heel is only slightly pitted, it is best left alone, since

mation of poor quality horn, and this is eventually

removal of the heel could lead to backwards rotation of

seen as defects such as sole ulcers and white line disor-

the pedal bone and so predispose to sole ulcers.

ders. The syndrome is sometimes referred to as 'claw-

One theory of hoof trimming recommends that it is

horn disruption', although once again, as the primary

advisable first to trim the medial claw to the correct *defect is in the corium, then this is the area to which*

shape and then use this as a template for trimming

attention should be focused. Although the term 'lamini-

the lateral claw. Whilst this system may have its merits,

tis' is often used, the majority of changes affect the

it is the opinion of the current author that it is not

whole corium, and particularly the papillary corium

always a correct course of action, and especially when

of the sole, where there are no laminae. Hence use of

dealing with lame cows. This is because it may be

the term 'laminitis' in cattle is not particularly accurate.

beneficial on welfare grounds to leave the medial claw

It is doubtful if laminitis occurs as a single entity

slightly larger than normal in order to increase its

in cattle, and the more general term of 'coriosis' is

weight bearing potential when there is a lesion in the

preferable.

lateral claw.

Changes associated with the corium

Timing of foot trimming

Coriosis can occur as a result of trauma, infection, nutri-

tional imbalance/excess and toxic states and commonly

There is no one correct time to trim feet. Potential

is a sequel to a combination of causes. The overall result

options include:

will be the same, namely altered horn formation with

• When overgrowth occurs. Leaving a foot with over-

the risk of lameness when the poor quality horn reaches

grown horn not only makes walking uncomfortable

the bearing surface of the sole.

but it also predisposes to the development of more

Ossent (1995) describes three stages in the patho-

serious lesions such as sole ulcers.

genesis of sole ulcers and white line disease, all of which

• When the cow is lame. Clearly all lame cows

arise as a consequence of coriosis:

should have the affected foot lifted, trimmed and

(1)

Disruption of blood flow within the corium, leading

examined.

to sludging, poor oxygenation of epidermal tissues

• At drying off. As many of the management and

and consequently poor keratin synthesis.

feeding 'insults' leading to lameness occur at the

(2)

The laminar suspension of the pedal bone within

time of calving, it is ideal to have feet in optimum

the hoof is disrupted and the bone sinks within the

shape at this stage. In addition, at the end of lacta-

hoof.

tion there may be a build up of horn from insults

(3)

Compression of the corium, especially beneath the

suffered in the previous lactation

flexor tuberosity of the sinking pedal bone, leads

to further ischaemic necrosis, disrupted horn for-

mation and consequently the production of a sole

Lesions causing lameness

ulcer.

The changes at the dermal–epidermal junction are

The majority of the lesions causing lameness are in the

still not fully understood. It is thought that they involve

foot. In this section these will be subdivided as follows:

an initial release of vasoactive substances. Vasodila-

• Sole ulcers and white line defects.

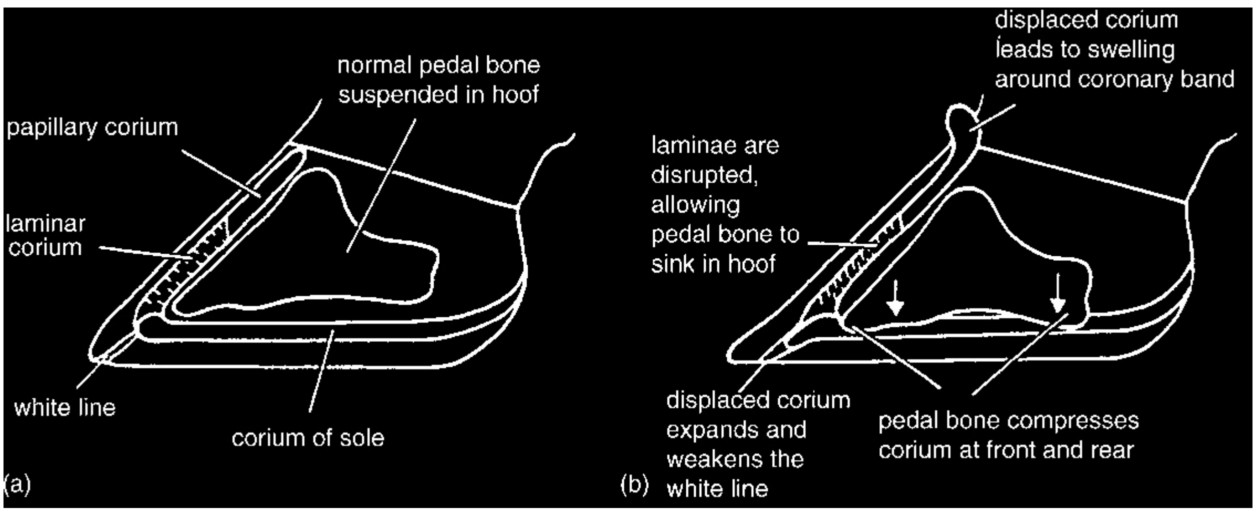
tion in the corium leads to vascular stagnation and

• Other hoof problems: foreign body penetration,

the opening of the arteriovenous shunts exacerbates

horizontal and vertical fissures.

this. The ensueing hypoxia leads to transudation,



thrombosis and ischaemic necrosis, and consequently

months later. The nature of the horn defects will

poor keratin synthesis and lamellar disruption.

depend on the severity of the initial corium damage,

Haemorrhage on the sole is often referred to as

and are likely to appear as:

'bruising'. This may be a correct term, although it

• Yellow discoloration – if serum only was released.

should always be remembered that the 'bruise' was

• Haemorrhage – if the blood vessels ruptured (Plate

formed by an insult one or two months previously, when

31.6).

the horn now on the surface of the sole was being pro-

• A sole ulcer – if the damage to the corium was so

duced. As such, bruising of the sole cannot be impli-

severe that horn formation was totally disrupted

cated as a recent cause of lameness. The effect of mixing

(Plate 31.7).

serum or blood with the horn can be likened to mixing

sawdust with concrete – it weakens it considerably. This

If there is a generalized inflammation of the corium,

is particularly the case for the white line, which is an

then the suspension of the pedal bone within the foot

inherently weak structure, and at the sole ulcer site

is disrupted, allowing the bone to sink within the foot,

where there may be almost 'neat sawdust' because so

as shown in Fig. 31.9. The corium is then displaced and *much haemorrhage is present. The whole process is*

the following changes occur:

very similar to the changes which occur when a finger-

• The 'sinking' bone puts further pressure on the

nail is bruised: the blood spot often starts at the corium

corium, especially beneath the flexor tuberosity, the

of the skin–nail junction and then slowly grows to the

heel or the toe. Ulceration of the sole, heel or toe

distal extremity of the fingernail over the next few

may result.

months.

• Lateral displacement of the corium into the white

line area leads to weakening and widening of the

Changes associated with the pedal bone

white line cement with increased risk of white line

defects.

The ventro-axial border of the pedal bone is arched in

shape. The pedal bone is suspended within the hoof by

the laminae, with a much stronger attachment to the

abaxial wall than to the axial wall (Fig. 31.8) of the hoof.

Digital suspensory

ligament

When weight is transmitted down the leg the bone

rotates slightly on the axial surface, putting increased

Firm attachment

weight on the flexor tuberosity. Increased weight

of ligament to

bearing puts extra pressure on the corium and if it is

P3

P3

abaxial wall

already in a fragile state, then it is likely to become

damaged. Pinching of the corium between the flexor

tuberosity of the pedal bone above and the horn of the

Fat pad in suspensory

sole beneath leads to 'bruising' of the corium. This leads

ligament at caudal

edge of P3

to defective horn formation and the changes will be

seen on the bearing surface of the sole one or two

Fig. 31.8

Suspension of the pedal bone within the hoof.

Fig. 31.9

Coriosis leads to disruption of the laminar suspension of the pedal bone.

• Dorsal displacement of the corium may produce

Note that no dressings are recommended: in fact many

a circumferential thickening above the coronary

would consider them to be counterproductive. This is

band.

referred to later.

• Anterio-ventral displacement of the pedal bone

(i.e. movement towards the toe) may leave a hori-

Heel and toe ulcers

zontal depression or 'furrow' in the heel horn. This

is a classic sign of disruption of the laminar sus-

Although sole ulcers are by far the most common, there

pension with subsequent movement of the pedal

can be areas of haemorrhage or even total perforation

bone.

at other areas of the sole. Toe ulcers are thought to

occur when the pedal bone sinks within the hoof 'bows

The poor laminar suspension on the axial wall com-

first' – that is, the front of the pedal bone drops before

pared with the abaxial wall (Fig. 31.8) leads to the axial

the flexor tuberosity at the rear.

aspect of the pedal bone, and especially its flexor

Heel ulcers are seen as small dark red/black marks

tuberosity, having the greatest contact with the corium

(Plate 31.8) in the central sole area towards the heel

of the sole. This explains the typical site of the sole ulcer

(Blowey, et al., 2000a). Plate 31.8 shows a typical heel in zone 4 (mid sole) of the hoof. Once the pedal bone

ulcer on the left claw and haemorrhage at the site of an

has dropped within the hoof it will never regain its orig-

early sole ulcer on the right claw. Some heel ulcers

inal position. In addition, a corium that has been

simply track down to the corium and fade to nothing.

damaged by ischaemic necrosis heals by fibrosis and is

Others lead to under-running and abscessation of the

therefore less able to produce good quality horn in the

sole at the sole–heel junction and can produce a marked

future. As a consequence, heifers affected by coriosis

lameness. Heel ulcers represent a significant cause of *during their first lactation are more susceptible to lame-*

lameness (Table 31.3). They often occur in association

ness in later lactations. For example, in one study,

with sole ulcers, although they are seen more commonly

heifers that developed lameness in their first lactation

on the medial claw of hind feet. The cause of heel ulcers

were almost three times as likely to go lame in their

is not known, although one theory is that they are pro-

second lactation than their non-lame counterparts.

duced by pinching of the corium under the caudal edge

Optimal management of the precalving and peripar-

of the pedal bone. At this point the bone is suspended

turient first lactation heifers is therefore vital as a long

in the pedal suspensory apparatus (Fig. 31.8), within

term lameness control measure.

which there are three fat pads acting as shock absorbers

Continual compression of the corium of the sole can

(Ossent & Lischer, 2000). The central fat pad has been

lead to generalized poor horn formation, sometimes

shown to undergo cartilaginous change, and it may be

seen in older cows where a sole ulcer totally fails to *the effect of this that leads to the formation of heel*

heal. In such animals a layer of very poor quality 'horn',

ulcers. Heel ulcers are hence in the central sole region sometimes little more than a layer of fibrous tissue,

at the junction of zones 4 and 6 (zone standardization

may form over the ulcer site, and the tip of the flexor

from the Liverpool International Ruminant Digit Sym-

tuberosity of the pedal bone can sometimes be palpated

posium 1990, cited by Greenough et al., 1997). Sole

as a hard lump immediately beneath.

ulcers typically occur in a more anterior and axial posi-

tion on the axial aspect in the centre of zone 4, and toe ulcers are seen in zone 5 at the toe.

Sole ulcers

A sole ulcer (Plate 31.7) is a physical condition, caused

White line defects

by trauma to a fragile corium, and treatment must

Weakening of the white line, brought about by the

therefore be aimed at minimizing this trauma. The main

inflammation associated with laminitis/coriosis, can

steps for treatment are:

result in a range of white line disorders. The most

• Dish the sole ulcer site so that weight bearing is

common of these are:

minimized.

• Remove any under-run horn around the ulcer, to

• Sterile abscessation.

eliminate pockets of necrotic horn and infection,

• White line separation.

thus allowing the formation of new horn.

• White line penetration and abscess formation, with

potential complications of infection tracking along

• Remove protruding granulation tissue.

the laminar corium towards the coronary band.

• Reduce the size of the affected claw as much as

possible, and maximize weight bearing on the sound

Sometimes the internal inflammation within the

claw. For more advanced cases, apply a block to the

corium is so severe that pockets of necrotic tissue are

sound claw (e.g. Plates 31.7 and 31.20).

formed. These can produce a sterile internal abscess

and as there may be no obvious tracts running from the

• It leaves a pit which can easily become impacted

outside, they may be quite difficult to locate and treat.

with stones or dirt, thereby impeding drainage and

In severe forms of coriosis the whole sole becomes

predisposing to further white line impaction.

separated by an accumulation of inflammatory fluid.

• By creating a pit, areas of under-run horn and

This is known as a false sole.

pockets of infection are much more likely to be

More commonly fissures develop vertically into the

missed. If a small area of adjacent wall is removed, it

weakened white line, a process known as white line sep-

is much easier to expose and drain the affected area.

aration (Plate 31.9). This occurs especially if the cows

Protruding granulation tissue is often an indication

are walking over rough or stony ground, or when they

that there is adjacent under-run horn that needs to be

make sudden turning movements, as when escaping

removed, and use of a block on the sound claw to

from an aggressive cow. Small stones may then become

prevent weight bearing on the affected claw improves *impacted and with continued walking these may even-*

the rate of healing. A swollen, hot and painful coronary

tually penetrate the corium. The most common point

band is caused by infection tracking into deeper struc-

for white line separation and penetration is at zone

tures such as the navicular bursa or tendon sheaths, and

3, where the rigid abaxial hoof wall joins the flexible

in such instances antibiotic therapy and/or more radical

heel. During locomotion this is where there are the

treatment is indicated.

greatest sheer forces between the rigid hoof wall, the

suspended pedal bone and the movements of the flexi-

ble heel horn. Once the corium has been penetrated,

Causes and control of coriosis (laminitis)

the invading foreign body (usually a stone or grit) intro-

duces infection. For white line abscesses near to the

Coriosis is clearly the primary factor responsible for

heel, natural drainage is through the soft horn of the

defects in the horn capsule. In this section the aetiol-

heel. White line abscesses close to the toe do not have

ogy, and consequently the control of coriosis, is *such an easy escape route and often infection tracks*

described under the headings of parturition, excessive

upwards through the laminae, to discharge at the coro-

standing, nutrition and general management.

nary band. This produces a more severe lameness

because at the toe the pedal bone is tightly attached to

Parturition

the hoof, and there is therefore very little room for the

pus to expand.

Many authors have shown an association between par-

Whereas a sole ulcer results in damage to the under-

turition and increased incidence of lameness, with the

lying corium, the majority of white line lesions prima-

peak incidence of white line lesions in first lactation

rily produce separation of the horn from the underlying

heifers occurring nine weeks after calving, and sole

horn-forming corium. Uncomplicated white line lesions

ulcers at 14 weeks postpartum (Leach et al., 1997). In therefore normally heal much more quickly than sole

cows the incidence peaks slightly later. Green et al.

ulcers. White line lesions in the axial groove are

(2002) showed that lameness from all causes peaks in

described on page 426.

the second and third month after calving. The rings on

The treatment of a white line abscess is very similar

a cow's horns, one for each calving (Plate 31.10), are said

to that for a sole ulcer, namely:

to be a reflection of the natural disruption in horn for-

mation (Blowey, 1998) that occurs at calving. Livesey

• Remove all under-run horn, even if this means

et al. (2000) suggested a decreased incorporation of

removing the wall from the sole to the coronary

amino acids into hoof horn at the time of parturition,

band, or the whole of an under-run sole. A few

presumably associated with a repartition of nutrients

authors recommend leaving a bridge of hoof wall to

(sulphur amino acids) towards milk production. Hirst et

prevent movement of each side of the bisected wall,

al. (2000) showed that cows that develop lameness in

but the danger of doing this is that the under-run

their first lactation are more likely to become lame in

infection will not be fully drained.

subsequent lactations, and suggested yield as a contrib-

• Reduce the size of the affected claw, to minimize

utory factor. Green et al. (2002), in an intervention

weight bearing, and leave the sound claw large.

study involving 1109 cow-years on trial, showed that

Blocks and dressings are discussed on page 431.

high-yielding cows were more likely to become clini-

When using a hoof knife to drain infection from the

cally lame than lower-yielding animals, but in the

white line, it is important to remove the short section of

affected group, lame cows produced 396 litres per cow

adjoining hoof wall. Digging a deep pit into the white

less milk than their non-lame counterparts.

line with the curved point of the hoof knife has two dis-

The changes that occur in all periparturient cows

advantages, namely:

appear to have a marked impact on the corium, horn

strength and subsequent lameness. There is a decrease

Although the average lying time of the heifers was ten

in the rate of rumination, and this leads to a 25–30 per *hours, some animals lay down for as little as five hours*

cent decrease in dry matter intake, at a time when the

each day. This group showed the highest incidence

cow's requirements (for the fetus and milk produc-

of lameness and quite severe haemorrhage persisted in

tion) are rising rapidly. There is an increased risk of

the sole horn for up to four months after calving. In

rumen acidosis and a marked immune suppression.

most dairy systems heifers are forced to spend longer

Dietary change, namely moving from a low concentrate

on their feet after calving. They will stand waiting to be

dry-cow ration to a high performance production diet,

milked, they spend longer standing to feed, because

further increases the risk of rumen acidosis and

they are often last to feed, and need to eat more as

coriosis.

lactation proceeds. They will have recently been mixed

Whatever the cause, the increased fragility of the

with the main herd and are now having to compete with

corium during the periparturient period means that it

older cows and fear may restrict their entry into a *is particularly susceptible to trauma. However, in most*

cubicle shed, especially if they are of low social domi-

dairy systems this is when the greatest trauma to the

nance and have had no previous cubicle training.

corium occurs, due to excess periods of standing

Excessive standing may be bad for the immediate

and aggressive interactive movements between cows

postpartum cow, but standing still is even worse. If the

as they become re-established in a different social

animal does not move, the vascular pumping mecha-

group.

nisms of the heel and digital cushion will be impaired.

Even if they calve outside in a field, for a few days

Vascular stasis predisposes to anoxia and damage to the

after calving cows, and especially heifers, will spend

corium, with resulting poor horn formation. It is essen-

far more time standing and their lying times will be

tial that there are adequate loafing areas to allow the

decreased. There is then more weight on the corium

cows to walk around freely. Overcrowding should be

and a greater potential for bruising. It is not known *avoided, even in collecting yards. Animals that are*

whether the decreased lying times are due to inherent

packed tightly together have little option but to stand

nursing behaviour (attending to the calf), discomfort

still. Adequate loafing areas also help to improve

from the perineum, an enlarged udder or to some other

oestrus expression and hence fertility.

factor.

The incidence of sole ulcers and white line disease

Diseases such as mastitis and metritis are more

will therefore be markedly reduced if animals are

common immediately after calving. This also increases

encouraged to maximize lying times in the immediate

the fragility of the corium and in extreme cases will

postcalving period, for example for the first two to six

produce hooves with hardship lines and horizontal

weeks after calving.

fissures. Heifers are likely to be worst affected, partly

because they have often had no prior experience of

Post-calving comfort: Of all the above factors, cubicle the housing and milking system and partly because in

comfort is probably the most important. Cubicles may
many large dairies the heifers have been reared totally
make the management of cows easier, but they are not
separate from the main herd. They are therefore addi-
always ideal in terms of cow comfort and lameness.
tionally exposed to a whole range of new infections
Several surveys have shown that the incidence of lame-
immediately postpartum, when immune suppression is
ness in cows in straw yards is much lower than in those
at its maximum, and this further depresses horn forma-
housed in cubicles. This must point to cubicles being less
tion. This leads to long periods of standing, produc-
than ideal, especially for the immediate postcalving
ing increased hoof wear at a time when hoof growth
cow. A small but increasing proportion of farms are now
is minimal. The 'negative net growth' which occurs
housing their freshly calved cows in 'maternity' loose
around parturition and housing is referred to below and
yards for the first two to six weeks after calving and then
on page 415.

transferring them to cubicles. Experience from such *systems suggests that in heifers especially, a postcalving*

period of loose housing leads to:

Excessive standing

• *Increased yields.*

Anything that leads to a decrease in lying times, espe-

• *A decreased incidence of lameness.*

cially in the immediate postcalving period when the

• *Improved cubicle acceptance when the heifers are*

corium is in its most fragile state, will increase the inci-

eventually transferred from the yard to the cubicles.

dence of sole ulcers and white line disease.

One experiment (Leonard et al., 1996) deliberately

The third factor is perhaps the most surprising. One

housed heifers in an overstocked cubicle building (17

might have expected that cows and heifers that had got

cubicles for 35 heifers) immediately after calving.

used to a straw yard would be very difficult to retrain

to use cubicles. The fact that the reverse is true proba-

Nutrition

bly indicates that parturition is a stressful experience

High starch/low fibre diets that lead to rumen acidosis

and that it is only when animals have fully recovered

undoubtedly predispose to coriosis and subsequent

that they are able to withstand the rigours of the cubicle

lameness, especially if fed both pre- and postpartum.

system. The major problem with straw yards is the

Blowey et al. (2000b) used 48 multiparous cows to

increased incidence of environmental mastitis and

compare high starch (wheat-based) with equal energy

hence perhaps the ideal situation would be a 'maternity

high fibre (sugar beet pulp) rations fed pre- and post-

group' housed in a low stocking density system of

partum. Sole haemorrhage scores at 24 weeks post-

luxury cubicles.

partum were significantly higher in the high starch

group. Livesey and Flemming (1984) showed that 64 per

Cubicle design: Cubicle comfort is obviously all-

cent of cows on a low fibre diet developed sole ulcers

important. Ideally, cubicles should be long enough and

compared with only 8 per cent on the high fibre ration.

wide enough (1.15 metres wide and 2.4 metres long) to

Concentrate intakes should be built up slowly after
accommodate the larger Holstein cows and with suffi-
calving, to reach a peak at no less than two weeks post-
cient space at the front to allow the cow to lunge
calving for average yielding cows and probably three
forward 1–1.5 metres as she stands up. If there are two
weeks for higher yielding animals, which peak later.
facing rows of cubicles, a length of 2.2 metres is ade-
Ideally no more than 4.5 kg of feed should be given in
quate. Cantilever-type divisions are ideal. Also recom-
the parlour. The inclusion of 1–3 kg of long-chop straw,
mended are a 100 mm fall from front to rear, a step of
well mixed with the ration, helps to stimulate rumina-
not more than 130 mm down into the dunging channel
tion, thereby promoting a good flow of saliva and
and a brisket rail at the front 1.75 m from the kerb,
decreasing acidosis. There is evidence that maintaining
which prevents the cow from shuffling too far forwards,
an ideal dietary cation–anion balance (DCAB) is ben-
but at the same time provides ample space for lunging
eficial (see p. 787). Acidosis can be recognized clinically

as she stands up.

by loose faeces, an increased incidence of digestive

When attempting to stand, the cow lunges forward

upsets, cud regurgitation and a sweaty coat.

1 to 2 metres and lifts herself first onto her hind feet,

Although high protein diets have occasionally been

then up onto her front feet. When she is lying down or

suggested as a cause of coriosis, most consider protein

half standing, therefore, much of her weight is taken

to be of less importance than other factors. High intakes

on her knees. If the floor surface is hard, and par-

of poorly fermented grass silage have also been impli-

ticularly if it is also rough, cubicle acceptance will be

cated, although this could be due to toxic amines rather

low. The worst possible cubicle floor is a stone base,

than high protein.

poorly compacted and with insufficient straw. In an

Even feeding during rearing influences the incidence

attempt to get comfortable cows will shuffle forwards,

of sole haemorrhage, with heifers fed high levels of con-

until they are so close to the wall that they are unable *centrate being the worst affected. High fibre diets are*

to lunge to stand. If a proportion of the cows are too

now recommended for rearing dairy heifers.

far forward in the cubicles, cubicle comfort should be

re-examined.

Most cubicle bases are made of concrete. This is fine

Trace elements and vitamins: Many attempts have been

provided that it is deeply bedded, although it is often

made to improve hoof condition by mineral, vitamin

difficult to retain a well-matted straw bed. A variety of

and trace element supplementation. The use of zinc,

mats and mattresses are available and these are cer-

particularly zinc methionine, is often promoted as a

tainly much better than concrete alone. However,

feed supplement having beneficial effects. If one of the

some bedding should be used, even with mats, other-

reasons for the production of poor quality horn at

wise hock sores will develop. A disadvantage of mats

calving is a temporary deficit of sulphur amino acids

is that it is difficult to get large amounts of straw

(see p. 419) then logic would suggest that supplemen-

bedding to adhere to them, although the cows enjoy
tation with zinc methionine might be beneficial at this
standing on rubber mats. Deep sand cubicles (for
time, since methionine is a sulphur amino acid and zinc
example 70 mm) also work well and reduce the inci-
promotes healing.
dence of mastitis, although sand may lead to problems
Biotin has been shown to influence the differentia-
with slurry disposal systems. Choosing the correct type
tion of epidermal cells into hoof horn; it boosts the pro-
of sand, which does not compact and consolidate, is
duction of keratin and it stimulates the production of
essential.
intracellular cementing substance (ICS). ICS is a vital
The best cubicles are comfortable cubicles. While
component of non-tubular horn, such as is found in the
design and dimensions may be important, comfort is of
white line, and this is perhaps why biotin supplementa-
even greater significance (see also pp. 40–42).
tion has a major effect on white line disease. Although

1.00

Unsupplemented = 0

0.95

Supplemented = 1

0.90

0.85

Fig. 31.10

Effect of biotin supplementa-

tion on white line lameness in dairy cows.

0.80

No effect was seen until after 130 days of

Proportion of cattle alive

supplementation (Hedges et al., 2001). Re-

0.75

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0

100

200

300

400

500

600

700

Dairy Science Association.

Time (days)

one might expect ruminal synthesis of biotin would

ness, placing particular emphasis on those factors which

meet the requirements of the cow, Da Costa Gomes

might damage the corium, especially in the early lacta-

et al. (1998) showed that with high concentrate diets

tion animal.

producing rumen acidosis, in vitro biotin synthesis

was reduced from 1.5 to 0.3 mg per day. Herds with sig-

Wet hoof: This is softer than dry hoof and therefore the nificant problems associated with horn quality may

sole is more likely to become penetrated or the corium

benefit from biotin supplementation, although atten-

bruised if the feet are damp. Cubicle passages should

tion to dietary management would also be important.

be scraped twice daily and the addition of small quanti-

In a study with 100 first lactation heifers, Midla

ties of slaked lime to the cubicle beds once a week will *et al. (1998) showed that supplementation with 20 mg*

help to dry the feet as well as control mastitis (see p.

biotin/day from calving produced a significant improve-

391).

ment in white line lesions at 100 days of lactation. In a

more extensive split herd intervention study involving

Floor surfaces: These should not be too rough, stony or over 1100 cow lactations in five UK dairy herds, sup-have broken concrete, all of which could damage the

plementation with 20 mg/day biotin significantly halved

corium. On the other hand, very slippery surfaces can

the incidence of lameness caused by white line lesions

lead to leg damage. An excellent demonstration that

(Hedges et al., 2001). Survival analysis demonstrated

cows do not like walking on concrete is shown in Plate

that supplementation needed to be given for 130 days

31.11. A strip of second-hand rubber belting, approxi-

before any difference in the two groups was seen (Fig.

mately 1.5 metres wide, has been laid along the centre

31.10). In addition, only 28 per cent of supplemented

of a concrete track which runs from a dirt yard to the

animals required a repeat treatment in the same digit, *milking parlour at a dairy in California. Although the*

compared with 72 per cent of unsupplemented controls

cows could walk anywhere they wished on the track,

(Blowey et al., 2000c).

note how they all prefer to walk on the rubber belt. In

Hagemeister (1996) showed that animals receiving

the UK, if cows are allowed to amble out to a field at

10 mg biotin daily had significantly fewer sole ulcers

their own speed they will usually choose to do so by

and less heel erosion than unsupplemented controls,

walking on the soft earth of a grass verge, rather than

and Lischer et al. (1996) reported a correlation between on stones (Plate 31.12). They even place their feet in

biotin supplementation and the rate of healing of

exactly the same spot each time, making holes in the

claw lesions. New horn formed more rapidly in those

ground. This preference for a softer surface has led to

cows supplemented with 20 mg biotin/day. A two-year

the development of specific cow tracks. The ground is

Canadian field study of 265 Hereford beef cows with

excavated to 0.3 cm deep and 1.0–1.5 metres wide and *a high prevalence of vertical fissures (sandcracks)*

lined with a permeable geotextile road construction

demonstrated that supplementation with 20 mg biotin/

membrane which prevents sinkage of the track. A

cow per day significantly reduced the prevalence of

drainage pipe runs along the base, surrounded by a

vertical fissures from 29.4 per cent to 14.3 per cent

large aggregate, perhaps having fine stone on the top

($P < 0.05$; Campbell et al., 1996).

(Fig. 31.11). This is covered with a second special tough-

ened membrane, which allows water to drain through

but will not allow mud to rise up through it. Finally a

General management

layer of bark strippings, sometimes known as Cundy

Many aspects of management have already been dis-

peelings, 100 mm (4 inches) deep, is placed on top of the

cussed in the housing and feeding sections. This section

upper membrane to provide a comfortable walking

will cover a few miscellaneous points relating to lame-

surface for the cows. Tractors and other vehicles must

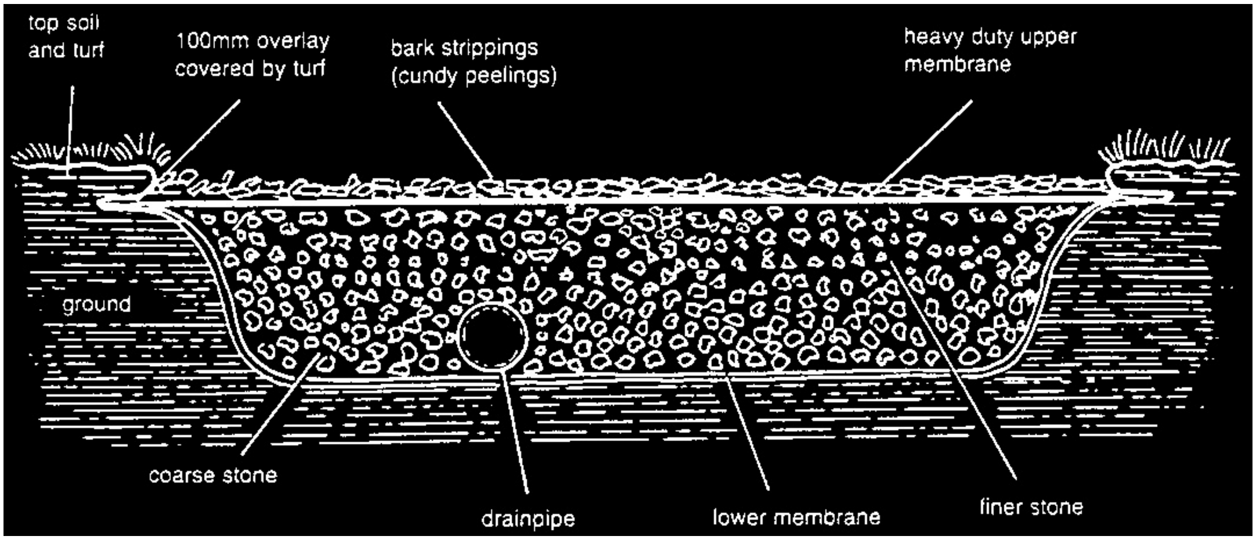

Fig. 31.11

Cross-section of a cow track.

not use the track. Similar tracks may be constructed

Hoof wear: Both inadequate and excessive hoof wear

in gateways, around water troughs and in other

can cause problems. Heifers reared and housed in

areas where the ground gets badly poached. On very

totally bedded areas (straw, shavings or sand) may not

well drained land some farmers have constructed a very

receive sufficient hoof wear. The toes become over-

simple track by scraping away the topsoil and then

grown, the foot rotates caudally and the corium may

unrolling a large round straw bale onto the underlying *become damaged at the sole ulcer site. The provision of stone. Wet bales, too badly soiled for straw yards, could a lightly abrasive concrete feeding area is essential, both be used. The straw needs replacing approximately every to keep the foot in shape and to stimulate sufficient two or three weeks, depending on the weather, but it horn production to produce the thick sole that is makes a good track and is certainly cheaper.*

needed in the postpartum animal. At the other extreme, The influence of floor surface on white line disease is cows or heifers (and especially fresh calvers) that are interesting. It is commonly stated that cows become made to walk long distances on gravel or even concrete lame because of a specific type of stone or gravel in a roads can wear their soles so thin that they are easily track, particularly if sharp flints are present. However, compressed by thumb pressure. This syndrome is beef cattle could probably walk along the same track common in the grazing systems of Australia, New without stones penetrating their feet. This strongly sug- Zealand and Uruguay. Heifers reared on pasture are

gests that it is the weakening of the white line which is
often introduced into the dairy herd immediately after
the critical factor and not the sharpness of the stones.
calving and expected to walk long distances to and from
grazing. This produces maximal wear at a time when
Rough handling: This has also been shown to have an
hoof growth is minimal, and soft soles with subsequent
effect. A survey of farms showed that cows which were
bruising of the fragile postpartum corium leads to an
forcibly rushed along farm tracks by a herdsman, dog
increase in white line disease and toe ulcers (see 'neg-
or tractor had a far higher incidence of lameness than
ative net growth', p. 415). If heifers are exposed to con-
farms where the cows were allowed to walk along at
crete or some other hard surface for a few weeks before
their own speed. This was presumably because in the
calving, this can stimulate an increased thickening of
latter case they chose their own footing, thus avoiding
the sole and the severity of the syndrome is reduced.
bruising to the sole and corium. Similarly, if heifers are
A similar 'soft sole' syndrome is seen in young bulls

introduced into a highly competitive situation where
introduced to work in a dairy herd, particularly if the
they are forced to make many sudden turning move-
bulls are large and do not use the cubicles. The soles of
ments, this both increases hoof wear and forces the wall
their hind feet, especially at the toe, can wear down to
away from the sole, leading to an increase in white line
the corium. Ideally, bulls in cubicle systems should be
defects. When walking, cows should be allowed to move
rested in a straw yard, for example cubicles by day and
at their own pace. Their heads will be down as they look
a straw yard by night, or alternate weeks in cubicles and
at the ground surface in front of them for a safe and soft
straw yards. On a daily basis bulls soon learn which is
footing. If cows are being driven too fast, or if they are
to be their period of lying and compensate for the
too crowded, then their heads will be high, they cannot
cubicles by lying in the straw yards for long periods of
see their footing and increased lameness may result.
time.

Conformation: Conformation affects the incidence of

***Slurry heel** (heel horn erosion, heel necrosis)*

lameness, which is therefore influenced by genetics and

In feet which have been exposed to slurry over a long

breeding. Bulls should be chosen to give a good depth

period of time, the smooth, soft and pliable heel horn

of heel and a good upright angle of the front wall, as in

often becomes black and pitted and in more extreme

Fig. 31.3.

cases totally eroded, especially in the axial area (Plate

31.13). Although perhaps not too serious externally,

Foot trimming: The final management factor that

slurry heel causes important internal changes. Removal

influences the development of lameness is routine foot

of weight bearing at the heel allows the foot to rotate

trimming. If parturition is a major stress period for

backwards, thereby predisposing to sole ulcers. In

the development of coriosis, then feet need to be in

advanced cases the flexor tuberosity no longer has

optimum shape at calving in order to minimize this

adequate support and as a result penetrates the horn *effect. This is achieved by hoof trimming at drying off,*

of the sole. The corium will be pinched as the cow

and at any other time when they are overgrown.

walks and sole ulcers develop.

Deep slurry heel fissures may develop into an under-

run sole, which may be further complicated by a sec-

Footbaths: The use of footbaths is discussed on p. 430.

ondary digital dermatitis. Erosion of the heel also

predisposes to white line defects, and by predisposing

to a caudal rotation of the claw, to sole ulcers.

Other causes of foot lameness

There is no one single cause of heel horn erosion.

As it is almost exclusively a condition of housed cattle,

Hoof disorders:

simple erosion by slurry seems to be the most probable

factor. Others have suggested the involvement of

• Foreign body penetration

specific bacterial infections such as Dichelobacter nodo-

• Slurry heel

sus (Toussaint-Raven, 1985) or Prevotella (Bacteroides)-

• Vertical fissure (sandcracks)

melaninogenicus (Greenough, 1987). Coriosis/laminitis

• Hardship lines and laminitis

may also be involved, leading to poorer quality heel

• Horizontal fissure

horn, which is then more susceptible to the corrosive

• Broken toe

effects of slurry.

• Axial wall fissures

Skin disorders:

Treatment and control

• Interdigital necrobacillosis (foul of the foot or

footrot)

Deep fissures may need to be investigated to eliminate

• Digital dermatitis (hairy warts)

(and correct) an under-run sole, but if the lesion is

• Interdigital skin hyperplasia (corns, growths or

relatively superficial it is best left and treated topically.

tylomas)

Removal of heel horn is commonly contraindicated,

• Mud fever

because to do so must inevitably lead to a caudal rota-

tion of the claw and increase the risk of sole ulcers.

Bone and joint disorders:

Hygiene is the best control measure, maintaining the

• Pedal bone fracture

feet in a clean and dry environment, with regular foot-

• Necrosis of the apex of the pedal bone

baths. Lime, used in cubicles for mastitis control, also

• Pedal arthritis

acts as a disinfectant and drying agent.

Vertical fissures (sandcracks)

Hoof disorders

Vertical fissures occur as a result of damage to a small

area of the periople and underlying coronary band.

Foreign body penetration of the sole

Horn formation is disrupted at that point, although the

Typical foreign bodies are stones (especially sharp

adjacent horn continues to grow. This leaves a gap (the

flints), nails (particularly those with flat heads), frag-

vertical fissure) running down the hoof wall from the

ments of wood, glass or tin and occasionally even the

point of disrupted production (Plate 31.14). In North

sharp root of a cast tooth will penetrate the sole. After
America vertical fissures are commonly seen in both
removal of the foreign body it is essential to provide
beef cattle and older dairy cows kept in sand lots where
drainage by opening the sole at the point of entry and
the combination of age, sand, wind and dry weather
removing all under-run horn.
removes the protective periople. Vertical fissures can

also be a result of a digital dermatitis infection on the
the interdigital space. White line lesions running
coronary band. A two-year Canadian field study of 265
obliquely along the axial wall are often referred to as
Hereford beef cows with a 37 per cent prevalence of
axial wall fissures (Plate 31.15). Recently there has been
sandcracks demonstrated that supplementation with
an apparent increase in incidence (Vermunt, 1998). The
10 mg/day of biotin significantly reduced the incidence
cause is unknown, but wet conditions underfoot have
of sandcracks from 29.4 per cent to 14.3 per cent
been suggested. Due to their position in the interdigi-

(Campbell et al., 1996).

tal space they are quite difficult to pare and lesions

For treatment, the full length of the fissure should be

which damage the coronary band can lead to perma-

opened using the curved tip of the hoof knife. Even a

nent vertical fissures. Digital dermatitis lesions affect-

small abscess can cause intense lameness. If the fissure

ing the coronary band in the interdigital space may be

is large, a block should be applied to the sound claw.

a further factor.

Hardship lines

Skin disorders

Any disruption in horn formation may leave a groove,

sometimes referred to as a 'hardship groove' (Gree-

Interdigital necrobacillosis

nough et al. , 1997), encircling the hoof wall. These are (foul of the foot, foot-rot)

the result of coriosis/laminitis. Inflammation of the

laminae is said to lead to massive pressure under the

This is a bacterial infection of the skin of the interdigi-

hoof wall, causing the wall to push forward and the toe

tal cleft. Two organisms are primarily involved, namely *to lift. The eventual effect is a concave front wall with*

Prevotella (Bacteroides) melaninogenicus and Fusobac-numerous hardship lines.

terium necrophorum. Cultural studies have suggested

that P. melaninogenicus should be further subdivided

into Porphyromonas asaccharolytica and Prevotella

Horizontal fissures (sandcracks)

species (Berg & Weaver, 1994). Dichelobacter nodosus

Animals severely ill, for example with mastitis, metritis

may also be involved. F. necrophorum is an obligate

or any toxic condition, may undergo a total cessation

anerobic Gram-negative bacterium found in the intes-

of horn formation. When horn production resumes,

tinal tract of both cattle and sheep and it is widespread

instead of a hardship groove, there may be a horizontal

in the environment, surviving for up to ten months. The

fissure encircling the hoof wall. Initially this may cause

A and AB biotypes produce a potent exotoxin which

no problem, but as the defect moves distally towards

causes a suppurative necrosis and depresses phagocy-

the toe it loses its support and attachment at the heel.

tosis, and a degree of synergism may exist between

The protruding 'thimble' of horn is then able to rotate

B. melaninogenicus and F. necrophorum. Injury to the on the underlying corium, causing pinching, pain and

interdigital skin may be required to allow entry of infec-

lameness. Both claws of all four feet may be affected.

tion. This is usually due to stones, stubble, kale stems,

The date of the illness can be calculated by measuring

hardened dung in the interdigital area, sticks, very dry

the distance from the coronary band to the fissure and

pasture, rough flooring, etc. Damage will be easier when

dividing this by the rate of horn growth, namely 5 mm

the skin is soft due to continued wetting. In some

per month.

instances the damage may be caused by penetration

For treatment, the loose 'thimble' of horn is removed.

of spirochaete organisms. Reservoirs of infection may

If the corium is extensively exposed on one claw, a

exist in wet, dirty areas such as the gateways to fields

block should be applied to the other claw if it is sound.

and around water and feed troughs. It is also possible

However, not all horizontal fissures lead to lameness.

that mild digital dermatitis or interdigital dermatitis

Some simply grow to the toe and are shed naturally. It

might be the cause of the initial damage.

is only necessary to trim the foot if the cow is lame. A

The condition has a worldwide distribution in both

cow with one long claw and one short, due to the hori-

dairy and beef cattle. Usually only one or a few animals

zontal fissure fragment having been shed from one claw

are affected at one time. However, the disease appears

only, is sometimes referred to as having a 'broken toe'.

to be contagious with the incidence increasing in wet

humid weather and interdigital skin damage. Epizootics

can arise when cattle are moved to a new environment

Axial wall fissures

or mixed together. The most probable source of infec-

The white line junction runs along the abaxial wall from

tion is discharge from the feet of infected animals. The

the heel to the toe, caudally along the axial wall at sole

same animal can be affected repeatedly and as suscep-

level and then passes obliquely in a proximal caudal *tibility only changes slightly with age, acquired immu-*

direction along the axial wall to the coronary band in

nity to the bacteria appears to be poor.

Clinical signs

physical damage to the interdigital cleft. Frosted

ground can also produce damage.

Typically 'foul' is seen as a sudden onset lameness, more

Disinfectant footbaths (formalin, copper sulphate,

commonly in the hind foot, and it is characterized by

etc.) provide excellent control and are discussed on p.

bilateral swelling above the coronary band of both

432. Antibiotic footbaths have been used in the control

claws, often with the digits forced apart. Pyrexia is

of superfoul where digital dermatitis may be involved.

common. Initial erythema of the interdigital skin pro-

gresses to a fissure and subsequent slough of the epi-

dermis to expose the underlying necrotic dermis (Plate

Digital dermatitis

31.16). Unless treated, lesions may progress to an infec-

This is a bacterial skin infection that primarily affects *tion of the navicular bursa, the flexor tendon sheath or*

the epidermis. First reported in Italy (Cheli & Mortel-

even the distal interphalangeal joint. However, these

laro, 1974), digital dermatitis now has a worldwide

complications are more commonly associated with the

distribution. Figures of frequency of occurrence vary

virulent condition known as 'superfoul'.

enormously depending on whether the incidence is

recorded as a cause of lameness or whether prevalence

Treatment

of lesions is recorded. Many cows show low-grade

lesions. For example, Laven (1999) found a lesion

A wide range of parenteral antibiotics including

prevalence of 41 per cent in 1810 hind feet examined,

penicillin, oxytetracycline, sulphonamides, tylosin, tilmi-

although only a few of the cows were lame. Within the

cosin, ceftiofur and cefquinome are all effective. The

UK, digital dermatitis now represents approximately 30

period of treatment required will vary with the severity

per cent of all cases of lameness, which is probably why

of the initial lesion. The foot should always be lifted and *the overall incidence of lameness in cattle has not*

examined to remove necrotic tissue and any predispos-

decreased since digital dermatitis was first reported in

ing foreign body and a topical antibiotic applied. Local

1987 (Blowey & Sharp, 1988).

treatment must improve the rate of healing and reduce

the spread of infection into the environment.

Aetiology

Superfoul

Histological studies were first to implicate spirochaetes

(Blowey et al., 1992; Read et al., 1992). These had a This is a peracute form of interdigital necrobacillo-predilection for keratinized cells and produced a toxin

sis with a poor response to treatment unless aggressive

which is keratolytic. A possible association between

therapy is instigated in the very early stages (David,

Borrelia burgdorferi and other Treponemes has

1993). Cultural examinations have indicated that the

been suggested. Digital dermatitis-infected cows had a

same organisms are present, although most cases are

higher seropositivity to B. burgdorferi strain B31 and seen in herds concurrently infected with digital der-Treponemes 1-9185MED and 2-1498 than control cows

matitis. An 'invasive spirochaete', similar to both digital

(Demirkan et al., 1999). Other workers have suggested

dermatitis and the spirochaete identified in peracute

the involvement of Dichelobacter nodosus and Campy-foot-rot in sheep, has been seen in lesions of superfoul.

lobacter faecalis

The main difference between foul and superfoul is the

While spirochaetes can often be found in large

speed of onset and the severity of the lesions. Necrosis

numbers at the junction of viable and necrotic tissue

of the interdigital skin may be seen within 12 hours, with

layers, they are often difficult to culture. However, suc-

deep necrotic fissures into the dermis within 24 hours.

cessful culture techniques have been reported. Two

Early and aggressive therapy is therefore essential. The

different spirochaetes have now been demonstrated.

treatments used are similar to conventional foul, but at

One is a long, filamentous organism 12 mm long and 3

a higher dose and for a longer period. Some benefit has

mm wide and the other a short spirochaete 5 to 6 mm

been reported from the use of local anaerobic therapy

long and 0.1 mm wide. They are also different on enzy-

such as clindamycin, spiramycin and metronidazole.

matic analysis (Walker et al., 1995). The most probable cause is an organism with characteristics most consis-Prevention and control: Environmental hygiene and

tent with the genus Treponema. Potential isolates sug-footbathing are the main control measures. If outbreaks

gested are T. phagedenis, T. vincentii and T. denticola.

occur, passages should be scraped with increased fre-

quency, more bedding can be used, and if cattle are

Epidemiology

outside, they should be moved to a different paddock.

Attention should be given to gateways, areas around

There is considerable confusion in the literature

water troughs and other gathering points to minimize

between incidence of disease seen as lameness and

prevalence of lesions, with few studies having examined

digital dermatitis (PDD) or 'hairy warts', although they

large numbers of feet at a single point in time. Laven

are now becoming increasingly common in the UK.

(1999) reported a 41 per cent lesion prevalence but did

Although the heel area is the most common site, *not relate this to lameness incidence. Hedges et al. lesions of digital dermatitis may also be seen in the (2000), in a study of over 1100 cow years in five UK interdigital space, on the sole following a sole ulcer, dairy herds, found that digital dermatitis ranked white line disease or some other lesion exposing the approximately equal to sole ulcers and white line corium, adjacent to the accessory digits or at the ante- disease, and accounted for around 20 per cent of all rior aspect of the interdigital space adjacent to the cases of clinical lameness examined. Lesions are most coronary band. Lesions at this point are particularly commonly seen in housed cattle, especially dairy cows, significant because they can damage the germinal layers but heifers and beef animals can also be affected. of the hoof wall to produce a vertical fissure. In chronic Lesions in hind feet are more common than in front feet cases granulation tissue may protrude from the fissure and there would appear to be relatively little immunity, and because the corium is inflamed exostoses develop because affected cattle are more likely to have lesions* *on the anterior wall of the pedal bone. Vertical fissures*

on both hind feet (Laven, 1999) and reinfections occur resulting from anterior digital dermatitis are currently

in the same cows year on year, suggesting recrudes-

a common indication for digit amputation.

cence of latent infections. Environmental hygiene is the

main factor influencing disease, with the most severe

Treatment

outbreaks occurring in housed cattle in winter, although

Most lesions regress following cleaning and topical

the increase in lesions and lameness seen in early lac-

application of antibiotics, although repeated treatments

tation (Laven, 1999) could also be a reflection of peri-

may be necessary. Lameness resolves but it is likely that

parturient immune suppression. The highest incidence

lesions persist to recrudesce at a later date. A wide

of disease is seen in the early lactation period and this

range of topical antibiotics have been used including

is associated with animals showing a high prevalence of

lincomycin, combined lincomycin and spectinomycin,

lesions prepartum. Disease incidence is higher in lac-

oxytetracycline, erythromycin, tylosin and tiamulin.

tating than dry cows. Suggested causes include lactating

Concurrent parenteral therapy is indicated for anterior

cows spending longer standing (for milking, moving and

lesions to reduce the risk of vertical fissure develop-

feeding), higher bacterial levels in slurry from higher

ment. Frequency of application varies with lesion sever-

concentrate diets, faeces are not as dry and stocking

ity, but ideally the lesion should be cleaned and treated

density is often higher.

for at least two consecutive days. Severe lesions should

be bandaged with topical antibiotics for 3–4 days.

Treatment of PDD (hairy warts) is more difficult

Clinical signs

because the organism is protected by 10–20 mm of kera-

tinized epidermis. Ideally these lesions should be ampu-

The earliest lesions of digital dermatitis are seen as a

tated at lower epidermal level, under local anaesthesia,

dry, painless, grey encrustation of hyperkeratotic mate-

and an antibiotic dressing applied for three to five days,

rial, often lining the caudal edge of the interdigital *although an antibiotic dressing alone may be sufficient.*

pouch. The pouch is most probably the major reservoir

Single topical treatments and footbaths are not effective

of infection in carrier animals, although similar encrus-

against PDD. Antibiotic and antiseptic footbaths are an

tations can be seen along the junction of the heel horn

important aspect of both treatment and control.

and skin. More advanced lesions, and those sufficiently

painful to cause lameness, are typically seen as a moist,

Prevention and control

light greyish-brown area of exudate, 10–20 mm in diam-

eter, often with matted hairs and encircling the inter-

Environmental hygiene is the most important control

digital cleft (Plate 31.13). Cleaning the lesions reveals a

measure and factors which produce a cleaner and/or

red, raw area of epidermitis, very painful when touched

drier foot environment will lower disease incidence.

and having a characteristic fetid odour and a granu-

Cubicle and feed passages should be scraped at least

lar 'strawberry' appearance. Advanced lesions create

twice daily and accumulations of stale slurry such as

superficial epidermal erosions and irradiate across
may be found in cross passages and around water
the heel bulbs, but ulceration into the dermis is rare:
troughs should be avoided. Feet should be kept as
most lesions retain an epidermal covering. Longstand-
dry as possible by good drainage, ample bedding and
ing, chronic lesions have a proliferative appearance,
the use of lime in cubicle beds (which also helps in
with marked epidermal hypertrophy and hyperplasia
mastitis control). Footbaths are an important control
(Plate 31.17). These lesions are more prevalent in North
measure, although antibiotics applied as a foot spray on
America where they are referred to as papillomatous
a whole-herd basis have also been effective.

Interdigital dermatitis (IDD)

grade digital dermatitis lesions are so common that
it is always worth applying a topical antibiotic. Larger
Considerable confusion exists in the literature over
lesions require surgical amputation, although many
whether IDD is a separate entity or whether it is a com-

recur. Regular footbathing through formalin is also said

bination of a chronic form of digital dermatitis confused

to resolve many lesions.

with stages of slurry heel. Many of the lesions attrib-

uted to IDD contain the spirochaete of digital der-

matitis. It is not generally considered to be a cause of

Mud fever

lameness, but large numbers of cattle are said to be

Mud fever occurs following exposure to cold, wet

affected and this predisposes to other lesions such as

and muddy conditions. The lower leg becomes slightly

digital dermatitis, foul, slurry heel and interdigital

swollen, with hard, dry and flaking skin. There may be

hyperplasia. Dichelobacter nodosus is said to be a

hair loss and even bleeding if the skin cracks.

common organism involved, but others dispute whether

For treatment, the legs should be throughly washed

this organism ever causes problems in the feet of cattle.

and dried followed by application of a greasy antisep-

tic ointment or a teat spray which contains a high level

Clinical signs

of emollient. As the organism Dermatophilus may be

involved, three days of injectable antibiotic (penicillin)

Many cases are mild, leading to irritation and hyper-

may also help (see p. 886; Blowey & Weaver, 2003).

aemia of the interdigital skin, with lesions spreading

onto the heel bulb. Fissures and necrosis of heel horn

can result, with coronary band lesions said to disrupt

Bone and joint disorders

hoof wall formation and lead to vertical fissures.

The latter is also characteristic of anterior digital

Fracture of the pedal bone

dermatitis

Bulling activity, with the mounting cow falling back

heavily onto hard or rough concrete, is the most

Control

common cause of a fractured pedal bone. Bones weak-

Environmental hygiene and regular footbathing with

ened by age, fluorine poisoning or a foreign body pen-

copper sulphate or formalin are said to be effective in

etrating the sole of the hoof may be at greater risk of

control.

fracture. Typically it is the inner claw of the front foot

that is involved and by adopting a cross-legged stance

the cow transfers her weight onto the sound lateral

Interdigital skin hyperplasia *(see p. 182)*

claw. However, the stance alone is not sufficient to diag-

Also called corns, tylomas, fibromas and just 'growths',

nose fracture of the pedal bone. Cows with ulcers in

interdigital skin hyperplasia is an overgrowth of the

both inner claws will adopt the same position. Most

natural skin fold adjacent to the axial hoof wall. There

animals heal well if a block is applied to the sound claw.

is a fold of interdigital skin adjacent to both the medial

and lateral claw, and the hyperplasia may develop from

Apical necrosis of the pedal bone

either side. It is an overgrowth of skin with gross hyper-

trophy of the epidermis. The term 'fibroma' is therefore

In a few cows, what initially appears to be a standard

technically incorrect. The lesion is hereditary in certain

white line abscess at the toe sometimes fails to heal,

heavier breeds of cows, especially beef breeds. In other

even though it may have been treated thoroughly. At *cases it is secondary to chronic irritation of the inter-*

the second examination there will probably be a char-

digital skin, for example due to low-grade foul, digital

acteristic foul odour and even with further extensive

dermatitis or simply impaction with dirt. Cows walking

removal of under-run tissues the toe fails to heal (Plate

over rough surfaces, leading to excessive splaying of

31.18). In such cases the apex of the pedal bone has

the claws, may show an increased incidence. Lameness

become infected (osteomyelitis). The negative net horn

occurs either when the lesion reaches such a size that it

growth (p. 415) which occurs in the periparturient

is compressed by the claws during locomotion or when

heifer, leading to erosion of toe horn, can be an exac-

it becomes secondarily infected, for example by digital

erbating factor, especially if housing coincides with par-

dermatitis or foul.

turition. A similar condition is seen in weaned beef

Mild cases can be treated by removing excess horn

calves that continually run around the pen when intro-

from the axial wall and the axial surface of the sole.

duced into feed lots.

Many lesions regress spontaneously when they are no

Treatment must involve removal of all necrotic bone.

longer traumatized during locomotion, although low-

Some clinicians report success with aggressive debride-

ment of the bone, but this has not been this author’s

generally results in a good response. There is an

experience. Provided the coronary band remains intact,

additional requirement to redress the lesion regu-

removal of the necrotic toe and the adjacent wall and

larly, however, and additional weightbearing on the

sole with an embryotomy wire may result in full reso-

remaining digit may lead to early culling. If ampu-

lution. Ideally, a radiograph is needed to identify the

tation can be performed at drying off, then a single

extent of the necrosis, and as many pedal bones are

dressing change after two to three days may be suf-

already severely eroded (Plate 31.19), total amputation

ficient, with the second dressing fully removed three

of the digit may be the best option (see p. 1119).

to four days later. Most cases heal remarkably well

(see also p. 1119).

Deep pedal infections

General treatment and control

Severe or neglected cases of sole ulcers, white line

of foot lameness

disease, interdigital necrobacillosis or foreign body

penetration can lead to infection tracking into deeper

Footbaths

tissues. Complications must be suspected when severe

Footbaths are an excellent preventive measure for

lameness follows treatment of an apparently standard

lameness and cows should be walked through once a

lesion,when swelling appears above the coronary band of

week during the winter housing period. Solutions of

the affected digit or when pus can be expressed from a

5–10 per cent formalin or 2.5 per cent copper sulphate

sinus when massaging the digit. In any of these instances

or zinc sulphate have been used, as have a variety of

it is the author's opinion that immediate and aggressive

other disinfectants. The main objective of a footbath *parenteral therapy should be instigated, for example oxy-*

is both to clean and disinfect the foot and in so doing

tetracycline (2 g twice daily), tylosin or penicillin. If

it should help to reduce the incidence of conditions

swelling of the coronary band was the only apparent

such as:

lesion, this may be sufficient to effect resolution.

Deep infections may produce a retro-articular

• Interdigital necrobacillosis

abscess (namely in the heel caudal to the deep flexor

• Slurry heel and heel erosion

tendon),

an infection of the navicular bursa,

• Interdigital skin hyperplasia ('tylomas' or 'corns')

osteomyelitis of the navicular (distal sessamoid) bone

• Digital dermatitis

or a purulent coronopedal arthritis. A range of treat-

Formalin also has a drying action on the foot.

ment options is available, all of which involve aggres-

However, it is unpleasant to handle and its use is not

sive antibiotic cover, and most will require a block

permitted in some countries. Similarly copper sulphate
applied to the sound claw, thus minimizing weightbear-
baths may not be permitted by some environmental
ing on the affected claw (p. 432). The option chosen
authorities because of the risk of pollution. Often two
will depend on the severity of the lameness and the
baths are used, the first containing water to wash and
clinician's preference, and includes the following:
clean the feet. There is then a raised concrete strip to
• Radical fenestration of the sole or wall to provide
drain off excess water before the cows walk into the
drainage, followed by regular flushing of the lesion
second bath containing the active chemical, as shown
to prevent overgrowth of granulation tissue which
in Fig. 31.12. The liquid in the bath needs to be only
would impede drainage (Blowey, 1990).
80–100 mm deep, as only the claws need to be
• Insertion of a drainage tube, the upper end of which
immersed. Overfilling, particularly with formalin, can
is strapped to the hock to allow ease of flushing at
lead to damaged skin on both feet and teats.

milking (Plate 31.20). The lower end is closed. A

For best effects cows should have their heels cleaned

practical method of siting this tube is to use a trocar

by a water spray as they enter the milking parlour.

and cannula to follow the sinus tract into the foot

Excess water then drains off during milking, after which

and then exit above the coronary band.

the cows should exit through a footbath and into a clean

• Permanent arthrodesis can be created by drilling

environment, with the whole herd being bathed on the

through the pedal joint and curettage of the articu-

same day to avoid cross-contamination. If done care-

lar joint surfaces.

fully, a single passage through an antibiotic footbath

• A surgical approach, opening the joint from the

will dramatically reduce the incidence of lameness due

heel, is also available.

to digital dermatitis in as little as 24 hours. Unfortu-

• Digit amputation is relatively simple. It can be per-

nately it does not eliminate infection from a herd.

formed in the standing animal under regional intra-

A range of antibiotics have been used to treat and

venous anaesthesia and provided that there is no

control digital dermatitis, and at varying concentrations.

major ascending infection of the flexor tendon it

In most countries none are licensed for this use. The

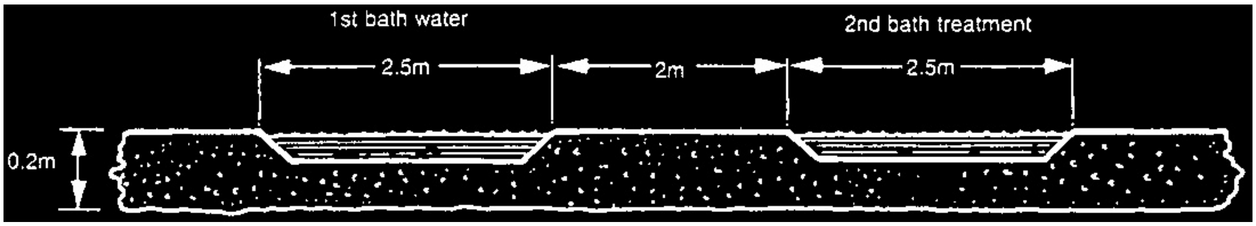

Fig. 31.12

Two footbaths in series.

following are the most common: oxytetracyclines at

disinfectants, a beta-ionine terpene compound and a

4–6 g/litre,

lincomycin at 1.0 g/litre,

combined

triplex of copper, a peroxy compound and a cationic

lincomycin/spectinomycin at 33 g lincomycin plus 66 g

agent. The latter was found to be at least as effective as

spectinomycin in 150 litres, erythromycin at 0.6 g/litre,

oxytetracycline.

tiamulin at 0.5 g/litre and tylosin at 1.3 g/litre. The

dosage and frequency of bathing required depends on

Nursing, dressings and footblocks

the severity of clinical signs, with a single or perhaps

two passages through a fresh solution once every four

Nursing

weeks originally being the most common recommen-

Lame cows obviously find walking difficult. They are

dation in the UK. (This was not effective on the hairy

much less able to compete with the rest of the herd,

warts seen in North America, however.) Although this

especially if they are at the lower end of the social

initially appeared reasonably effective, by the late 1990s

dominance scale, which is commonly the case with lame

all antibiotics appeared to be losing their effectiveness

heifers. In addition, they find it difficult to manoeuvre

and revised concepts of footbathing were considered

in and out of the cubicles. Cubicles are not easy to use

(Blowey, 2000). At that stage footbaths were instigated

at the best of times and if a cow is not fully mobile

only when lameness appeared and usually when a *cubicles are even more difficult to negotiate. This*

small but significant proportion of the herd was lame.

results either in lame cows spending longer time stand-

Clearly at this stage lesions have progressed to quite an

ing, which exacerbates the digit lesion, or, when down,

advanced stage and a single treatment is likely to be less

they spend a long time lying and do not feed sufficiently,

effective.

resulting in marked weight loss. Ideally lame cows

If footbaths were instigated at an earlier stage, before

should be transferred into a straw yard, where it is

lesions appeared and especially if dry cows were treated

easier for them to lie down and get up and where there

on a preventive basis prior to calving, then it was likely

is less competition for food. Many herdsmen have

to be more effective. A system of continual daily foot-

commented that moving lame cows from cubicles into

bathings in 2.5–5 per cent formalin for periods of two

straw yards results in an increase in yield in as little

to three weeks (Brizi, 1993; Blowey, 2000) was effective

as 24 hours, especially in heifers.

in reducing lesion severity, although even this does not totally eliminate infection from a herd and the treatment has to be repeated after intervals of three to four

Foot dressings

weeks. Some herds now use footbaths on a continual

Opinions vary over the need to apply a bandage and daily basis. Although formalin and other disinfectants dressing to an exposed corium, for example following do not penetrate the epidermis as well as antibiotic the trimming of sole ulcers or white line lesions with solutions, regular use eventually leads to drying and under-run sole. There appears to be a minimal risk of sloughing of superficial keratinized tissue. The black infection from the environment penetrating the corium, debris of hairy warts can be peeled off after two weeks even if cows with extensively under-run soles are of treatment, although in a proportion of cases characallowed to walk out into the slurry, and it is surprising teristic granular areas of active dermatitis may still be how quickly the exposed corium becomes covered by a visible beneath. Individual severely affected cows can *layer of new horn. On the other hand, there are several*

be stood in formalin for 20–30 minutes and this also

potential disadvantages in applying a dressing, any of

results in resolution of lesions. The system has also been

which may retard healing. These include the following:

effective against combined outbreaks of foul and digital

dermatitis.

• Unless changed almost daily, the dressing will

A variety of other footbath chemicals have been used

absorb infection from the environment and impede

including acidified ionized copper sulphate, hydrogen

drainage. Impeded drainage may allow infection to

peroxide/peroxyacetic acid or quaternary ammonium

spread, producing further under-run horn.

• Dressings prevent exposure to air and air often

improved by forcing the claws apart with a small roll of

promotes healing.

paper towel. With the PVC shoe the glue is mixed in

• The presence of a bulky dressing on the sole means

the shoe until it forms a paste. When the paste is just *that the affected sole becomes weightbearing. This*

starting to set the shoe should be pushed as far back

could make sole ulcers worse and cannot be bene-

towards the heel as possible. It is very important that

ficial in the production of new horn.

the shoe or block supports the heel, otherwise the cow

• Astringents, sometimes used to reduce granulation

rotates backwards onto the sound claw, leading to dis-

tissue from a sole ulcer, may damage the corium

comfort and very rapid wearing of the block. Although

and hence discourage the formation of the new

some authors recommend removing blocks after two or

horn, which is so badly needed to cover the sole.

three weeks to retrim the sound claw, most clinicians

consider this unnecessary. On average, PVC shoes have

Few clinicians now use dressings on uncomplicated

been shown to remain in place for over two months,

sole ulcers or white line abscesses and most consider

allowing ample time for the new sole to reform (Blowey

that this results in improved healing. Dressings are

et al., 1999). The PVC shoes can easily be removed by *needed following amputation of a digit, amputation of*

clipping around their outer wall with hoof clippers.

large interdigital skin hyperplasia lesions, treatment of

extensive digital dermatitis and occasionally to control

haemorrhage.

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Footblocks

*Arkins, S. (1981) Lameness in dairy cows. Parts I and II. Irish The use of a block applied to the sound claw is an excel-Veterinary Journal, **35**, 135–40; 163–70.*

lent practice as it both promotes healing and con-

Bell, E.M. & Miller, A.M. (1977) Lameness in cattle. Interim siderably improves the welfare of the cow. A variety of

report, Edinburgh School of Agriculture.

devices are available, for example:

Berg, J.N. & Weaver, A.D. (1994) Bacterial aetiology of

diseases in the foot rot complex: recent research and

• Tie-on shoes and boots

nomenclature changes. In Proceedings of the International

• Nail-on blocks

Symposium on Disorders of the Ruminant Digit, Banff,

• Blocks and shoes which are glued on

Canada, pp. 51–7.

Blowey, R.W. (1990) A simple treatment of deep foot infec-

Tie-on shoes are the least popular, because they are

tions in cattle. Veterinary Record, ***127****, 515.*

difficult to fix and by encasing the whole foot keep it

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damp and can retard healing. They also do not reduce

An Illustrated Guide. Old Pond Publishing, Ipswich.

weightbearing on the affected digit as effectively as

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Record, ***146****, 10.*

Nail-on blocks are used successfully in skilled hands,

Blowey, R., Girdler, C. & Thomas, C. (1999) Persistence of although the sole of the claw to be blocked needs to be

foot blocks used in the treatment of lame cows. Veterinary flat. They are cheap and fast to apply, but they do not

Record, ***14****, 642–3.*

remain in situ for as long as the glue-on blocks: they Blowey, R.W., Hedges, V.J., Green, L.E. & Packington, A.J.

(2000c) The effect of biotin supplementation on the treat-

may move slightly and occasionally create sole ulcers

ment of white line lesions in dairy cows. In Proceedings of under the rear edge of the block. The nail holes must

the 11th International Symposium on Disorders of the Rumi-

also weaken the sound claw.

nant Digit, Parma, Italy, September 2000.

Wooden blocks, rubber blocks and PVC shoes, all of

Blowey, R.W., Ossent, P., Watson, C.L., Hedges, V.J.,

which can be glued onto the sound hoof, are the most

Green, L.E. & Packington, A.J. (2000a) Possible distinction popular products. The PVC shoe (Plates 31.7 and 31.20)

between sole ulcers and heel ulcers as a cause of bovine

gives the best support because it is glued to both the

lameness. Veterinary Record, ***147****, 110–12.*

wall and the sole, and weightbearing is therefore trans-

Blowey, R.W., Phipps, R., Jones,A.K. & Barringer,A.J. (2000b) ferred to the wall, which is the correct weightbearing

A comparison of the effects of high fibre and high starch

structure. The glue also sets more rapidly, thus facilitat-

diets on hoof lesion score in multiparous dairy cows. In

ing ease of application, especially in colder climates.

Proceedings of the 11th International Symposium on

Disorders of the Ruminant Digit, Parma, Italy, September However, on cows with very large feet it may not be

2000.

possible to push the shoe sufficiently far back towards

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cattle. Veterinary Record, ***122***, *505–8.*

discomfort.

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scraped totally clean and dry with a hoof knife, avoid-

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ing even finger contact. Access to the inner wall can be

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Chapter 32

Lameness Above the Foot

A.D. Weaver

Introduction

Diseases of skin and subcutis

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Nerve paralyses

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Tarsal cellulitis

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Introduction

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Carpal bursitis

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Suprascapular paralysis

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Downer cow syndrome

439

Introduction

Fractures

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Introduction

441

Lameness above the foot accounts for only 5–15 per

First aid

442

cent of dairy cow lameness, and perhaps twice as great

Fracture repair

442

a proportion in beef cattle, for which data are lacking.

Long bone fractures: external fixation

442

Economic conditions in the UK and elsewhere in

Long bone fractures: internal fixation

444

Western Europe have led to an increase in the size of

Introduction

444

the average dairy herd (see p. 23), but the labour force

Humeral fractures

444

Femoral fractures

444

has been reduced. Additionally, only a minority of

Tibial fractures

444

farmers have been financially secure enough to improve

Growth plate and other injuries

444

older dairy units, or to replace them with new accom-

Vertebral fractures

445

modation. A personal survey of dairy cattle housing

Pelvic fractures

446

(Weaver, 1997) revealed their construction dates to

Dislocations and subluxations

447

be 1955 to 1994 (n = 49) mean 1976, i.e. over 20 years Hip joint

447

old. Seven units had undergone structural improve-

Sacroiliac luxation and subluxation

448

ments 5 to 28 years (mean 19 years) later. In the period

Stifle joint: femoropatellar

448

1997 to 2000 two units were completely rebuilt, while

Stifle joint: femorotibial

449

six stopped operating as dairy farms. The result has

Fetlock joint: metacarpophalangeal and

been an apparent increase in both minor and more

metatarsophalangeal

450

Muscle and tendon injuries

451

severe injuries in dairy cows. In the worst scenario a

Introduction

451

routine (herd fertility) visit to a dairy unit can reveal

Specific muscles

451

two downer cows, both needing urgent nursing care (see

Contracted flexor tendons

451

p. 440), while the labour – two or three experienced

Traumatic flexor tendon injuries

452

persons – is not always available immediately to move

Joint diseases

453

such cows to straw-bedded boxes.

Osteochondrosis

453

Non-digital lameness problems due to poor accom-

Hip dysplasia

453

modation arise from inadequate size and quality of

Degenerative arthritis

454

cubicles, false economy of bedding requirements, over-

Infectious (septic) arthritis

455

crowding of cubicles and feeding areas, inappropriate

Introduction

455

mixing of first lactation heifers with mature cattle

Septic arthritis: joint ill in neonate

455

Septic arthritis: older cattle

457

(leading to bullying, slipping and trampling of younger

Miscellaneous neuromuscular diseases

458

stock), and an increasing tendency to push cattle

Spastic paresis

458

around rather than permit them to move at their own

Spastic syndrome

459

speed.

The results, discussed elsewhere in this chapter,

the forward phase of the stride shortened. After one

include an increased incidence of skin and subcuta-

week muscular atrophy causes increased prominence of *neous problems such as tarsal cellulitis (p. 460), carpal*

the scapular spine ('sweeney').

swelling (p. 460), traumatic tendon injuries (p. 451),

pelvic damage (p. 446) and hip dislocation following

Treatment

falls (p. 447). Not one of these conditions is new.

However, as housing systems in the present economic

Treatment is purely palliative. Vitamin B complex may

climate fail to satisfy two of the five freedoms – freedom

be given systemically. The prognosis is usually good.

from thermal and physical discomfort, freedom from

fear and stress – there is a renewed obligation to rec-

Brachial plexus injuries

ognize the deficiencies in specific dairy units and to

advise on both economic and welfare grounds, the need

Aetiology

for radical improvements. The introduction of herd

Trauma, as from sudden caudal and ventral displace-

health assurance schemes (p. 52) and increased welfare

ment of the shoulder and entire forelimb, together with

checks on many farms means that housing conditions *abduction can lead to separation of any group of the*

for dairy herds are likely steadily to improve.

nerve roots C6 to T2. The nerves mainly affected are

Economic conditions render many of the treatment

the radial, median and ulnar. Occasionally, the nerves

and management modalities in this chapter hopelessly

are damaged by penetrating injury in the axilla with

non-economic except in valuable predigree stock. It is

extensive additional damage to the vasculature. More

therefore all the more important that early and accu-

frequently, the plexus is injured during traction in dys-

rate diagnosis (e.g. septic arthritis in neonate, p. 455,

tokia and severe abduction of the forelimb.

tibial fracture, p. 444) is sought and the options are dis-

cussed fully with the responsible person on the farm.

Pathology

Nerve paralyses

The avulsion close to the spinal cord results in a com-

plete loss of motor supply to the forelimb. Occasionally,

Introduction

the cranial segments of the network (supplying the *suprascapular and axillary nerves) are spared.*

Nerve paralyses of the forelimb include the suprasca-

pular, brachial plexus and radial. The main hindlimb

involvement is with the femoral, obturator, tibial, per-

Clinical signs and diagnosis

oneal and sciatic. The usual common aetiological com-

The forelimb is non-weightbearing and maintained in

ponent is trauma. The typical age of affected individuals

flaccid extension, with a tendency for the digits to be

varies from neonate to mature cow. The treatment in all

dragged. Sensation is absent from the level of the elbow

forms involves careful nursing and supportive care (e.g.

distally. Muscular atrophy is evident after seven days.

oral fluids), and management of the primary lesion (e.g.

Differential diagnosis includes radial paralysis

fracture). Sometimes multiple nerve injuries occur

(dropped elbow, more localized loss of skin sensation)

as in the downer cow syndrome, which is considered

and humeral shaft fracture with or without radial nerve

separately (p. 439).

injury (see p. 444), and forelimb dislocation.

Suprascapular paralysis

Treatment and prevention

Aetiology and pathology

Since brachial plexus avulsion has a very poor prog-

The suprascapular nerve originates from cervical 6 and

nosis, treatment is not usually justified. In calves with

7 roots. It may be involved in brachial plexus injuries

partial avulsion, anti-inflammatory drugs and limb

(see below). The nerve supplies the supraspinatus and

support are suggested. Affected cattle should be con-

infraspinatus muscles. It has no sensory component. It

fined to a well-bedded stall and care should be taken

is occasionally injured by blunt trauma in calves butted

to avoid the development of decubital damage to the

by others at mangers and troughs when the vertical bar

analgesic lower limb.

barrier bruises the scapular region. Associated injuries

can include fractures of the scapular neck or acromium.

Radial paralysis

Clinical signs and diagnosis

Aetiology and pathogenesis

Suprascapular paralysis causes few clinical signs ini-

The nerve (roots C7–T1) is damaged in its distal portion

tially. The shoulder joint may be slightly abducted and

secondarily to humeral shaft fractures, which tend to be

Cattle maintained in lateral recumbency under general

anaesthesia should have soft supporting surfaces and

the down forelimb should be extended forwards to

reduce the pressure on the vasculature to the lower

parts of the limb. Also, the upper foreleg should not be

roped tightly down against the table, whereby it would

increase pressure on the lower leg.

Femoral paralysis

Aetiology and pathology

The femoral nerve (L4–6 spinal nerve roots) has a short *course, ramifying in the iliopsoas and quadriceps*

muscles. It is liable to damage in the oversized fetus of

large-framed breeds (Simmental, Charolais, Holstein)

Fig. 32.1

Radial paralysis of right foreleg of six-year-old

at delivery when presented in the 'hiplock' or 'stifle

Friesian cow. Paralysis was present on standing following 120

lock' position, which tends to cause femoral hyper-

minutes in right lateral recumbency for surgery of a septic paro-extension as forced traction is exerted. The femoral

tiditis under general anaesthesia. Total recovery took 48 hours.

nerve, usually unilaterally, is drawn against the pubic

The classical signs are present: dropped elbow, flexed carpus

brim at the pelvic inlet. The injury can occur in either

and inability to extend forelimb for weight bearing.

anterior or posterior presentation. The lesion is some-

times a rupture of the nerve, but more frequently

spiral, comminuted and to have sharp protruding spikes

involves very severe perineural haemorrhage and

of bone. Radial nerve paresis frequently occurs follow-

oedema. In other cases, the quadriceps femoris muscle *ing a long (one to two hour) period of general anaes-*

is severely stretched and incurs damage to its vascular

thesia in lateral recumbency when the primary damage

and nerve supply. The resulting quadriceps atrophy

is a compressed vascular compartment. A dairy cow

presents with typical clinical signs.

trapped under the lower horizontal bar of a cubicle divi-

sion can also, on release, have radial paralysis. While

Clinical signs and diagnosis

partial paralysis is more common, complete radial

paralysis can result from brachial plexus injuries or

The animal, usually a neonate, is unable to maintain the

severe trauma. Cattle entering a crush fast and banging

stifle in extension due to quadriceps dysfunction. The

the shoulders against the yoke gate occasionally have a

joint is flexed and the digit rests with minimal weight

temporary partial radial paralysis.

bearing. Usually, hock and digital joints are also flexed,

though the toe is not dragged. A small area of loss of

skin sensitivity may be detectable lateral and proximal

Clinical signs and diagnosis

to the stifle joint. Quadriceps atrophy within 10 to 14

days results in a triangular depression in the lateral

The main signs are a dropped elbow due to triceps

cranial part of the thigh. Fibrosis of the remaining

paralysis, knuckled fetlock and an inability to advance

quadriceps muscle mass develops later. The stifle joint

the limb (Fig. 32.1). If the limb is placed in its usual

may become unusually prominent. Differential diagno-

position, the fetlock flexes as an attempt is made to bear

sis involves dorsal or lateral patellar luxation, septic

weight. Sensory loss can be detected over the elbow and

gonitis, femoral fracture or growth plate separation, hip

lateral aspect of the forearm.

dislocation and quadriceps rupture.

Differential diagnosis includes humeral fracture with

or without radial paralysis.

Treatment and prevention

The prognosis is guarded or poor. Recovery is unlikely

Treatment and prevention

in calves with femoral nerve rupture. The recovery time

The prognosis is good if the nerve has not been sec-

for regeneration was about four months in an experi-

tioned by humeral bone fragments. Treatment is sup-

mental study when a 5 mm (1/4 inch) length of femoral

portive, keeping the animal on soft bedding and on

nerve was resected surgically (Buchthal et al., 1984).

non-slip surfaces. The fetlock should be bandaged to

Treatment is primarily careful supportive nursing care.

prevent iatrogenic trauma. Anti-inflammatory drugs

Calves should receive colostrum by bottle within 6

and vitamin B complex may be given systemically.

hours of birth if the injury has prevented rising to suck.

Clean and dry bedding is essential. The calf should

management should be reviewed to avoid a high inci-

be frequently turned. Analgesics, anti-inflammatories,

dence of dystokia in heifers and to prevent damage

and vitamin E and selenium preparations should be

during forced extraction of the fetus.

given.

Tibial paralysis

Obturator paralysis

Aetiology and pathology

Aetiology and pathology

Tibial paralysis is rare. It is associated with iatrogenic

damage following deep infections in the caudal thigh

Obturator paralysis classically involves unilateral or

musculature or lacerating injuries in the medial aspect

bilateral damage to the nerve, usually in heifers during

of the hock with associated damage to related tendons.

dystokia due to fetal oversize or maternal immaturity,

when the nerve (L4–L6 nerve roots) is damaged by fetal

pressure on its course along the medial aspect of the

Clinical signs and diagnosis

ileum or along the pelvic floor. Experimental section of

Tibial paralysis results in hock flexion from inability pri-

the nerve, which innervates the adductor muscles (gra-

marily to cause gastrocnemius contraction, which would

cilis, pectineus, adductor and external obturator), has

result in hock extension. It also causes hyperextension

caused mild abduction of one or both hind limbs but

of the digits in that the weight is borne more on the

experimental animals have been able to rise without heels. Skin sensation is absent over the caudal aspect

difficulty (Vaughan, 1964; Cox, 1981). A common

of the metatarsus and digits. Differential diagnosis

synonym for obturator paralysis, ‘calving paralysis’, is

includes peroneal paralysis and gastrocnemius and

considered a misnomer since the latter is usually asso-

flexor tendon rupture.

ciated with the ‘downer cow’ syndrome (Cox &

Onapito, 1998) (see p. 439). Many clinical cases of so-

called obturator paralysis have a more complex aetiol-

Treatment and prevention

ogy involving branches of the sciatic nerve or primary

Treatment is symptomatic, involving confinement and

muscle damage.

vitamin B complex injections.

Clinical signs and diagnosis

Peroneal paralysis

Abduction of the hindlimb (unilateral) or a straddled

Aetiology and pathology

gait (bilateral) are the classical signs. Confusion clini-

cally may result from the stance adopted by a heifer

As with the tibial nerve, the peroneal nerve is a major

with an oedematous and overstocked udder and with

branch of the sciatic nerve (L6–S2 nerve roots). Its

pelvic fractures. Rectal and vaginal examination

common site of damage is over the lateral aspect of the

may reveal minor pelvic damage associated with the

stifle joint where the nerve lies relatively close to the

paralysis. Some cattle are recumbent and such recum-

skin surface. It is liable to injury following sudden (falls)

bency is rarely due to simple unilateral obturator injury.

or chronic pressure (prolonged recumbency).

Cattle are liable to slip with gross hindlimb abduction,

giving rise to hip luxation. Skin sensation remains

Clinical signs and diagnosis

unimpaired. Diagnosis is based on the history of pos-

sible injury at parturition and on the characteristic

The hock is hyperextended, and fetlock and digits are

stance and gait.

flexed (knuckled over) (Fig. 32.2). The foot can be

placed in its normal position. Skin sensation is lost

dorsally from the fetlock distally to the coronary band.

Treatment and prevention

Diagnosis is easily made on the clinical signs and

The animal should be kept on non-slip surfaces to avoid

sensory loss. Differential diagnosis involves tibial par-

possible hip luxation or femoral neck fracture. Sand on

alysis and painful digital diseases.

the concrete floor of a calving/isolation box, overlaid

with plenty of straw, is ideal. The hocks and hind feet

Treatment and prevention

should be kept close together by a figure of eight

pattern of rope above the hocks or fetlocks. The dis-

The prognosis is good with recovery usually evident in

tance between these joints should not exceed 30 cm (12

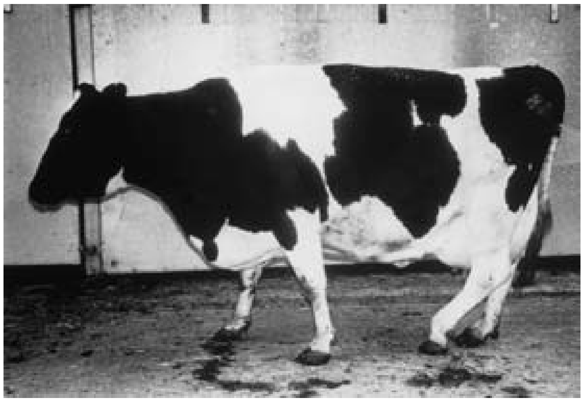
a few days. Self-induced trauma to the fetlock is mini-

inches), which permits the animal to rise. Supportive

mized by application of a soft bandage or a light resin

care should be continued for several days. Breeding

cast to the fetlock.



***Downner cow syndrome** (see p. 797)*

Defined as ‘a cow down in sternal recumbency for unknown reasons’, the syndrome usually affects high-yielding dairy cows in the first 48 hours postpartum. In the UK the incidence appears to be increasing as a result of overcrowding in cubicle houses (see p. 43). Veterinary attention may not be sought for 24 hours, as a response to calcium borogluconate therapy is awaited. The condition has a multiple aetiology including traumatic, metabolic, neurological and toxic infectious causes. The following are examples:

• Traumatic: sacroiliac luxation and subluxation,

Fig. 32.2

Peroneal paralysis in six-year-old Friesian cow

bilateral or unilateral coxofemoral luxation, *showing extended hock and knuckling of fetlock. Two days pre-*

rupture of gastrocnemius muscle, pelvic fracture,

viously the digit had also been flexed. Some weight is now borne massive blood loss (profound anaemia).

on claw normally. Total recovery took another three days.

• *Metabolic:*

non-responsive hypocalcaemia,

hypokalaemia.

• *Neurological: lymphosarcoma infiltration into tho-*

Sciatic paralysis

racic or lumbosacral spinal canal, bilateral peroneal

paralysis, complications of obturator paralysis.

Sciatic nerve paralysis involves the nerve that originates

• *Toxic infectious: septic metritis, acute coliform*

from three ventral roots (L6, S1–2). Damage to L6 root

mastitis (pp. 334, 519).

may be an important component of 'calving paralysis'

or obturator paralysis (Cox, 1981) (see p. 438). The

The primary recumbency, whether due to dystokia

sciatic nerve is liable to damage unassociated directly

(46 per cent of cases), milk fever (38 per cent), or other

*with parturition but in prolonged unilateral recum-
causes (16 per cent) (Chamberlain, 1987), is followed by
bency. The site is usually close to the medial aspect of
secondary recumbency. The usual explanation for the
the femoral greater trochanter and may be associated
development of a downer syndrome in a cow, which is
with struggling. Such circumstances can involve partial
unsuccessfully treated for clinical signs diagnostic of
recovery from milk fever or postparturient hypocal-
hypocalcaemic parturient paresis or milk fever, is that
caemia, as the cow struggles to rise on a slippery surface
the hypocalcaemia has been treated too late and that
(e.g. concrete) (Cox & Onapito, 1998). Rarely, sciatic
unrecognized traumatic injury has already taken place.
paralysis is secondary to femoral neck or pelvic fracture
Half of all 'downer cows' develop within 24 hours of
(pubis, ischium), or iatrogenic in origin from septic
parturition. They tend to be high producers. The inci-
infection arising from intramuscular injections.
dence is higher in winter. Survey data indicate a con-
siderable range (3.8–28.2 per cent) in the incidence of*

downner cows as a percentage of cases of milk fever. One
Clinical signs and diagnosis
study revealed that 33 per cent of downer cows recov-
The limb is entirely non-weightbearing. Sensation is
ered, 23 per cent were slaughtered, and 44 per cent died
lost from the limb distal to the stifle except for a strip
or were euthanized.
on the medial aspect of the thigh distal to the mid-
Pressure damage causes ischaemia of muscles and
metatarsal region, which is supplied by the saphenous
nerves. Following a variable period of struggling,
branch of the femoral nerve. Differential diagnosis
further skeletal injury such as gastrocnemius muscle
should include femoral fracture, the signs of which will
rupture may occur. The differential diagnosis is often
include crepitus, possibly swelling and abnormal mobil-
difficult since frequently a non-responsive milk fever
ity, and septic gonitis and tarsitis.
cow does not appear to have any further specific
abnormality.
The aetiology of this pressure damage involves

Treatment and prevention

effects resulting from the ‘compartment syndrome’

The prognosis is usually hopeless. Many cases are pre-

(Cox & Onapito, 1998). Increased pressure develops

sented as ‘downer cows’. It is vital that this paralysis be

within an osteofascial compartment following external

recognized early, so that long-term nursing measures

pressure or internal filling of the compartment with

will not be instituted. Early slaughter is advisable.

blood or oedematous fluid, or both. External pressure

results in ischaemia, ‘leaky’ vessels, and a postcompres-

study (Chamberlain, 1986), CK peaked at 24 hours after

sion swelling. The effects of the crush syndrome, which

onset of recumbency in cows that recovered to stand,

refer to the systemic results or muscle damage, involve

and at 48 hours in cows that became permanent

largely the absorption of muscle breakdown products.

‘downers’. Plasma or serum CK values reflect the total

One specific cause of the downer cow syndrome is

mass of injured muscle, but CK half-life is such that it *pressure damage to the hindquarters following a period*

is of doubtful value as a prognostic indicator several

of prolonged recumbency (3–6 hours or more), result-

days after initial recumbency, when little further active

ing both in extensive muscle damage and reversible or

muscle damage may be occurring.

irreversible changes in the sciatic nerve caudal to the

Plasma aspartate aminotransferase (AST) is elevated

proximal end of the femur and to the peroneal nerve.

in animals with muscle damage. This enzyme is also

Consideration of the aetiology and pathology of

released in cardiac myopathies, but postpartum

traumatic factors is reviewed in other sections (see

increases in downer cows are almost invariably related

Fractures, p. 441; Dislocations and subluxations, p. 447;

to the muscle component.

Muscle and tendon injuries, p. 451).

In cows recumbent for over 48 hours (at the time

of second clinical examination), clinical pathology can

be reassessed. Urinalysis may now reveal proteinuria

Clinical signs and diagnosis

indicative of myoglobinuria (from muscle breakdown),

By definition the animal is recumbent. The cow is

ketonuria and bilirubinuria (from partial anorexia).

usually alert, eats, and can defecate and urinate.

If the aetiology of the persistent recumbency remains

Affected cows make little or no attempt to rise in the

in doubt, a repeat complete clinical examination should

hindlimbs. Some alert cows move around using the

bear in mind less common causes (e.g. infiltration of

forelimbs and have been termed 'creeper cows'. Cows

lymphosarcoma into the spinal canal). A careful

confined to a stanchion do not have facilities to demon-

recheck of the history may aid diagnosis at this stage.

strate this movement, which may appear after the

animal is transferred to a well-bedded stall or box. Dull

Treatment and prevention

or comatose and anorectic cows may be 'downers' due

to systemic toxic factors (coliform mastitis, severe

The downer cow should be moved to a well-bedded

metritis). Occasionally, downer cows are hyperexcitable

loose box not later than 24 hours after the onset of *due to hypomagnesaemia or hypocalcaemia (see*

recumbency. Ample food and water must be provided

Chapter 46).

in low, wide-based containers.

Rectal palpation is crucial to evaluate various

The primary aim is to raise the cow. Any attempt

traumatic aetiologies: sacroiliac (sub)luxation, pelvic

should be made on a relatively non-slip surface. Per-

fracture, severe, intrapelvic, soft tissue injury and

sonnel should be ready to assist with tail support fol-

coxofemoral luxation, as well as to check the state of

lowing provocative stimulation (e.g. electric goad). Hip

the uterus (puerperium). External assessment includes

clamps, e.g. Bagshaw hoist, may be applied to the wings

palpation of the spine for abnormal angulation,

of the ilium for a maximum of 20 minutes. Usually, the

swelling, or crepitus (fracture), musculature of the

ability of the cow to bear weight is obvious. While slung

hindlimbs, especially the adductor group medially

in this manner, the hindquarters should be checked for

(muscle rupture), manipulation of the upper hindlimb

symmetry and the opportunity taken to flex and extend

and pelvis for evidence of fracture or dislocation, and

each hindlimb to check for fractures. Other devices for

determination of possible loss of skin sensation. The

elevation include air cushions or bags, webbing slings

possibility of acute coliform mastitis should be investi-

and water flotation tanks (Smith et al., 1997). Some

gated. The cow should be turned to the opposite side

cows that can stand following hoisting require to be

for similar examination of the other hindlimb. Cows

hobbled above the hocks or hind fetlocks to prevent

usually prefer to lie with the more painful hindlimb

abduction of the hindlimbs.

uppermost.

Hip clamps may be repeatedly applied for a few

Downer cows have variable changes in blood mineral

minutes of forced elevation of the hindquarters to

levels, some showing a persistent hypocalcaemia,

improve circulation. When lowered, the cow should

hypophosphataemia, and possible hypomagnesaemia.

be placed with the previously dependent side

The role and significance of hypokalaemia is disputed.

uppermost.

The release of potassium from damaged muscle cells

The most important component of treatment is good

does not necessarily cause hyperkalaemia because the

nursing. The cow must be made comfortable. Owners

usual coexisting hypocalcaemia has a tendency to cause

should be observant for the possible development of a

hypokalaemia. All cases show an elevated creatine

toxic (e.g. coliform) mastitis during recumbency. Rapid

kinase (CK), which is specific for muscle injury. In one

loss of weight, signs of systemic toxicity, and anorexia

are grave prognostic indicators. Soft bedding is essen-

Prevention of the downer cow syndrome is particu-

tial for effective nursing in all downer cows, which

larly vital today since treatment is very labour-intensive

should be turned several times daily.

and repeated veterinary involvement is too costly for

Fresh water should be available alongside a bucket

the minimal profit margins of many dairy farms.

containing a commercial electrolyte solution. Par-

enteral treatment includes repeated injection of solu-

tions containing calcium–phosphorus–magnesium with

Fractures

glucose and potassium. Additional potassium should

only be given by stomach tube (e.g. 50 g KCl daily).

Introduction

Tripelennamine hydrochloride given as 12 ml solution

In the assessment of bovine fractures, several factors

i.v. is an effective stimulant and antihistaminic that

require consideration in each clinical situation.

makes a downer cow appear more alert (Chamberlain,

1987). Analgesics such as phenylbutazone, flunixine

meglumine and ketoprofen should be restricted to cows

Economics

with obvious signs of pain.

The prognosis is good in well-nursed ‘creeper cows’

With some exceptions, economic consideration is a vital

with some voluntary hindlimb movement and cows that

factor. Many cattle not used for breeding, e.g. steers,

are capable of a short period of weight bearing when *are best slaughtered at once, since treatment would be*

hoisted or slung. The prognosis is poor in animals with

costly. Young potentially valuable breeding stock fall

no hindlimb movement. Proprioceptive reflexes should

into a different category, where slaughter value is neg-

be repeatedly checked in such cows.

ligible in comparison with the potential value following

Generally, excellent nursing, a consistently good

fracture healing.

appetite, and some spontaneous movement should

encourage owners to persist and practise patience.

Size, age and sex

Valuable prognostic indicators for survival in a

limited British survey of 64 downer cows were as

Young cattle respond well to restrictions imposed

follows.

during fracture immobilization. They tend to rise easily

despite external fixation and to be less liable to develop

• On day 2 of recumbency: body condition score,

decubital lesions. The soft thin cortices of long bones in

quality of nursing care, absence of hypocalcaemia, *calves make plate and screws generally an unsuitable*

relative hypomagnesaemia, and lower AST and CK

means of internal fixation. Calves have a remarkable

enzyme levels.

ability rapidly to produce a fibrous response at a frac-

• On day 4 of recumbency: survival was associated

ture site and early callus formation.

with little further rise of CK and with continued

good nursing.

Disposition

A US survey of 15 veterinarians' experience with

slings used on 145 cows showed a recovery rate of 52

An advantage of fracture healing in cattle compared

per cent.

with horses is their tolerant disposition making han-

Prevention depends primarily on the avoidance of

dling easier.

parturient paresis associated with milk fever (see

Chapter 46). Calving should take place in properly

Location and character

designed areas with good footing. Many farms will *benefit from stalls with 30 cm (12 inches) clean sand as*

Generally, the more proximal the fracture, the more dif-

bedding. On problem farms, successful reduction of the

ficult is its anatomical reduction and rigid fixation. Thus

incidence of downer cows has been primarily attributed

humeral and femoral fractures have notoriously low

to improved observation for the initial signs of milk

recovery rates, while metatarsal and metacarpal frac-

fever and its prompt treatment.

tures usually heal well. Fracture of the distal phalanx,

Periparturient cows should be placed onto a minimal

in which displacement is minimal, is discussed else-

slip surface and sand is excellent for this purpose if

where (see Fracture of distal phalanx, p. 429).

staw-bedded calving boxes are not available.

Comminuted fractures are the rule in cattle. Many

A high incidence of downer cows in first-calf heifers,

fractures are closed initially but become open follow-

where hypocalcaemia can be ruled out, may be due to

ing inappropriate handling such as movement to a stall.

dystokia. Breeding policies may require modification

The prognosis for open fractures, especially proximal

such as use of a smaller breed bull or later first service

fractures (humerus, tibia, femur), is guarded. Soft tissue

dates for heifers.

damage is often limited to haematoma and oedema

formation resulting from the original insult and move-

physis. A minimum of equipment is required, and

ment of the fractured bone ends. In certain instances,

extensive experience is unnecessary. External fixation

significant nerve damage (e.g. to radial nerve in a spiral

is unsuitable for more proximal sites, in open fractures

humeral shaft fracture) may be an important consi-

with gross contamination and fractures occurring

deration in the prognosis.

in two limbs simultaneously. Young cattle develop

Most fractures tend to be oblique or spiral in cattle.

osteomyelitis following open long bone fractures more

Maintenance of reduction while external or internal

frequently than older cattle. Careful examination of the

fixation is applied tends to be more difficult than with *fracture site, preferably after clipping of the skin, is*

transverse fractures.

essential to avoid missing an open fracture. External

fixation alone may be contraindicated in very heavy

animals.

Duration of fracture

Unlike small animals and horses, the duration of a

Choice of materials and technique for

bovine fracture before presentation can often be 12–24

external fixation

hours, a consequence of the relatively casual methods

of husbandry practised on some farms. The result is

Immobilization techniques include the splint or cast,

invariably a greater degree of soft tissue injury than

the modified Thomas splint, and both methods together.

in a freshly presented fracture. One effect of a longer

Casting materials available today include plaster of

duration of movement at a fracture site is an open

Paris (one form of which is rapid-setting), thermoplas-

fracture.

tic polyester polymers (Hexcelite), and polyurethane *resin incorporated into woven material of polyester*

(Cuttercast, Baycast) or fibreglass (Deltalite/Scotch-

First aid

cast). Casts should always be applied over a layer of

padding. The depth of padding should be considerably

Fractures should be immobilized on the farm premises

greater if soft tissue swelling is anticipated at the frac-

as soon as possible. Suitable materials include padding

ture site and also should be generous over bone promi-

with old towels or sheeting, and splinting with polyvinyl

nences. The padding should extend beyond the

chloride tubing, or stiff rods such as broomsticks placed

intended proximal point of the cast. The cast should

at 90° to each other (e.g. cranial and lateral surfaces of

immobilize the joints proximal and distal to the fracture

the forelimb to stabilize metacarpal fracture) and fixed

site. Thus, in a one-month-old calf with a distal

in position with duct tape. The joints above and below

metacarpal shaft fracture, the cast should extend at

the fracture should be immobilized. This technique is

least 8 cm (3 inches) proximal to the radiocarpal joint *impossible in femoral, tibial and humeral fractures. In*

and similarly distal to the fetlock.

tibial fractures, a Robert Jones bandage comprising

Positioning is very important in applying a cast.

layers of cotton wool firmly bound by cotton bandage

General anaesthesia is rarely necessary; xylazine is

can achieve adequate immobility if sufficient bulk is

usually adequate for restraint and analgesia. The limb

applied.

must be forcibly extended for fracture reduction and

then maintained immobile until the cast has set. Trac-

Fracture repair

tion on the distal part of the limb may be aided by

inserting wire through holes drilled in the toes.

In certain fractures (e.g. rib) spontaneous healing is the

The advantages of a lightweight cast include

rule. In others (e.g. external angle of ilium) repair

increased comfort and ease of rising, and are achieved

usually takes place but a sequestrum may form. The

by fibreglass (e.g. Vetcast, Deltalite, Scotchcast), which

sequestrum generally is only a cosmetic blemish but *has a strength five times greater than plaster of Paris.*

sometimes becomes infected and then requires removal.

Weight reduction is also possible using several layers of

Most fractures require treatment by methods of

plaster overlaid by fibreglass casting tape, once the

external or internal fixation, or both, if recovery is to

plaster has hardened. Strength combined with lightness

take place.

is the result.

Some fractures require radiography before reduction

and immobilization to determine the extent and sever-

Long bone fractures:

ity of bone damage. Fractures may also be radi-

external fixation

ographed two to three weeks after immobilization to

assess the degree of healing. Removal of the cast at this

External fixation of fractures is usually satisfactory if

time is often unnecessary. The radiolucency of

the site is distal to the humerus or proximal tibial meta-

cast materials varies, plaster of Paris being poor,

Deltalite/Scotchcast fair with some mottling, and Cuttercast/Baycast is excellent.

Extension bars have sometimes been incorporated into external casts. These U-shaped metal stirrups have the curved part of the U distal to the toes, so that weight is borne by the bar and transferred proximally to the cast, into which the two arms of the extension bar are buried during cast application. Such a device is only useful if there is a specific indication to avoid weight bearing by the digits. The effective increase in limb *length makes standing up and ambulation more diffi-*

cult. A modification is the hanging cast. This device

comprises one or more intramedullary pins that are

drilled through the proximal fracture fragment, and

onto which a U-shaped bar is fitted after the usual

external immobilization has been applied. When weight

is borne, it is transferred proximally to load bearing by

the proximal fracture site, so that the fracture site is not

stressed.

Thomas extension splints may be put on either fore-

limb or hindlimb. Good padding is essential both at the

points (axilla, inguinum) where maximal pressure will

be applied, as well as at any contact points more dis-

tally. The Thomas extension splint must be 'made to

measure' for the individual case (e.g. circumference of

proximal and distal rings, length of cranial and caudal

Fig. 32.3

Bilateral distal metacarpal fractures in a one-day-old

longitudinal bars). In growing stock the length should

Saler calf. Circular lesions result from pressure of obstetrical be slightly greater (e.g. 5 cm or 2 inches) than necessary, *chains applied during forced extraction. In the absence of*

to permit growth. Some devices have expansion clamps

percutaneous infection (seen here) external immobilization from or rings on the longitudinal bars to allow continual

mid metacarpal to coronary level is indicated.

modification.

The bottom ring should be wired to the foot to main-

tain the leg in extension. Bandages and padding should

be placed around the limb at potentially exposed areas

Humeral fractures in cattle aged two and a half

before they are taped to the longitudinal bars. In the

months to three years can heal four to six weeks fol-

hindlimb, the metatarsus may be fixed to the caudal bar,

lowing Thomas splintage (Wintzer, 1961). In other

the tibial (gaskin) area to the cranial bar. The extension

cases, immobility has been unsatisfactory and non-

splint should be checked carefully for fit and effective

union has resulted despite massive callus formation.

immobilization of the fracture site before release of the

Open fractures, at sites where external fixation is

patient. Many cases will benefit from combination of an *practical, require particular attention. The presence of*

external cast (e.g. fibreglass) and a Thomas extension

skin perforation should carry the presumption of an

splint.

open fracture even if bone cannot be seen or palpated

Cattle up to 350 kg (800 lb) will generally adapt well

through the injury. The wound is cleansed and carefully

to Thomas splintage. Patients should be confined to a

explored. Any free bone fragments should be removed.

stall with relatively little straw bedding. Assistance to

Larger wounds require debridement. It may be useful

rise may be needed initially. The cast or splint should

to take tissue samples or a blood clot for microbiolog-

be checked daily for skin abrasions, cast fracture or

ical culture in the case of valuable cattle. Wounds

slackness.

should be copiously irrigated with a polyionic solution

Neonatal and other calves less than a month old with

(isotonic balanced electrolyte with neutral pH). The

simple fractures and rapid callus formation may require

value of adding a 0.1 per cent povidone-iodine solution *external support for two weeks only (Fig. 32.3). Other*

(1 : 100 dilution of povidone-iodine 10 per cent solution)

young cattle should be checked for progress at three

has not been established in cattle.

weeks by removing the cast with an oscillating saw.

Antibiotics should be given parenterally in all open

Sometimes the same splint may be reapplied (e.g. with

fractures in cattle. Natural and synthetic penicillins

Deltalite, Cuttercast).

are the first choice. Systemic antibiotics should be

continued for seven to ten days. Antibacterial sensitiv-

Humeral fractures are difficult to plate due to their

ity patterns may be checked via samples taken at an

short length and spiral configuration. Multiple bone

early stage and before antibiotics are given. Samples

fragments often necessitate the use of lag screws.

should preferably be taken from infected bone at

In older and heavier cattle, internal fixation is less

surgery rather than from discharging sinus tracts where

successful due to greater mechanical forces. Often *contamination with surface pathogens will complicate*

long-term Thomas splintage is adopted.

interpretation of laboratory results. Antibiotic therapy

should be instituted as soon as possible following iden-

Femoral fractures

tification of an open fracture. Small wounds may be

covered with a sterile protective dressing, but any exter-

Femoral shaft fractures are relatively common in calves.

nal support of the fracture site should be removed after

Most have a history of forced extraction. The existence

three to five days to permit quick assessment of the

of concurrent disease should be evaluated (e.g.

wound. Young cattle develop osteomyelitis following

colostrum intake). No form of external immobilization

open fractures more frequently than adults. The reason

is helpful. Internal pinning (Steinmann) rarely achieves

may be a richer blood supply in the damaged area.

sufficient immobility of the fracture site. The technique

of choice is usually plate and screws, possibly double

plating, with two plates placed at about 90° to each

other (lateral and cranial).

Long bone fractures: internal fixation

Similar techniques may be attempted in older cattle.

Reduction may present major problems. The huge

Introduction

mechanical force acting at femoral fracture sites makes

Economic factors are often important in considering

bending of the plates or loss of screws common. Some

internal fixation of bovine long bone fractures. Exper-

femoral shaft fractures eventually heal with some

tise in the discipline is also essential for successful

months of stall rest alone.

reduction and rigid support under aseptic surgical

conditions.

Tibial fractures

Anatomical factors mean that long bone repair by

internal fixation is most frequently required in humeral,

Tibial shaft fractures are amenable to a variety of

femoral and tibial fractures. Young calves have very

fixation techniques since exposure is relatively easy.

thin cortical bone and screws are liable to loosen or be

Problems arise with severely comminuted or multiple

stripped during insertion. Failure is the common result.
fractures extending into the proximal and distal meta-
Both access to the fracture site and reduction are much
physes. As alternatives to plate and screws, and addi-
simpler in the calf than adult.
tional support by a Thomas splint, some tibial fractures
In adult cattle, where the cortex is thick and dense,
may be immobilized by cerclage wire with external
the major problems are associated with general anaes-
support. Others best lend themselves to transfixation
thesia (e.g. regurgitation, rumen tympany, compromised
pinning. In this method two or three 6 mm Steinmann
ventilation), the soft tissue mass through which the frac-
pins are placed through both cortices of both proximal
ture site is approached, and the initial difficulty of
and distal segments under strict asepsis, the protruding
anatomical reduction, when muscle spasm compounds
ends are cut to protrude about 2.5 –5 cm (1–2 inches)
the degree of overriding of the fragment ends.
from the skin, and a resin (methylmethacrylate) bridge
Specialist texts should be consulted for details of

is placed over these protrusions to immobilize the frac-

internal fixation of specific bovine fractures (Ferguson,

ture site. The sites of skin puncture should be carefully

1997).

covered with dressings to reduce the chance of infec-

tion tracking along the pins and causing osteomyelitis,

which is the primary complication of this technique.

Conservative treatment often fails to result in accept-

Humeral factures

able fracture resolution due to insufficient stabilization

Animals up to yearling size (e.g. 250 kg, 550 lb) are

of the break. This often results in the development of

amenable to internal fixation unless the fracture is

severe lateral deformity of the limb with associated

severely comminuted. Such fractures are usually mid-

weight loss.

shaft oblique and spiral. The radial nerve is often

involved (p. 436). There is often severe overriding,

Growth plate and other injuries

making reduction difficult. Intramedullary pinning

(or stack-multiple-pinning) combined with cerclage

Separation of the growth plate is a common complica-

wiring is often the technique of choice.

tion of forced traction in dystokia. The usual site is the

fracture involving the acetabulum. The simplest method

of treatment is confinement, which has a low success

rate. Alternatively, the femoral head may be resected to

permit development of a pseudoarthrosis, but lameness

usually persists along with obvious muscle atrophy and

compensatory conformational changes in the contra-

lateral limb. Finally, internal fixation by Knowles pins *or lag screws has been successful but requires intraop-erative radiography to ensure the correct direction of insertion from the lateral aspect of the greater femoral trochanter.*

Vertebral fractures

Aetiology and pathology

Elsewhere in this chapter, reference is made to long bone fractures and growth plate separation (p. 444) resulting from excessive traction during dystokia. But vertebral fractures due to forced traction, usually in an exotic beef breed such as Charolais, can lead to fracture and/or luxations in the caudal thoracic or cranial lumbar region (preferentially T12–L3). The common form is a fracture of the caudal physis of T13 (Schub & Killeen, 1988).

Postmortem changes include perirenal and

Fig. 32.4

Separation and displacement of distal metacarpal

perivertebral haemorrhage,

fractured ribs,

cord

growth plate in 15-month-old Limousin bull. Complete recovery

compression, severed cord, subdural haemorrhage,

followed manipulation and traction reduction (over 1000 kg pull) and myelomalacia.

and four weeks immobilization in resin cast.

Clinical signs and diagnosis

distal metacarpus or metatarsus (Fig. 32.4). Non-weight

The calf is alive before traction is applied in dystokia,

bearing swelling and crepitus are major clinical

but following delivery the calf is weak, usually recum-

signs.

Cases must be distinguished from distal

bent, with a swollen head, dyspnoea, and spinal devia-

metacarpal/metatarsal shaft fractures and fetlock dislo-

tion. These calves usually die within 24–48 hours from

cation or subluxation. Most cases respond to manual

neurogenic shock (pain, trauma, hypoxia).

reduction and some weeks' immobilization in a cast.

The normal rigidity of the spine in the affected tho-

Other sites of growth plate separation include the

racolumbar region invariably cannot tolerate the spinal *distal femur, distal tibia and distal radius. Apart from curvature induced during typical traction on forelimbs external support, cross and Rush pinning are suitable of a fetus in anterior presentation when these dorsal methods of immobilization. The pins in the first method structures become stretched and convex. When fetal traverse the epiphysis obliquely to emerge through the hips lock on entering the maternal pelvis, the thoraco-opposite metaphysis. In Rush pinning, the pin is lumbar region is approximately level with the maternal directed from the epiphysis to slide in a sledge-runner vulva. If the fetal body is then twisted and bent from fashion proximally along the internal surface of the side to side, acting as a pivot, a considerable risk of opposing diaphysis. Although such pins are liable to excessive shearing or traction forces can develop. displace rather easily, healing is rapid and the success rate is high.*

Treatment and prevention

A specific and difficult orthopaedic problem is fracture of the femoral neck and separation of the proxi-

The magnitude of traction forces in dystokia should be

mal femoral epiphysis. Most cases result from dystokia.

appreciated. Two men can exert a 350 kg pull for 30

Diagnosis is difficult as precise localization of the frac-

seconds. A calf-puller device can produce over 500 kg

ture requires radiography. The differential diagnosis

traction. Adequate lubrication of the birth canal and an

includes proximal femoral shaft fracture and pelvic

instinctive reluctance to use more than manual pressure

are the two most important preventive measures, since

Osteoporosis is a predisposing factor to pelvic

treatment is useless. A greater willingness to adopt

fracture in some high-yielding dairy herds.

caesarean section in oversized viable fetuses will

Other pelvic fractures involve the wing or shaft of the

help prevent further accidental injuries *(see p. 1115).*

ilium, tuber ischii, and the acetabular margin. The ilial

fractures usually involve massive trauma, such as falls

down cliffs. Tuber ischii damage may result from road

Pelvic fractures

traffic accidents in which the impact is caudal. Acetab-

ular margin fracture chips often involve traumatic hip

Aetiology and pathology

luxations.

Severe pelvic fractures are rare in cattle. Trauma is

almost always involved. The most common pelvic frac-

Clinical signs and diagnosis

ture involves the tuber coxae, which is damaged during

The degree of lameness varies considerably from nil

passage through a narrow doorway or in a sudden fall

(tuber coxae) to severe and even to recumbency (pubic

laterally onto hard ground (Fig. 32.5). Unlike other and ilial shaft fractures). The external bony landmarks pelvic fractures, the tuber coxae fragment may be are frequently asymmetrical. Crepitus may be obvious pulled ventrally by the fascia lata, becoming a as the animal walks. Rectal palpation will often permit sequestrum from an inadequate blood supply and may localization of the crepitus and an appreciation of develop a septic draining tract to the exterior. surrounding soft tissue injury. One useful technique is Another specific condition is separation of the pubic palpation during lateral rocking of the hindquarters. symphysis, resulting from excessive traction on a fetus Fractures of the ilial shaft, pubis and cranial ischium in the pelvic canal of an immature heifer. can be appreciated on such rectal exploration. Vaginal palpation should be performed in mature cows and recently calved heifers.

Clinical diagnosis of acetabular fractures, which tend to involve the dorsal rim, is difficult as the localized crepitus must be distinguished from coxofemoral dislo-

cation (in which the greater femoral trochanteric position is abnormal) and femoral neck or physeal fractures (which may be suspected from the increased mobility of the hip region in the affected limb). Radiography is essential for diagnosis in some cases, but, due to size and equipment constraints, is rarely feasible.

Other differential diagnoses include pelvic bruising leading to heamatoma formation and pelvic abscessation.

Haematomas rarely cause lameness, while abscesses tend to have a more gradual onset and a protracted course. Several sites of pelvic fractures can lead to nerve trunk (sciatic, femoral, obturator) and blood vascular damage (middle uterine artery, internal pudendal, internal iliac arteries and veins).

Fractures of the bodies of the ischium and pubis invariably involve the obturator foramen, usually also the obturator nerve, and are serious in that marked pain and discomfort tend to cause prolonged periods of recumbency and a reluctance to stand. Commonly, both bones are fractured, making the pelvis unstable, and *healing is then unlikely. In some cases, healing is liable*

to be accompanied by excessive callus formation. This

sometimes extends to produce hip osteoarthritis and a

persistent lameness.

Fig. 32.5

Fracture of right wing of ilium in adult cow, showing

Degenerative osteoarthritis of the hip in the older

asymmetry relative to the greater femoral trochanter and ischial bulls and cows leads to considerable peripheral new

tuberosity.

bone formation. Sometimes, following minor trauma,

small portions of the new acetabular dorsal rim

appreciated on limb abduction and flexion. Rectal

are chipped off (pathological fractures), leading to a

palpation aids localization of crepitus to the hip. It will

sudden increase in severity of the lameness. Often such

also help to differentiate the less common directions of

fracture chips will heal by fibrous tissue, but lameness

luxation. In cranioventral luxation, abnormal move-

persists.

ment may be appreciable cranial and lateral to the

pelvic inlet when the cranial border of the pubis is fol-

lowed. In caudoventral luxation into the region of the

Treatment and prevention

obturator foramen, movement may be noted as the leg

Surgery is indicated in few cases of pelvic fracture, e.g.

is abducted, flexed and extended, released, taking the

tuber coxae sequestrum. The only useful treatment is

femoral head out of and back into the margin of the

generally rest in a well-bedded stall. Use of hip clamps

foramen.

(e.g. Bagshaw hoist) to raise animals is contraindicated.

Diagnosis may be confirmed in smaller cattle on ven-

Few cattle become acclimatized to slings, which may

trodorsal radiographs. Differential diagnosis includes

increase the discomfort caused by the fracture. Cases of

femoral neck fractures, physeal separation, pelvic

pelvic fracture should be reassessed after three to four

(acetabular) fractures, and greater femoral trochanteric

weeks of good nursing, and, in the absence of obvious

fractures.

improvement, most cases should be salvaged.

Treatment

Dislocations and subluxations

Manipulative reduction should be attempted in all

uncomplicated cases of craniodorsal luxation seen

Hip joint

within 24 hours of the onset. The chance of successful

manual reduction decreases markedly thereafter. Cases

Aetiology

of caudoventral dislocation, which are often recumbent,

Coxofemoral luxation is sporadic, occurring mostly in

perhaps due to additional obturator damage, have a

two to five-year-old cattle. It has an association with

poorer prognosis.

parturition and the early postpartum period. At this

The common craniodorsal luxation is treated by

time, ligamentous relaxation is maximal and obturator

careful positioning of the patient so that the body is

or other nerve injury during dystokia may predispose

fixed while the affected upper leg can be extended in

cattle to abduct the hindlimbs and to slip the feet *various directions. Deep sedation (xylazine) is advis-*

laterally resulting in a splayed-leg collapse.

able. The leg is forcibly circumrotated in ever-increas-

Hip dislocation can occur in various directions,

ing circles by an assistant to loosen up the periarticular

craniodorsal being most frequent (about 80 per cent

soft tissues, which may be in spasm. A large, firm block

of total), and cranioventral and caudoventral being less

is placed between the ground and the medial femoral

common.

region to act as a fulcrum when inward pressure is

exerted on the stifle, tending to cause hip abduction.

The limb is subject to controlled traction along the

Pathology

longitudinal axis of the limb. The veterinarian should

The gross pathological changes in luxation include

concentrate on distal pressure on the greater tro-

rupture of the joint capsule and of the ligament of

chanter. The amount of femoral head movement

the femoral head (teres ligament), loss of articular car-

usually increases with time, and manipulation should *tilage and surrounding soft tissue, haemorrhage and*

not be quickly abandoned. Reduction is usually very

oedema.

obvious, and traction should be stopped at once, other-

wise a caudoventral luxation may be produced. Once

replaced, the limb is circumrotated slowly and carefully

Clinical signs and diagnosis

in an attempt to remove blood and other debris from

A sudden onset of lameness is the only consistent sign.

the acetabulum. The animal should not be permitted to

Other so-called typical signs refer only to the common

stand at once, since spontaneous reluxation is liable.

craniodorsal luxation, when the leg is held rotated out-

The hindlimbs should be shackled above the hocks or

wards, the hock medial, and stifle more lateral than

fetlocks for 24–48 hours. A good non-slip surface should

normal. The leg may appear shortened and the greater

be beneath the cow when standing up and, if available,

femoral trochanters are asymmetrical, the affected side

a hip hoist is a useful aid.

being relatively more dorsal. Movement of the limb is

A high success rate has followed open surgery for

somewhat restricted and painful. Crepitus may be

reduction of hip dislocations (Tulleners et al., 1987). In

this series few cases responded to manipulation. As

region. The dropped spine may develop over two to

experienced by others, caudoventral and cranioventral

three days and be preceded by evidence of localized

dislocations present special problems since limb trac-

pain. Rectal palpation of luxation reveals the sacral

tion cannot be exerted in the correct direction. The

promontory has been pushed caudally and depressed,

standard surgical approach is medial and cranial to the

so reducing the dorso-ventral diameter of the pelvic

greater trochanter through the gluteal musculature.

inlet. Very severe cases may be unable to stand as a

Care should be taken to avoid the sciatic nerve. The

result of spinal nerve trauma.

femoral head is mobilized and moved appropriately

In cases of subluxation and distortion, the signs are

with a combination of manipulation by a non-sterile

relatively mild. Some hindlimb ataxia and weakness
assistant handling the hock, which can be easily rotated
may appear. Crepitus may be noted during rectal pal-
slightly or, at will, abducted, and moved by appropriate
pation as the cow is walked forwards, and localized
instrumental leverage. Toggling through the femoral
swelling over the ventral part of the joint is diagnostic
head and acetabulum to produce an artificial
when the history indicates a sudden onset.
intra-articular ligament was unsuccessful in a long-
Differential diagnosis includes coxofemoral osteo-
term study.
arthritis, pelvic fractures, obturator or other nerve
Recumbency following hip dislocation and for
damage, lumbar spondylitis and progressive hindlimb
a period after successful reduction necessitates a careful
paralysis (spinal abscess, lymphoma).
watch for the possible development of acute severe
mastitis, since many cases have recently calved. Excel-
Treatment and prevention
lent nursing in good comfortable surroundings is essen-

tial for recovery.

The prognosis is favourable for cases of distortion and

Apart from a surgical series (Tulleners et al., 1987) in subluxation that are confined to a well-bedded stall for

which many animals were immature and, therefore,

a few days. More severe, recumbent cases of luxation or

better surgical candidates, most cases have a guarded

subluxation have a guarded or poor prognosis. A

prognosis for craniodorsal dislocation and a poor prog-

sacroiliac luxation never undergoes spontaneous repo-

nosis for any other direction. Recumbency at presenta-

sition and manual reduction is impossible. However,

tion makes recovery less likely.

some cows can survive for years with sacroiliac luxation

Hip dislocation is the clinical diagnosis in some

despite the bizarre appearance of the hindquarters.

'downer cows' (see p. 439).

In nursing affected cows, no forcible attempt (hip

clamp, electric goad) should be made to make them

stand. Analgesics (phenylbutazone) every second day

Sacroiliac luxation and subluxation

for one week may increase comfort.

Aetiology

Sacroiliac displacement involves a partial or complete

separation of the fibrocartilaginous joint surfaces. The

Stifle joint: femoropatellar

aetiology usually involves excessive ligamentous flac-

cidity around parturition, when most cases occur. Some

Aetiology and pathology

cases involve a degree of dystokia. A condition of

Patellar luxation may occur dorsally, medially and

sacroiliac distortion is recognized when there is no dis-

laterally. Dorsal displacement (fixation) is seen in

placement, but excessive mobility of the joint surfaces

mature cattle as an intermittent condition, unassociated

is detectable. In true luxation considerable haemor-

with any known trauma. Medial patellar displacement

rhage and soft tissue damage occurs in the joint space

is rare and is usually congenital. Anatomical defects

and peripherally (haematoma formation).

predisposing to medial luxation have not been clearly

identified, though in newly calved heifers with large *udders the abducted hindlimb posture may lead to tem-*

Clinical signs and diagnosis

porary medial patellar luxation.

Signs of sacroiliac luxation are characteristic. The

Lateral patellar luxation is occasionally seen as a

lumbosacral spine is dropped relative to the sacral

specific entity in mature cattle and young calves. This

tuberosities of the ilium, which are correspondingly

luxation in calves may sometimes be secondary to

prominent. Cows initially prefer recumbency and show

quadriceps atrophy resulting from femoral paralysis

slight ataxia, hindquarter weakness, and some knuck-

(see p. 437). In calves that first show signs at three

ling of the hind fetlocks. These signs are attributed to

months (Weaver & Campbell, 1972) without a history

associated bruising of the ventral nerve roots of L5–S2.

of femoral paralysis, no predisposing factors have been

Crepitus can be easily elicited from the sacroiliac

identified.

week. Surgery is preferably carried out in the standing case as an aseptic procedure following sedation and local analgesia. A large udder or a difficult temperament makes recumbency (affected side down) necessary in some cases. The surgical site is superficial to the most distal palpable point of the medial patellar ligament, close to its insertion into the tibial tuberosity.

A 4 cm (11/2 inch) long vertical skin incision is made cranial to the ligament. A tenotome is inserted just deep to the ligament with the blade in a vertical position. A Hey Groves knife, with a blunt rounded point, is ideal for this surgery. The conventional disposable scalpel blade and (Bard) handle are unsuitable since slight movement easily results in breakage and loss of the *blade. The cutting edge is rotated through 90° towards*

the skin and the medial patellar ligament is sectioned

Fig. 32.6

Upward patellar fixation in 15-month-old Canadian

Holstein heifer. The degree and duration of caudal extension

without damaging or entering the joint cavity. A single

were unusual. Heifer recovered following medial patellar

non-absorbable skin suture achieves adequate wound

desmotomy.

apposition. The operated cow should walk normally at

once. No deleterious long-term pathology has been

reported in operated cattle.

Both medial and lateral patellar luxation are treated

Clinical signs and diagnosis

by a joint overlap procedure. In lateral luxation the

In dorsal patellar luxation or fixation, the first sign may

femoropatellar joint is incised longitudinally about 1 cm

be initial hindlimb stiffness followed by a jerky action

(1/2 inch) medial to the patella, which is replaced in the

in which the limb remains extended caudally longer

trochlea. The capsule is closed by vertical mattress *than usual, and is then pulled forwards and upwards in*

sutures in a joint capsular overlap procedure. Some-

a movement resembling equine stringhalt (Fig. 32.6).

times this technique fails to maintain the patella in

This action may be intermittent and separated by

position. The fascia of the thigh may then be split dor-

several normal strides, or it may be repeated. If the

sally to permit replacement. Bilateral cases should be

animal is pushed backwards, the hindlimb may become

operated with a one week interval (Husband & Weaver,

fixed temporarily in extension. This extension may

1995). In medial patellar luxation, the overlap proce-

persist, whereby the foot is dragged along the ground

dure is carried out lateral to the patella.

(permanent upward fixation). Palpation reveals the

patella to be more prominent and dorsal than usual, and

the patellar ligaments are unusually easily felt. The

Stifle joint: femorotibial

patella is now resting partly in the supratrochlear fovea,

Aetiology and pathology

while the medial patellar ligament is felt to be fixed *around the medial trochlear ridge.*

Complete femorotibial luxation is rare and incurable.

Both medial and lateral patellar fixation are associ-

Subluxation is relatively common and is typically seen

ated with a characteristic posture. The stifle is markedly

in the mature cow or bull as a result of primary cranial

flexed, and the limb collapses on weight bearing, exactly

cruciate injury (see p. 455). Predisposing factors include

as in femoral paralysis (p. 437). Bilaterally affected calves

heavy weight and sudden twists and falls as when

prefer recumbency. The patellar position is obvious visu-

mounting or being mounted by cows in oestrus. The

ally and on palpation. It can usually be replaced on to the

cranial cruciate ligament is partially or completely rup-

femoral trochlea but may immediately reluxate. Radi-

tured (Fig. 32.7). Damage to the caudal cruciate is less

ography can confirm the abnormal position but is a

likely. One or both tibial menisci are often torn and dis-

superfluous procedure. Differential diagnosis includes

placed at the time of rupture (Fig. 32.8). Secondary

femoral nerve paralysis, quadricep muscle rupture, *osteoarthritic changes quickly develop with initial loss*

gonitis and distal femoral epiphyseal separation.

of articular cartilage from the femoral condyles,

followed by exposure and erosion of subchondral

bone and peripheral osteophyte proliferation at the

Treatment and prevention

joint margins.

Dorsal patellar luxation should be treated by medial

Detachment of the medial meniscus has been

patellar desmotomy if signs persist for more than a

reported in young (1 month to 1 year) dairy cattle

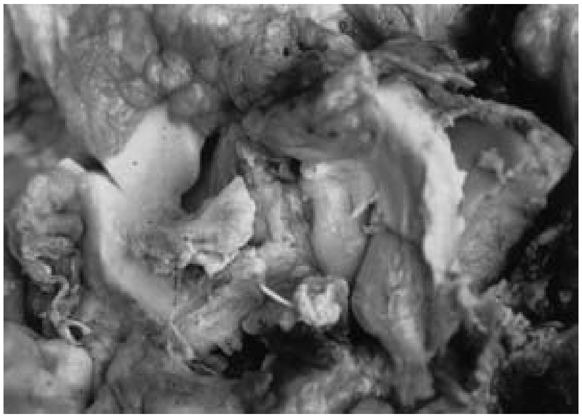


Fig. 32.8

Degenerative osteoarthritis of stifle joint of aged cow exposing damaged menisci and tibial condyles. Menisci are eroded and partially detached, allowing partial eburnation of the underlying tibial condyles. Surrounding musculature is pale due to extensive fibrosis.

and if radiographic facilities are available, lateral views of the stifle may demonstrate significant (approximately 2.5 cm (1 inch)) cranial displacement of the tibial plateau relative to the femoral condyles. In some cattle, arthrocentesis is advisable to rule out septic gonitis and to demonstrate the presence of cartilaginous debris and blood in the femorotibial joint. Other differential diag-

Fig. 32.7

Degenerative osteoarthritis of stifle of aged beef cow

noses include collateral ligamentous injuries, patellar *showing ruptured cranial cruciate ligament, massive osteophyte proliferation along margins of femoral trochlea and cartilaginous fracture, and, in young cattle, proximal tibial epiphyseal*

loss on femoral condyles.

separation.

Treatment and prevention

following injury to the medial collateral ligament.

Radical surgery involving replacement of the ruptured

Mounting activity has been postulated as a major

cranial cruciate ligament by skin or synthetic material

aetiological factor (Nelson et al., 1990).

has occasionally been successful. These cases have

either been experimental animals in which the ligament

has been sectioned, or smaller animals in which surgery

Clinical signs and diagnosis

has been done very soon after the original injury.

A sudden onset of a medium degree lameness is char-

Most cases have lacked adequate long-term follow-up

acteristic of femorotibial subluxation due to cruciate

studies.

injury. There is generalized soft tissue swelling and

crepitus may be spontaneous or may be induced by *rotating the point of hock laterally and medially to*

Fetlock joint: metacarpophalangeal

produce some rotation of the tibial joint surfaces. The

and metatarsophalangeal

tibial tuberosity may be unusually pronounced and a

Aetiology and pathology

‘drawer-forward’ sign may be demonstrable initially.

The animal, placed in lateral recumbency with the

Dislocation is rare. It invariably involves rupture of

affected limb uppermost, has the stifle put into moder-

both collateral ligaments as well as the intra-articular

ate extension. The clinician then attempts to move the

structures. Trauma is usually so severe that massive soft

proximal tibial region cranially, relative to the femoral

tissue injury exposes the joint surfaces. Subluxation

condyles. Sometimes this movement is even apprecia-

either in a medial – lateral or cranial – caudal direction

ble as the animal walks. If not diagnostic on palpation,

is seen sporadically.

Clinical signs and diagnosis

screws can be drilled from the caudal surface of the cal-
caneus into the distal portion of the tibial shaft to
Clinical signs include a non-weight bearing stance,
immobilize the tarsus for some weeks so that fibrous
swelling, obvious gross displacement and crepitus on
repair at the rupture site can take place.
manipulation of the distal extremity. Diagnosis is
Cranial tibial (peroneus tertius) rupture is also trau-
usually easy. Differential diagnoses include epiphyseal
matic, resulting from falls or from excessive traction
separation in calves, and distal metacarpal, metatarsal
upwards of the hindlimb by ropes strung over an over-
and proximal phalangeal fractures. Subluxation pres-
head beam and followed by severe struggling. The
ents with similar signs of gross swelling but crepitus may
animal has a characteristic gait. While the hock is
be hard to elicit. Subluxations can be successfully
abnormally extended, the stifle remains flexed, in other
reduced following sedation and extension. A support
words the reciprocal stifle–hock action is lost. When
bandage or cast should be applied subsequently.

standing, any abnormality may be hard to detect, but

the limb can be extended caudally so that the metatar-

Treatment and prevention

sus and tibia form a straight line while the stifle remains

flexed. The gastrocnemius tendon is then slack. The site

Treatment is usually hopeless. If the joint surfaces can

of muscle rupture varies from its origin in the extensor

be replaced to be congruent, a synthetic collateral liga-

fossa of the femur to the insertion and to the muscle

ment may be inserted by utilizing steel wire anchored

belly itself. Some area of painful swelling is apparent

to screws drilled into each epiphysis. Alternatively, the

and most cases respond to stall rest over a period of one

ligaments may be replaced with polypropylene mate-

to four weeks.

rial. It is usually impossible effectively to suture

Adductor muscle damage has been briefly discussed

together the ruptured ends. In young calves the syn-

under downer cow syndrome (see p. 439).

thetic material may require later removal to permit

Ventral serrate rupture is spectacular due to loss of *normal growth of the epiphysis, otherwise the material*

its normal anatomical function of supporting the chest

is left in situ. Meniscopexy was successful in treatment in the form of a sling between the forelegs. The scapu-of 20 out of 27 young cattle with medial collateral liga-

lar cartilage projects above the level of the thoracic

mentous and medial meniscal injury (Nelson et al.,

spine and is readily palpated subcutaneously. The

1990).

prominence varies in degree, being more obvious when

weight is borne and less obvious in the forward swing

Muscle and tendon injuries

of the limb. Colloquially termed ‘loose shoulder’,

Channel Island breeds, especially the Jersey, appear

to be predisposed. This feature may reflect a smaller

Introduction

muscle mass relative to body weight. The aetiology in

The muscles most liable to rupture include the gas-

young cattle is possibly related to muscular dystrophy

trocnemius, the adductor group and the cranial tibial

(vitamin E and Se deficiency; see page 258). Cases may

(peroneus tertius). All three are particularly liable to

be associated with turn-out to pasture. Pathological

damage when a heavy cow is struggling to rise postpar-

examination of chronic cases in adult cattle reveals

tum (see Downer cow syndrome, p. 439).

severe muscle degeneration, fibrous tissue proliferation

and serous infiltration. While mild cases may recover

completely, complete rupture is incurable, but animals

Specific muscles

move around well, remain productive and emergency

The gastrocnemius is particularly exposed to damage as

slaughter is rarely necessary.

a primary extensor of the hock. Prolonged recumbency,

excessive weight, and possibly mineral imbalance

leading to a degree of osteomalacia can predispose to

Contracted flexor tendons

gastrocnemius rupture.

The common site is the tendon–muscle junction. The

Aetiology and pathology

rupture is usually complete and leads to considerable

swelling due to extravasation of blood and the devel-

Contracted digital flexor tendons are the commonest opment of oedema. The hock is dropped and weight

congenital abnormality in cattle. The name ‘contracted

bearing is minimal. Diagnosis is rarely in doubt since

tendons’ is a misnomer, as the primary abnormality is

the clinical picture is typical.

an arthrogryposis or articular rigidity, usually in flexion

Gastrocnemius muscle rupture is treated by stall rest

(Fig. 32.9). Most cases are mild and self-correcting as

and maintenance of the hock in extension by means

the calf moves around to an increasing extent. Some

of a Thomas splint. In yearling animals, compression

are more severe and sometimes associated with

diameter polyvinyl drainpipe may be placed on a well-

padded limb to immobilize the flexed joints in *maximum extension. Such a splint in a neonatal calf must be checked by weekly removal and replacement. The toes should be left exposed to encourage weight bearing and walking. If the stance is not corrected in four weeks, surgery is indicated.*

More severe cases will only respond to desmotomy, which should be undertaken at two to three weeks old, after the immediate neonatal stress period. Correction of carpal flexion is possible at the mediopalmar side of the carpus by an initial longitudinal incision through the retinaculum flexorum, exposure of the superficial part of the superficial flexor, and by complete transection of the retinaculum flexorum, which also involves section of the radial carpal flexor. If normal extension is not

Fig. 32.9

Contracted flexor tendons (forelimb) and flexed hocks

achievable, the deep flexor and deep part of the super-

in a neonatal Holstein calf, which was unable to stand. Syn-

ficial flexor are transected, preserving carefully the neu-

onyms: arthrogryposis or articular rigidity.

rovascular bundle of median artery, vein and nerves.

Finally, the palmar carpal ligament may be sectioned.

Exceptionally, with a radius–metacarpus angle <100°, it

other congenital defects such as cleft palate and

may be preferable to perform radiocarpal arthrodesis

arthrogryposis (see p. 177).

with resection of one or both carpal rows. The wound

Contracted tendons usually affect both deep and

is closed by sutures and then bandaged and cast for five

superficial flexors, and sometimes the suspensory liga-

weeks.

ments (see p. 178). The condition is bilaterally sym-

Correction of fetlock flexion is similarly a multistep

metrical in the forelimbs. The hindlimbs may have

procedure. The skin incision is at the mediopalmar

abnormal hock extensor rigidity and fetlock flexion.

aspect of the metacarpus, and the superficial portion of

Some breeds (e.g. Belgian Blue) have a very high

the flexor tendon is transected. The deep flexor and

incidence in which a relationship is suspected between

deep part of the superficial tendon may be sectioned

relatively excessive fetal size and abnormal intra-

similarly for adequate extension. Small stab incisions

uterine posture. Dystokia is almost invariable in such

may be made in the suspensory ligament. Bandaging

cases. Akabane virus and the ingestion of various toxic

and cast immobilization of the limb are again necessary.

plants (e.g. Lupinus species and locoweed) have been

Surgery is likely to be unsuccessful in very severe

alleged in other high incidence outbreaks.

cases of contracted tendons where abnormal flexion

creates an angle of <90°

between radius and

metacarpus.

Clinical signs and diagnosis

Prevention of the primary aetiological stimulus is

Mild cases show about 10–20° excessive flexion of the

difficult as arthrogryposis leading to contracted tendons

carpus and fetlocks. Forced extension discloses the taut-

may result from infectious agents (bovine virus diar-

ness in the flexor tendons and suspensory ligament. The

rhoea (BVDV), akabane virus) or toxic plant material.

abnormality is generally symmetrical. Some calves may *have a split palate and arthrogryposis of the carpi and*

Traumatic flexor tendon injuries

tarsi. Joints are not swollen and extension is not unduly

painful. When moved, mild degrees of abnormal flexion

Sporadic traumatic injuries occasionally affect the

will result in calves moving on the pastern, but, in severe

flexor tendons and often result from contact with farm

cases, the calf is totally recumbent or will walk on the

machinery. Adult cows may injure both deep and super-

distal skin of the fetlock and rapidly develop abrasions

ficial flexor tendons in the metatarsal region, and an

and cellulitis, perhaps allowing secondary infection to

open infected wound results. Careful debridement

establish itself and bring the risk of a septic arthritis.

under IVRA is indicated. A septic tenosynovitis neces-

sitates pressure lavage with sterile isotonic saline b.i.d.

for several days and systemic antibiotic cover. Selected

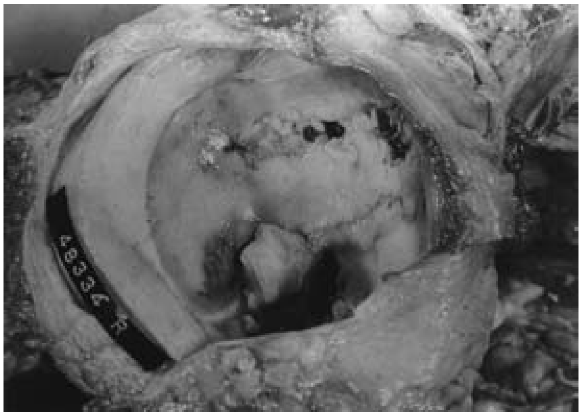
Treatment and prevention

cases of complete transection of both flexor tendons

Some cases resolve but in others splinting of the leg is

may heal following tenorrhaphy (e.g. carbon fibre or normally sufficient. A half-section of a 5 cm (2 inch)

polyamide) and application of a limb cast. Despite



prolonged convalescence most cases continue to be lame

Treatment and prevention

and the prognosis is guarded (Anderson et al., 1996).

Theoretically, as in the horse and dog, removal of the

cartilaginous flap and curettage of the underlying bone

is indicated. Surgical treatment has, however, not been

Joint diseases

adopted in cattle for economic and anatomical reasons.

Management measures in high-incidence situations in-

Osteochondrosis

clude a more restricted calorie intake and transfer to a

softer bearing surface to reduce concussion. Lame

Aetiology and pathology

steers should be confined. Osteochondrosis in a bull

should stimulate consideration of its conformation as a

Osteochondrosis (OCD) is seen in young fast-growing

possible predisposing factor.

beef cattle on a high calorie intake. Recently an

American series of 29 cattle with osteochondrosis was

dominated by dairy breeds, primarily mature males

(Trostle et al., 1997). Normal endochondral ossification

Hip dysplasia

is disturbed at the cartilaginous endplate of the epiph-

Aetiology and pathology

ysis and at the metaphyseal growth plate, and is associ-

ated with a failure of vascular invasion. The thickness

Hip dysplasia is seen in bulls of various fast-growing

of articular cartilage increases as a result of continued

beef breeds,

predominantly the Hereford and

growth and lack of wear, whereupon the failure of ade-

Aberdeen Angus, though isolated cases have been

quate nutrient diffusion causes a degeneration of the *reported in numerous other breeds. In the Hereford chondrocytes. The result is a characteristic cleft for- breed, particular families have been alleged to have a mation, producing cartilaginous flaps that undergo high incidence. The condition is probably a sex-linked endochondral ossification (osteochondrosis dissecans). heritable characteristic. Although some cases are Another process is the formation of subchondral cyst- observed in the neonate, most develop in calves four to like lesions.*

twelve months old with erosion of the acetabular carti- It is not yet known to what extent the changes are lage close to the attachment of the accessory cartilage, generalized, as most surveys have only examined spe- which normally functions to extend the effective artic- cific joints (e.g. stifle, carpus or atlanto-occipital). ulating surface (Fig. 32.10). The femoral articular carti- Changes tend to be symmetrical. Sometimes the joint lage usually undergoes a shallower but more extensive surfaces of several forelimb bones are normal, while sig- erosion.

nificant changes occur in their physes. Osteochondrosis

Later changes include traumatic synovitis, fraying of

has been reported in the coxofemoral, femoropatellar,

the intra-articular ligament, and a tendency to subluxa-

femorotibial and tibiotarsal joints of the hindlimbs, and

tion. Secondary degenerative joint disease follows in a

in the scapulohumeral, humororadial, radiocarpal, and

few weeks.

metacarpophalangeal joints of the forelimbs.

Clinical signs and diagnosis

Steers and young bulls are predominantly affected.

Some lesions cause no clinical signs, while others

produce a mild progressive lameness. Some lesions heal

following production of fibrocartilage. This accounts for

the larger percentage of lesions in autopsies than in

clinical series of lame cattle. Other lesions progress to

become a secondary degenerative osteoarthritis or

degenerative joint disease (DJD). Exacerbations of a

mild slight lameness have been attributed to additional

joint trauma. If warranted, a doubtful case may be

radiographed, but cartilaginous defects are unlikely to *be demonstrated unless pneumoarthography is per-*

formed. Suspicious evidence of osteochondrosis is the

Fig. 32.10

Severe hip dysplasia seen in right acetabulum of

presence of a free calcified body within the joint ('joint

nine-month-old Hereford bull. Severe fissuring and loss of carti-mouse').

lage and erosions in subchondral bone.

Degenerative arthritis

Aetiology and pathology

Degenerative arthritis (degenerative joint disease,

DJD) is attributed to a 'wear-and-tear' phenomenon.

This chronic non-infectious disease involves primary

degeneration of articular cartilage, generally accom-

panied by secondary sclerosis and eburnation of sub-

chondral bone, peripheral osteophyte formation and

surrounding soft tissue proliferation.

Though a common incidental finding at slaughter, its

primary clinical significance is as a cause of progressive

debilitating lameness involving major weight-bearing

joints. In one study of the stifle and hip joints of cattle

Fig. 32.11

Severe hip dysplasia evident in ventrodorsal

disease, atrophy frequently led to partial condemnation

radiograph of pelvis of five-month-old Angus bull that had

at slaughter (Weaver, 1977). A recent US study in 21

experienced progressive hindlimb lameness for two months.

processing plants revealed that 11.9–16.5 per cent of

Both femoral heads are subluxated and severe secondary

beef and dairy cows and bulls had stifle arthritis

osteoarthritis affects the acetabular rims.

(‘stifled’) or a broken leg. The stifle injury resulted in

the loss of 17.9 kg tissue from trimming ($9.72 per

carcase) (Roeber et al., 2000). Other studies have shown the frequent involvement of the hock and carpal joints.

Clinical signs and diagnosis

Overweight and straightlegged cattle may be predis-

Lameness develops slowly and is preceded by a period

posed to early DJD but control studies are lacking.

in which abnormal lateral swinging of the hindquarters

An inherited DJD of the stifles of Holstein cattle has

is seen. The bull calf spends increased periods in recum-

been reported (Kendrick & Sittmann, 1966). Nutri-

bency. Feed intake is reduced and hindquarter atrophy

tional imbalance leading to osteochondrosis (see p.

starts. Unilateral or bilateral crepitus is detectable in

453), which can lead to secondary DJD, is another aeti-

the hip region and may be localized more precisely if

ological possibility.

rectal palpation is feasible. The development of sub-

Subchondral bone cysts were the most frequent cause

luxation is recognizable from demonstration of the

of stifle lameness in a Canadian survey (Ducharme et

Ortolani sign: with the hand resting on the skin over

al., 1985). The lateral tibial condyle was most frequently the greater femoral trochanter, when weight is taken off

affected, followed by the opposing femoral condyle.

the hind leg, a distinct 'plop' is felt as the femoral head

The age range was six to eighteen months.

drops into the acetabulum from its previous position on

Early fibrillation of articular cartilage leads to

the dorsal acetabular rim.

necrotic and degenerative chondrocytes, which results

In smaller calves, ventrodorsal pelvic radiographs

in decreased proteoglycan production in the cartilagi-

may demonstrate secondary joint changes and a ten-

nous matrix. The cartilage becomes soft and somewhat

dency to subluxàtion (Fig. 32.11). Any radiographic

yellowish. Chondrocyte destruction causes release of

suggestion of shallowness of the acetabulum is usually

lysosomal enzymes, especially cathepsin D. Fibrillated

the result of the secondary changes and not a primary

cartilage withstands stress relatively poorly, and fissur-

anatomical feature.

ing, thinning, or cartilaginous erosion follows.

Differential diagnosis is important in apparently uni-

Pain in DJD originates from the exposed subchondral

lateral cases. Stifle disease, acetabular and other pelvic *bone and from the associated capsulitis and synovitis.*

fractures, hip luxation and slipped femoral epiphysis are

Clinically, the joint enlarges as a result of the increased

all to be considered. A confirmed bilateral hip lameness

volume of synovia and soft tissue proliferation.

in young bulls is usually diagnostic of hip dysplasia.

Clinical signs and diagnosis

Treatment and prevention

A progressive lameness with gradual muscle atrophy

No successful treatment has been reported. Affected

and weight loss is commonly seen. The affected limb,

bull calves and yearlings should be slaughtered. The hip

usually hind, tends to be dragged as flexion of the

joints should be retained for pathological confirmation

affected joint is reduced. Movement of the stifle or hock

of the clinical diagnosis.

results in palpable joint enlargement. In the stifle,

proliferative changes (osteophyte formation, periartic-

tides and is considerably more expensive. Prolonged

ular fibrosis) affect both femoropatellar and femorotib-

low-dosage therapy with phenylbutazone in cattle with

ial compartments, and crepitus may be noted. Some

painful arthritides has not led to any demonstrable

cases of stifle DJD reflect a secondary response to

deleterious effects such as gastrointestinal ulceration or

cranial cruciate rupture or meniscal injury. In the hock,

renal papillary necrosis. Corticosteroids and dimethyl

major changes are usually seen craniomedially, affect-

sulphoxide (DMSO) have also been advocated. The

ing the intertarsal and tarsometatarsal joint space

majority of young cattle with stifle lameness due to sub-

(similar to equine 'spavin'). Relatively rarely do

chondral bone cysts formation recovered following con-

changes extend proximally to the tibiotarsal joint.

servative treatment (Ducharme et al., 1985). Preventive Degenerative joint disease of the hip can be suspected

measures include attention to the conformation of

in older cows when the more distal parts of the limb

further breeding stock, especially bulls, to avoid a

are normal clinically and where crepitus can be

hindlimb conformation that is liable to lead to exces-

detected over the gluteal region and confirmed on

sive concussive forces in progeny.

rectal palpation.

Subchondral bone cysts can only be diagnosed on

radiographic examination. Cases of DJD, ligamentous

Infectious (septic) arthritis

rupture and septic arthritis show ranging radiographic

features. Degenerative joint disease of the stifle and

Introduction

hock shows the extent of the proliferative reaction.

Infectious arthritis in this context is synonymous with

Lateral radiographs of the stifle in rupture of the cranial

septic arthritis. The rare primary septic arthritis devel-

cruciate ligament have the 'drawer-forward' features

ops from direct joint penetration by a contaminated

seen in dogs. Septic arthritic cases on radiography

foreign body. This section considers secondary septic

demonstrate soft tissue swelling and distension of the

arthritis resulting from spread of pathogens from an

joint capsule in early cases and, when more advanced,

adjacent localized focus, and tertiary septic arthritis *the radiographic changes include loss of subchondral*

resulting from systemic or haematogenous spread from

bone.

a focus elsewhere in the animal.

Synovial fluid analysis is only justified when the dif-

ferential diagnosis includes infectious arthritis or when

fluid is withdrawn prior to injection of a local analgesic

Septic arthritis: joint ill in neonate *(see p. 249) solution to assess whether lameness is lessened.*

Aetiology and pathology

Synovia in DJD is clear or slightly turbid, increased

in volume, does not clot, has a low (<15 per cent)

Joint ill in calves is classified as a tertiary septic arthri-

polymorphonuclear lymphocyte count,

a normal

tis. The primary infection is in the umbilicus, often as an

protein (<2 g/dl), and a near-normal mucin precipitate

umbilical abscess with extension along the umbilical

(Weaver, 1997).

veins towards the liver. Otherwise, spread is from a

Differential diagnosis, apart from infectious forms of *primary enteric infection. Common pathogens isolated*

arthritis, includes fluorosis as a primary cause of DJD,

are Escherichia coli, Streptococcus and Staphylococcus osteoporosis, rickets and osteoarthritis deformans, all

spp., Arcanobacterium pyogenes, Erysipelothrix in-

three of which occur in young growing animals, and

sidiosa and Salmonella spp. Usually, more than one osteomalacia. A sudden onset of lameness sometimes

joint is affected, commonly the carpus, tarsus and

represents an exacerbation of a non-clinical DJD fol-

femorotibial joints. The route of haematogenous spread

lowing a periarticular fracture (e.g. caudal surface of

is through metaphyseal or epiphyseal vessels or, alter-

tibia in femorotibial DJD).

natively, the synovial membrane. Establishment of foci

of infection is naturally favoured by the slowed flow

rate of blood through a network of venous sinusoids in

Treatment and prevention

the metaphyseal vessels.

Treatment is purely palliative. Affected cattle should be

Pathological changes start with an intense polymor-

rested. Ketoprofen (10 per cent solution iv or im) has *phonuclear inflammatory response in the synovial recently been shown to have analgesic properties in membrane, the permeability of which is increased, per-lame cattle. Phenylbutazone may be given (initially mitting protein leakage into the synovial fluid. Later 5 mg/kg orally daily, then 5 mg/kg every second day) release of lysosomal and other enzymes into the for its analgesic and anti-inflammatory properties. synovia causes degeneration of the articular cartilage, Aspirin (100 mg/kg orally b.i.d.) is an alternative which is weakened by defective nutrition due to an regimen. Flunixin meglumine has few obvious advan-overlying fibrin deposit. The result is extensive loss of tages over either phenylbutazone or aspirin for arthri-articular cartilage, acute synovitis, thickening of the*

colostral intake) are at higher risk. Lameness becomes severe after a few days.

Radiology is not a great aid to diagnosis, as the only initial abnormality is the soft tissue swelling. After two to three weeks, changes suggestive of joint destruction are apparent.

Arthrocentesis is a more valuable aid to diagnosis in early cases. Apart from an increased volume, synovial fluid in a calf with joint ill is turbid, clots, and has a loose flaky character in the mucin precipitate. The protein *content is >5 g/dl and a Giemsa smear reveals an almost pure (98 per cent) and massive population of polymorphonuclear lymphocytes. Taken aseptically, synovial fluid may be submitted for culture, but is often problematical with this particular material (see p. 457). Differential diagnosis must be made from physeal and intra-articular fractures.*

Treatment and prevention

Early and vigorous treatment is essential in joint ill. High therapeutic levels of systemic antibiotics should be given for two to three weeks. Intra-articular antibiotic medication is usually contraindicated, as the blood supply ensures adequate concentrations are obtained in synovia following systemic injection. Suitable antibiotics include penicillin, ampicillin and tetracyclines. Joint lavage with a sterile polyionic solution or

Fig. 32.12

Extensive soft tissue swelling of lateral aspect of left

physiological saline is helpful. Generally, an in–out,

carpal region in a six-month-old Hereford calf. Bone lysis is

through-and-through system using two 14 gauge *evident in the distal part of the radial carpal and fused second needles is effective. Open arthrotomy with removal of*

and third carpal bones. Lysis resulted from transverse fracture the fibrin clots and purulent material along with curet-of the proximal surface of the distal component of the joint.

tage of the articular surfaces has been successful in

Recovery followed removal of the bone fragment, curettage

some series. It appears more useful in less complex

and irrigation.

joints such as the stifle and fetlock rather than in carpus

or tarsus.

Recently intra-articular therapy with gentamycin-

impregnated polymethylmethacrylate beads has proved

joint capsule, and sepsis in the growth plate and

useful in neonatal septic arthritis with concurrent

metaphysis (particularly associated with salmonella

osteomyelitis. Such beads must be removed at a second

infection).

surgery. Use of gentamicin-impregnated collagen

sponges (Garamycin,

Essex Chemie,

Lucerne,

Switzerland) which do not need later removal appear

Clinical signs and diagnosis

more promising, and further larger studies are awaited

The first sign is lameness. Later, joint swelling (Fig.

(Steiner & Zulauf, 2000).

32.12) and pain are apparent. The joint capsule may be

Supportive care is important. Casting for three weeks

distended from an increased synovial volume. The pres-

of joint immobility (e.g. in fetlock) followed by band-

ence and physical nature (serous, fibrinous or purulent)

aging for support reduces discomfort and so maintains

of such synovial effusions can be readily detected on

the appetite. Low level oral dosage with phenylbuta-

ultrasonography (7.5 mHz linear transducer) in carpal,

zone can improve the general attitude (p. 1050). Some

stifle and hock disorders (Kofler & Martinek, 2000).

calves also require management of the enteritis by fluid

The polyarthritis is rarely symmetrical. Not all cases are

therapy (see pp. 195, 209) and others require drainage

associated with either gross umbilical sepsis or with

of an umbilical abscess. Inadequate levels of gamma *severe enteritis. Calves that are immune depressed as*

globulins may, with difficulty due to the large volumes,

a result of low gamma globulin levels (inadequate

be corrected by giving intravenous plasma.

Septic arthritis: older cattle

coccus and Streptococcus spp. Fusobacterium necrophorum and Bacteroides melaninogenicus (anaerobe) Aetiology and pathology

have occasionally been reported. The major problem

The main site of septic (infectious) arthritis in mature

is A. pyogenes. Once infection is in the synovial *cattle is the distal interphalangeal joint resulting from*

fluid, joint destruction involves the same processes as

secondary spread from a focus in the sensitive solar

described for DJD. The difference lies in the speed of

laminae or from complications of interdigital necro-

destruction. The synovia is usually turbid or frankly

bacillosis (see pp. 420 and 426).

purulent.

Septic digital arthritis is fully discussed elsewhere (p.

Some reports from the UK (Bracewell & Corbell,

455). Other joints liable to be affected by septic arthri-

1979; Wyn-Jones et al., 1980) and USA (Madison et al. , tis include the fetlock, either by extension along the

1989) noted an idiopathic, acute suppurative gonitis

digital flexor sheath from a digital focus, or by direct

with severe lameness and synovitis. Articular erosions

trauma from a deep wound (Fig. 32.13). The major

were evident radiographically on the lateral tibial

hindlimb weight-bearing joints, the tarsus, stifle and hip

plateau. Much evidence indicates the likelihood that

are occasionally involved as a result of haematogenous

Brucella abortus vaccination may have been the cause.

spread such as pyaemic vegetative endocarditis (e.g.

from primary reticuloperitonitis) or in the tarsus

Clinical signs and diagnosis

from contiguous spread from an infected subcutaneous

bursitis.

Septic arthritis in a major weight-bearing joint causes

Organisms commonly recovered from septic arthritis

a rapidly progressive disease with severe lameness,

in adult cattle include A. pyogenes, E. coli, Staphylo-swelling and localized pain. In contrast to DJD, the

animal may be anorexic and milk yield can drop

abruptly in dairy cattle. Crepitus is not usually appar-

ent. Arthrocentesis reveals a flocculent or purulent fluid

that clots. It has a high leucocyte count of which over

90 per cent are polymorphs. The protein content often

exceeds 8 g/dl and the mucin precipitate is abnormally

flocculent.

A category 'suspect septic' refers to an early septic

process associated with obvious lameness but appar-

ently normal yellow synovia. The presence again of a *high percentage of neutrophils in a dense leucocyte population is confirmation of early septic arthritis.*

Radiography in early (<10 days duration) septic arthritis is usually unhelpful. Ultrasound, on the other hand, can delineate the limits and physical nature of the fluid. From 14 days onwards, subchondral bone destruction and a peripheral periostitis are suggestive of joint sepsis.

Culture of synovial fluid is frequently negative in terms of isolation of pathogens, especially if antimicrobial therapy has already started. It is helpful if synovia is immediately inoculated into a diphasic culture bottle with sodium polyanetholsulphonate to enhance recovery of the organism. Culture of synovial biopsy material is usually more rewarding but is frequently impractical.

Treatment and prevention

The prognosis for septic arthritis is guarded or poor. Early aggressive treatment is essential. Parenteral

Fig. 32.13

Massive periosteal proliferation of fetlock region (metatarsophalangeal joint) of a four-year-old Holstein cow

antibiotic therapy should be initiated as soon as pos-

resulting from sepsis of the joint originating from an ascending sible. Until sensitivity, based on synovial cultures,

septic tenosynovitis.

is available 48 hours after sampling, penicillin or

ampicillin is the drug of choice for most pathogens.

This spasm leads to severe extension of the hock. The

Penicillin is most likely to be effective in vivo against condition has been observed in numerous breeds, but

all common pathogens except Staphylococcus aureus

the highest incidence in dairy and beef cattle respec-

(where erythromycin, lincomycin, gentamicin, or

tively is probably in the German and Dutch Friesian

cephalosporin may be better) and coliforms (gentam-

and the Aberdeen Angus.

icin or trimethoprim–sulphadiazine).

It is hypothesized that an overactive stretch reflex is

The joint should be irrigated and drained (through-

the major mechanism (De Ley & De Moor, 1977).

and-through lavage) through two wide-bore

Selective deafferentation of the gastrocnemius muscle

inflow–outflow portals produced by 14 gauge needles.

by resection of the dorsal root fibres containing affer-

Alternatively, small arthrotomy incisions may be made

ent nerve fibres (L5–6) abolished clinical signs. Plasma

for the same purpose. Irrigation should be done with

SGOT is reduced, and alkaline phosphatase is increased

large volumes (>5 l) of polyionic solutions, physiologi-

in affected calves, which also show a decreased P, Ca,

cal saline, or with dilute (0.1 per cent) povidone-iodine

and homovanillic acid concentration in CSF. The last-

solution.

named effect indicates a lowered metabolic rate of CNS

Radical surgery also has a place if suitable facilities

dopamine (De Ley & De Moor, 1975).

exist for the maintenance of asepsis and for general

Gross and histopathological CNS lesions have gen-

anaesthesia. Radical surgery comprises opening the

erally been absent.

joint following section of collateral ligaments and inci-

sion of joint capsule, evacuation of purulent material,

Clinical signs and diagnosis

curettage of infected cartilaginous surfaces, restoration

of joint stability by suturing capsule and ligaments, and

The typical clinical signs are characteristic, and diffi-

immobilization of the area, if in the distal limb, to

culty arises only in very early cases. Signs may start at

prevent ankylosis. Such surgery appears more success-

six weeks to six months, rarely later. Cases encountered

ful in the fetlock, carpus and tarsus than in the stifle,

in adult cattle are best considered to be forms of pro-

elbow, or shoulder joints.

gressive hindlimb paralysis, likely to involve spinal cord

Idiopathic gonitis (p. 1014) carries a good prognosis

pressure resulting from vertebral exostoses.

for recovery, regardless of the method of treatment.

The affected hindlimb is extended so that the hock

Heifers were treated successfully with a variety of

angle is approximately 180° (normal is about 140°). The

antimicrobials, including procaine penicillin G, neomycin

calf walks with a tendency to drag the toes. The limb may

and ampicillin, and, in some cases, with through-and-

jerk intermittently at rest. It is advanced in a pendulum-

through needle lavage with a polyionic solution. Lateral

like style. Later, less weight is taken and the calf may hop

patellar arthrotomy with curettage of lytic areas on the

forward. Palpation reveals a very firm gastrocnemius

lateral tibial plateau may be useful adjunct therapy.

muscle and tendon. The hock can be flexed manually

There is no place for intra-articular antibiotics.

without causing pain. On release the hock immediately

Drainage of infective material from a poorly vascular-

adopts the original extended position (Fig. 32.14).

ized area is important, whereas systemic antibiotics ade-

Lateral radiographs of the hock of calves affected for

quately penetrate the well-vascularized joint capsule.

several weeks show several features indicative of the

Antibiotics should be given for at least two weeks.

chronic overextension. The distal part of the tibial

Preferred antibiotics are usually penicillin G, ampi-

metaphysis is abnormally curved caudally; the distal

cillin, ceftiofur and gentamicin. Non-steroidal anti-

tibial and tuber calcanei growth plates are widened;

inflammatory drugs should be given if pain is severe and

exostoses are present around the distal tibial growth

persistent. The dosage is as for cases of DJD *(see p. 455).*

plate, along with some osteoporosis. Often the most

striking feature is a cranial curvature of the proximal

part of the calcaneus.

In early cases, differential diagnosis includes dorsal

Miscellaneous neuromuscular

patellar luxation, septic or non-infectious gonitis or tar-

diseases

sitis, fracture dislocation of the calcaneus, joint ill and

luxation of the biceps femoris muscle.

Spastic paresis *(see also p. 179)*

Aetiology and pathology

Treatment and prevention

Spastic paresis is a progressive condition of the hind-

Since spastic paresis has a hereditary predisposition,

limbs of unknown origin. It is characterized by con-

breeding animals should be salvaged. Surgery can suc-

traction of the gastrocnemius muscle and tendon and of

cessfully alleviate the condition by either tenotomy or *other associated calcanean tendons and muscle bellies.*

neurectomy.

muscle is awkward, complete tibial neurectomy has been advocated (Boyd & Weaver, 1967). Surgery is performed under sedation and epidural block, or general anaesthesia. The site is the lateral thigh, between the two heads of the biceps femoris muscle. The tibial and peroneal nerves are identified by stimulation by forceps or by electrical means. Tibial nerve stimulation causes hock extension and fetlock and digital flexion. The tibial nerve should have a 2 cm (1 inch) portion removed at its most proximal point. Complications following this surgery are uncommon.

Spastic syndrome

Aetiology and pathogenesis

Fig. 32.14

Severe spastic paresis of left hindlimb of a

four-month-old Friesian heifer, showing overextension of hock

This chronic progressive disease, which is initially char-

joint. Note spasm and elevation of the tail, and arched back

acterized by clonic–tonic spasms of the hindlimb

as calf attempts to put more weight on the forelimbs.

musculature, is also known as 'crampy', 'stretches'

or progressive hindlimb paralysis. The aetiology is

unknown despite several attempts to find significant

pathological lesions in the brain or spinal cord. Idio-

pathic muscular cramps is one current proposed expla-

Tenotomy has traditionally involved section of the

nation for the signs (Wells et al., 1987).

gastrocnemius tendon and partial section of the super-

The condition occurs in mature cattle of many

ficial flexor tendon a little proximal to the point of the

breeds, both dairy (e.g.

Holstein, Friesian and

hock in the standing animal under local anaesthetic

Guernsey) and beef (Hereford, Angus). The incidence

infiltration. A 6 cm (21/2 inch) vertical skin incision is

in at least one breed (Danish Red) is significantly

made caudally over the Achilles tendon to expose the

higher in bulls than cows. Many affected cattle have

two tendons. After section, the skin is sutured and the

straight rear legs and poor hock conformation. Many

immediate surgical effect is usually pronounced hock

bulls with spastic syndrome have spinal spondylosis. A

flexion, with the joint initially close to the ground.

single recessive gene with incomplete penetrance may

Initial results have been consistently favourable, but a

be the mode of inheritance.

gradual recurrence of the abnormal posture is fre-

quently seen, especially in older (six to ten-month-old)

calves. Bilaterally affected calves should have the

Clinical signs and diagnosis

second leg operated four weeks following initial

surgery.

Sudden episodic spasmodic contractions affect the

It has been claimed that this classical operation *muscles of both hindlegs, and sometimes also the back, ignores the fact that a second, deeply situated, tendon neck and forelegs. The animal appears to be normal of insertion of the gastrocnemius muscle is left during recumbency. Signs are evident soon after rising. untouched. A modified operation, therefore, involves a The onset of the syndrome is slow, and signs may lateral approach just cranial to the Achilles tendon, appear for a few months only to disappear for several which is dissected to isolate the caudal component of weeks. The hindlimbs are hyperextended caudally in a the gastrocnemius tendon, from which a 2 cm (1 inch) fixed manner that may persist for several minutes. length is resected. The superficial flexor tendon is left Spasms may extend forward to the forelimbs and neck untouched. The cranial tendon of the gastrocnemius is muscles. The head is extended and the forefeet identified and a similar tenectomy performed. In some advanced with the back arched. If then forced to move, cases, the dense fascia caudal to the distal end of the the gait is stiff and ungainly, and episodic lifting of the* tibia is transected (Pavaux et al., 1985).

hindlimbs may also be seen during forward movement.

Neurectomy of the tibial nerve or of its gastrocne-

Animals generally spend considerable periods

mius branches is the alternative to tenotomy. Clinical

recumbent when the condition is advanced.

results have been better than with tenotomy. Since

Other conditions that may confuse an initial diagno-

identification of the multiple (seven or more) branches

sis are relatively few but include bilateral DJD affect-

of the tibial nerve innervating the gastrocnemius

ing the stifle or hock, and severe spinal spondylosis.

Treatment and prevention

pressure points and poor vascularity, may result in

localized abscessation and pyaemic spread to the lungs,

The spastic syndrome is incurable. Palliative treatment

liver, kidneys and heart. The common organism is A.

has included vitamin D, bone meal (not available in

pyogenes.

many countries) and sedatives. Phenylbutazone has

Affected cattle should be put out on soft bedding,

provided temporary relief in some cases. Affected bulls

the wounds should be cleansed with chlorhexidine

and apparently normal bulls that sire affected progeny

hydrochloride, and systemic antibiotics should be

should be culled from any breeding programme.

injected for five to seven days to prevent systemic

spread. The prognosis for healing is good if appetite is

Diseases of skin and subcutis

maintained unless clinical signs of involvement of other

organs (e.g. heart) are apparent, and suggestive of sep-

ticaemic spread.

Skin wounds are more liable around the limbs than the *trunk and head. Their nature and treatment are ade-*

quately discussed in textbooks of general surgery. One

Tarsal cellulitis

unusual bovine problem is the constricting foreign

body, usually rubber or wire, which slides over the foot

Aetiology and pathology

to the level of pastern or metacarpus or metatarsus

Almost all cases of hock enlargement result from

where it slowly becomes embedded in a mass of gran-

repeated trauma against concrete surfaces in stanchions

ulation tissue to present as a circumferential wound

or loose housing. Typically, soft tissue swelling over the

(Fig. 32.15). Such wounds require careful investigation

lateral aspect of the tarsus may be a false or acquired

because the band may be very deep and contacting

bursitis. Medial swelling of the joint is minimal unless

bone.

the lateral enlargement is pronounced. Lameness is

Two specific disorders are discussed below. Gener-

rare unless the fluid distension becomes massive, when

ally, damage to skin and subcutis is more liable over *mechanical restriction of joint flexion causes stiffness, pressure points such as the lateral aspect of the stifle, or a low-grade infection arises. Radiographs have elbow and hock. Loss of the integument permits low- repeatedly shown the absence of bone changes. grade infection to become established. In a very con- The swelling is usually symmetrical. Hair loss and taminated environment such damage, arising from skin excoriation are evident. Usually the skin is not broken. Occasionally, a central area of skin sloughs, permitting a dirty red–brown material to escape. At this time, septic infection can supervene and a purulent discharge may be noted for several days before granulation tissue fills the cavity of the false bursa.*

Clinical signs and diagnosis

The distribution of the swelling and absence of lameness are almost characteristic (Fig. 32.16). An infectious tarsitis causes a more diffuse swelling and obvious lameness, as will a tarsal bone fracture. Tarsal hydrarthrosis first causes synovial distension of the joint capsule cranially and medially, then both medial and *lateral to the caudal border of the tibiotarsal bone, and*

cranial to the base of the calcaneus. Tarsal hydrarthro-

sis is a cosmetic blemish and causes no lameness.

Treatment and prevention

The seasonal occurrence of tarsal bursitis, becoming

increasingly severe during the housed period and dis-

appearing in the summer grazing months, is evidence

Fig. 32.15

Circumferential wound of metatarsal soft tissues.

This two-year-old crossbred Hereford steer had a wire embed-

that tarsal bursitis is related to the specific environment.

ded deep to the soft tissues, resulting in mild lameness. Wound Errors and deficiencies usually can be found in the

healed in four weeks following removal of foreign body.

lying-in areas of loose-housed herds. Some cows may

Fig. 32.16

Right tarsal bursitis in a five-year-old Holstein cow

Fig. 32.17

Severe bilateral carpal bursitis in an eight-year-old

with digital problems resulting in prolonged recumbency. Left

Friesian cow associated with Br. abortus

infection

supratarsal skin shows evidence of previous injury.

(Czechoslovakia).

refuse to use cubicles and remain out on the slurry-

cellulitis in that the swelling resolves in cattle when at

covered concrete. They often have problems rising from

pasture. Some cases have been associated with Br.

the slippery surface, during which the wet skin of the *abortus infection (Fig. 32.17; see also p. 580).*

lateral part of the hock is repeatedly abraded. Other

cows suffer injury when they rise awkwardly in poorly

designed or badly bedded cubicles. Standings that are

Clinical signs and diagnosis

up to 30 cm (12 inches) too short for the particular

A soft and painless swelling develops on the dorsal

breed and neck rails placed 5 cm (2 inches) too low may

aspect of the carpus, usually with evidence of skin con-

force cows to stand with the hind feet in the passage-

tusion. It tends to be symmetrical and no breed or age

way. Careful observation (e.g. during oestrous detec-

predilection is recognized. Minor swellings are merely

tion) will usually disclose the specific problem.

a cosmetic blemish. The exceptional large grapefruit or

Treatment should be conservative and medical. It

melon-sized mass may cause slight mechanical lame-

should never involve a long incision to drain fluid from

ness but is painless. The fluid appears to be synovia-like,

the false bursa, neither should one attempt radically to

yellow and clear, but less tenacious. It is produced by *dissect out this bursa. Most cases are best left untreated*

the bursal lining. The cavity tends to be multilocular.

in the absence of lameness. If lameness eventually

Differential diagnosis from a precarpal abscess or septic

occurs as a result of a low-grade tarsal infection, sys-

carpitis, both of which are painful and cause lameness,

temic antibiotics (oxytetracyclines) rapidly reduce the

is simple.

size of the swelling. Corticosteroids are usually ineffec-

tive. Infected cases may be bandaged daily and be irri-

gated with warm water, but the response tends to be

Treatment and prevention

incomplete. A cluster of cases indicates a need to check

the loafing areas and cubicles (Hughes, 2000).

Surgical drainage is rarely necessary. Such drainage (as

in tarsal bursitis, p. 460) is fraught with the risk of intro-

ducing infection into a sterile site. The skin is more

Carpal bursitis

liable to contamination every time the animal lies

down. It is hard to protect the area with a bandage.

Aetiology and pathology

Most cases respond if placed in a well-bedded straw

Carpal bursitis or carpal hygroma involves the skin,

yard (winter) or put to pasture (summer), i.e. into sur-

subcutaneous precarpal bursa and adjacent soft tissues.

roundings where predisposing trauma can be avoided.

Very rarely does infection extend into the joint.

Drainage is needed only when gait, feed intake and

Repeated contusion from contact points of the stan-

production are affected. The drainage should be done

chions, stalls, or floor in housed cattle is the main pre-

as an aseptic procedure. A mixture of antibiotic and

disposing factor. The condition is similar to tarsal

corticosteroid solution should be instilled into various

sections of the collapsed cavity and such injection

feature of mature and older bulls. In one extensive

should be repeated at weekly intervals.

series of bulls followed to slaughter, severe signs of tail

Radical surgical removal of the bursa and excessive

and hindlimb paralysis were only seen in two cases,

skin is possible, but is a haemorrhagic and time-

though all bulls had varying degrees of ankylosing

consuming process despite the presence of a tourniquet

spondylitis.

proximal to the carpus. General anaesthesia is usually

Differential diagnosis includes other causes of spinal

required as adequate local infiltration of the bursal wall

cord compression such as aberrant migrating larvae and

is impractical.

infiltrating neoplasms such as lymphosarcoma as well as

Destruction of the bursal lining with an astringent

hindlimb degenerative joint disease.

(copper sulphate) or irritant disinfectant (tincture of

iodine) is not advisable, as a severe local reaction is pro-

duced, and dissection, curettage and repeated irrigation

Treatment and prevention

of the wound are essential steps before secondary

The prognosis depends on the degree and extent of

healing eventually occurs.

nerve damage. In the progressive ataxic or paraplegic

Prevention involves careful attention to the housing

case, it is poor. Mild cases may improve following rest *system for the existing herd. Problem cows should be*

and use of corticosteroids and diuretics to reduce the

put into straw yards before the swellings cause a clini-

oedema. Animals should be bedded on deep straw to

cal problem.

prevent the development of decubital lesions. Many

mild cases relapse following partial recovery. Slaughter

on humane grounds is often the action of choice.

Ankylosing spondylitis

Aetiology and pathology

Mineral imbalance-related lameness:

Generally confined to old bulls and defined as an

rickets, osteomalacia *(see also p. 253)*

acquired fusion of the ventral aspects of the bodies of

the caudal thoracic and lumbar vertebrae, sufficient

Aetiology and pathology

pressure may be exerted on the ventral and lateral

Mineral, indeed nutrient, imbalance can result in lame-

spinal cord tracts or the ventral nerve roots to cause

ness from calfhood through the growing yearling stage

some hindlimb weakness, ataxia or paralysis. Exostoses *to maturity and old age. The pattern almost invariably*

first develop on the ligaments of the caudal 2–3 thoracic

involves an imbalance or deficiency of two or more

and cranial 2–3 lumbar spinal bodies (T11–L3). Degen-

factors.

erative changes in the intervertebral discs may predis-

During growth the important elements in normal

pose to exostosis formation. The new bone may extend

development of healthy bone collagen, which is the

into the spinal canal as 'replacement bone'. Sometimes,

framework for provisional calcification of the zone of

possibly resulting from a fall or a violent ejaculation,

hypertrophied cartilage, are vitamin D, copper, protein

part of the exostosis may fracture, the fracture line

and energy. Mineralization of the cartilaginous matrix

extending through the vertebral body. Fluid exudate

results in deposition of much calcium, phosphorus and

(blood, oedema) from the fracture may cause pressure

carbonate, with lesser amounts of sodium, magnesium

on the spinal cord.

and fluoride. Vitamin D, calcium and phosphorus are *essential to the formation of this bone mineral.*

In the prenatal period, identified deficiency diseases

Clinical signs and diagnosis

resulting in abortion or the birth of progeny with

An early sign may be a reluctance or difficulty in mount-

skeletal defects include lupinosis (congenital arthro-

ing cows, attributable to the mechanical effects of a rela-

gryposis), manganese (contracted tendons), and zinc

tively inflexible thoracolumbar spine. Usually there are

and vitamin A deficiencies (multiple defects).

no premonitory signs and the bull suddenly has difficulty

Vitamin D deficiency in calves leads by a complex

in rising and may adopt a ‘dog-sitting’ position or may be

pathway involving the parathyroid gland, kidney and

completely paraplegic, dragging the digits caudally.

intestine to deficient calcification of long bones and of

Sometimes marked ataxia suddenly develops.

the cartilaginous matrix. The result in calves is rickets.

The site of trauma can rarely be accurately defined

The zone of provisional calcification is widened but

due to problems of size. Crepitus is rarely elicited.

the new osteoid is not mineralized. In adults, the same

Swelling of the back musculature is not seen. On rectal

deficiency causes osteomalacia, which is rare except in

examination, exostoses may be palpable dorsal to the

northern Australia and South Africa. Usually a calcium:

aortic bifurcation, but such exostoses are a normal

phosphorus imbalance is also involved. Vitamin

D-deficient diets may be identified on some farms

where feed is home-mixed.

Clinical signs and diagnosis of rickets

Calves have enlarged metaphyses and growth plates of

the long bones, especially the distal metatarsus and

metacarpus, fetlock and pastern. The swellings are

rather painful to pressure. The costochondral junction

exhibits the classical 'rickety rosary' in calves. Radio-

graphic changes include a widened area of radiolucency

at the growth plate with flaring of the distal metaphy-

ses, usually in the carpus, pastern and fetlock.

The diagnosis rests on the soft tissue swelling at

Fig. 32.18

Distal right radial septic physitis in two-year-old

characteristic sites, lameness, and in cases of doubt,

Holstein heifer. Weight bearing is minimal due to severe pain

feed analysis. Serum or plasma may reveal depressed

and soft tissue swelling. The aetiology, in the absence of

levels of calcium, phosphorus and an elevated alkaline

penetration, was probably haematogenous.

phosphatase.

Differential diagnosis includes physeal dysplasia and

joint ill (polyarthritis).

Clinical signs and diagnosis of osteomalacia

A haematogenous form is seen in calves six to twelve

months old as a result of Salmonella infection, which The relative or absolute phosphorus deficiency, usually

localizes in the metaphysis, physis and epiphysis of long

acquired from low phosphorus pastures, is classically *bones such as the metacarpus as well as the upper limb*

associated with the development of pica and osteopha-

where an embolic process may be responsible (Kersjes

gia, variable degrees of lameness including pathological

et al., 1966; Gitter et al., 1978). Blood flow through the fractures of long bones, weight loss, stiffness and recum-metaphyseal sinusoids is slow, facilitating easy bacterial

bency. Deficiency tends to be exaggerated in cows due

deposition and proliferation. Many clinical cases are

to the demands of pregnancy and lactation. Fertility

multifocal and cause rapid destruction of bone. Other

may be severely reduced. Hypophosphataemia is

organisms in calves include A. pyogenes and E. coli. In accompanied by normal blood levels of calcium. The

older, growing cattle, less than two years old, a growth

condition must be distinguished from DJD.

plate osteomyelitis may involve the distal metatarsus or

Vitamin D-deficient osteomalacia in grazing animals

distal tibia. Common bacterial isolates are A. pyogenes

is seen in temperate climates with a shortage of sun-

and Salmonella spp. (De Kessel et al., 1982). Periartic-cured hay and affects cattle stressed by the demands

ular soft tissue swelling is prominent (Fig. 32.18). The *of pregnancy and lactation. The clinical manifestation*

radiographic extent of bone destruction is very variable

resembles the phosphorus-deficient form.

and appears to be unrelated to the involvement of

epiphysis and metaphysis, which are equally likely to

be affected. Many cases have infected sequestra in

Treatment and prevention

the osteomyelitic focus.

In rickets, increased vitamin D in the ration along with

In adult cattle, osteomyelitis of long bones is a spo-

restoration of a normal Ca : P ratio with adequate intake

radic isolated phenomenon. The aetiology may again

brings a rapid response.

involve haematogenous spread, or may arise following

Osteomalacia in adult cattle is treated by dietary

direct trauma. Open long bone fractures are an obvious

supplementation with rations high in phosphorus.

example (see p. 441). Less obviously, saucer fractures of

the diaphysis may lead to formation of a sequestrum.

Sequestra in long bones of cattle are related to common

Osteomyelitis

sites of lacerating wounds, notably the proximal half of

the dorsal aspect of the metatarsus (Firth, 1987). This

author hypothesizes that severe contusion alone may

Aetiology and pathogenesis

produce sufficient subcutaneous soft tissue damage to

Osteomyelitis of the limb bones in cattle occurs in two

render the area susceptible to infection and subsequent

forms: one in growing cattle, the other in adults.

adjacent bone sequestration.

A chronic sequestrum in a long bone may develop a

sation, septic myositis or extensive intramuscular

fistulous tract, which permits easier delineation of the

abscessation. Open wounds should, therefore, be

bone by insertion of a positive contrast agent for a

explored with a sterile probe.

fistulogram.

Osteomyelitis of long bones without evidence of skin

A specific form of osteomyelitis is Brodie’s abscess,

trauma must be differentiated from fissure fractures,

which is a circumscribed abscess lined with a granular *subperiosteal haematoma, subcutaneous abscesses and*

membrane surrounded by sclerotic bone. Synonyms are

rare bone tumours. In calves, haematogenous bacterial

chronic fibrous osteomyelitis and chronic bone abscess.

infection of metaphysis, growth plate and epiphysis

Though the lining is histologically a definite pyogenic

must be distinguished from joint ill, epiphyseal separa-

membrane, bacteriological culture may be sterile. Both

tion and metaphyseal fractures.

F. necrophorum and A. pyogenes have been involved in cases of Brodie's abscess in three and six-months-old

calves (Weaver, 1972).

Treatment and prognosis

Cattle with systemic involvement (pyrexia, anorexia)

should be given parenteral antibiotics for three to five

Clinical signs and diagnosis

days. Many cases respond to this therapy. Non-

responsive cases should be considered for surgery. This

Osteomyelitis usually causes severe, continuing pain

applies particularly to cases of Brodie's abscess and

with local swelling. These signs relate to the active *incision should be made over the metaphysis to attempt*

process such as long bone infection following an open

aspiration of the contents of the abscess if subperiosteal

fracture when, if left untreated, purulent material,

in position. In other cases a sinus tract through the

sometimes with bone spicules, is discharged to the

cortex may be enlarged to evacuate the contents and to

exterior. Cellulitis may be severe and additional

permit curettage of the adjacent necrotic bone and

sinuses may form.

pyogenic membrane.

Osteomyelitis in calves where infection is within and

Cattle with open long bone fractures and

surrounding the epiphysis presents differently. Locali-

osteomyelitis should have sequestra removed and

zation of the lameness may be difficult due to the

check radiographic films taken. Treatment then

absence of local swelling but pain is usually evident.

depends on the type of fracture and extent of

Chronic osteomyelitis may not cause lameness when

osteomyelitis. The options are discussed elsewhere *the infected focus is effectively walled off by dense*

(p. 442).

sclerosed bone (involucrum). Sometimes, in such cases,

Calves with bacterial infection of the metaphysis

lameness suddenly develops as infection flares up once

sometimes respond to parenteral antibiotics alone,

more.

otherwise local debridement and irrigation of the focus

Osteomyelitis rarely extends to involve joints except

is justified.

in the digit and any resentment to joint flexion is usually

due to extension from the diaphyseal or metaphyseal

focus.

Physeal dysplasia

Systemic effects of osteomyelitis include lassitude,

mild fever and a reduced appetite. Radiology is indi-

Aetiology and pathology

cated in most cases to confirm the diagnosis, to deter-

mine the extent of the pathological process, and to

Physeal dysplasia, also loosely termed epiphysitis

assess the possibility of useful surgical intervention.

(though the epiphysis is not involved in an inflamma-

Osteoporosis results from the loss of bone by erosion

tory process), is primarily a defective development of

and its replacement by infected granulation tissue.

one or more growth plates, which later may become

Periosteal new bone is often evident and is variable in

necrotic and inflammatory and later still may be puru-

amount. Initially, the periosteum is elevated over an

lent. The problem usually affects the lower limb, espe-

osteomyelitic focus with an underlying loss of cortical

cially the carpal and fetlock joints. The pathogenesis

density. Later, in animals where a sequestrum forms,

apparently involves a reduced blood supply to the

new subperiosteal bone is deposited while sclerosis is

growth plate as a result of uneven or excessive mechan-

evident around the sequestrum.

ical pressure. The metaphyseal side, dependent on an

Differential diagnosis of osteomyelitis with an open

adequate blood supply for calcification and ossification,

wound involves determining the primary lesion. Some

is more affected than the epiphyseal surface. The patho-

cases of wounds may not involve the periosteum and

logical process has not been thoroughly investigated in

lameness may reflect pain due to subcutaneous absces-

cattle, but necrosis of the ground substance, resulting

from folding of the cell columns and loss of continuity,

has been noted histologically in housed fattening cattle.

Poor-quality, uncomfortable floor surfaces predispose

rapidly fattening cattle with limited exercise space to

physeal dysplasia.

Gross pathology reveals some subcutaneous oedema

and red or red–grey discoloration around the growth

plate, which is either necrotic or, in severe cases, puru-

lent. In its most severe form the growth plate undergoes

separation.

Copper deficiency or a combined copper–molybde-

num deficiency (see pp. 254, 298) has also been associ-

ated with physeal dysplasia as a result of defective

collagen formation. The abnormal collagen does not

permit normal mineralization. The result is stiffness and

lameness in calves with a characteristic distal metatarsal

swelling. Another result is an increased incidence of

long bone fractures.

Clinical signs and diagnosis

Fig. 32.19

Massive septic myositis in right hindquarters of

two-year-old Saler bull. The light area (shaved) shows the site The swellings are usually symmetrical, and hindlimbs

of exploratory needle puncture. Abscess cavity contained 12

are affected more often. The enlarged area in the lame

litres of pus. Actinomyces pyogenes was recovered in pure calf or yearling is painful. Weight loss is rapid in beef

culture. Severe oedema extends down to the hock. Recovery fol-

cattle aged nine to eighteen months. Occasionally,

lowed drainage and irrigation.

several animals in a group of cattle are affected simul-

taneously following violent exercise, for example at

lameness should be salvaged before there is further

turning out to pasture from confined housing. Isolated

weight loss.

cases may result from trauma on slats.

In the copper-related form the limbs may be bowed

either laterally or medially, the gait is stilted, and the

Lameness of iatrogenic origin

swellings tend to be symmetrical. However, other signs

of copper deficiency are present, including unthriftiness,

Some forms of upper limb lameness may be the result

a rough discoloured hair coat and diarrhoea.

of treatment for disease or injury. Various entities

Radiographic features include rarefying lesions with

have been discussed elsewhere: radial paralysis from

an increased width of the growth plate with irregular-

prolonged lateral recumbency during anaesthesia (p.

ity and fragmentation, but with an absence of reactive

436), neonatal long bone fractures and physeal separa-

change around the metaphyseal margin. The radi-

tions resulting from excessive traction in dystokia

ographic changes are more severe in cattle with physeal

(p. 444), and traumatic injury and transection of

separation and secondary repair. Milder radiographic

the gastrocnemius tendon (p. 451). Another form of

changes are evident in many cattle of the same group

iatrogenic damage is that following intramuscular injec-

that do not show lameness.

tions. Occasionally, particularly in calves, the sciatic

The list of differential diagnoses includes rickets,

nerve may be injured. More frequent is the develop-

traumatic separation of the growth plate, bacterial

ment of an abscess following a subcutaneous injection,

ostitis, septic arthritis and fractures. Radiography is

which rarely causes lameness but remains a cosmetic

necessary to permit this differentiation.

blemish. When a non-sterile preparation, or a dirty

syringe and needle are used for an intramuscular

injection, the results may be more serious. As a rule,

Treatment and prevention

infection is sealed off by fibrous tissue with no ill-

Only the copper-related syndrome is responsive to

effects. Sometimes the result is a massive abscess,

treatment by an appropriate diet change. Mild non-

which causes lameness and requires prompt surgical

copper-related cases respond to rest and external

drainage and daily irrigation to prevent recurrence

support by lightweight casting. Most cases of such

(Fig. 32.19).

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Adult Cattle

Fertility

Chapter 33

Reproductive Physiology in Cattle

P.J. Hartigan

Introduction

471

sidered necessary to do this in a text addressed prima-

The hypothalamus

471

rily to clinicians? Essentially, because we believe that it

The anterior pituitary gland

473

will enhance the reader's understanding of the patho-

Neuroendocrine links

473

genesis of many of the reproductive problems encoun-

Feedback

474

tered in practice and, as a consequence, it will foster a

Endocrine signals: generation and reception

476

more methodical and perceptive approach to diagnosis

Systemic constraints on reproduction

477

and treatment. Underpinning that belief is the knowl-

Puberty

479

Male physiology

481

edge that efficient reproductive performance in the

Morphology of the testis

482

female is dependent on an integrated and

The spermatozoon

485

precisely timed sequence of hormonal changes that are

Neuroendocrine control

485

regulated by the hypothalamus in response to changes

The epididymis

487

in the external and internal environments. Of course,

Seminal plasma

488

this means that the sequence and timing of the hor-

Female physiology

488

monal changes are vulnerable to a great variety of stres-

Oestrous cycle

488

sors and noxious agents. Many of these deleterious

Pregnancy

498

factors have been recognized – and will be mentioned

Physiology of the postpartum period

502

later in the relevant sections – but it is likely that many

more remain to be discovered, in particular subtle but

significant stressors associated with modern develop-

ments in cattle husbandry. The individual best placed

Introduction

to identify 'new causes' of reproductive inefficiency is

the informed clinician working with problem herds;

Reproductive efficiency in a cattle enterprise is a func-

however, such insights are less likely if the investigator

tion of good management. Therefore, it is important

is not fully alert to the central role of the neuro-

that the help and advice provided to management by

endocrine mechanisms and their sensitivity to the effects

the veterinarian should be based upon a sound appre-

of dietary and metabolic factors, hormone imbalances,

ciation of the physiological mechanisms that control the

stressors, drugs, age and many other influences.

principal reproductive events.

The essential numerical data on reproduction in *cattle are well known: puberty in bulls and heifers at*

10–15 months of age; normal oestrous cycles of 18–24

The hypothalamus

days (mean = 21 days); normal oestrus lasts 12–24 hours

(mean = 18 hours); ovulation occurs about 24 hours

In the neuroendocrine system the dominant role is

after the LH peak at the beginning of oestrus; normal

played by the hypothalamus, which acts as a relay

gestation lasts 278–293 days; the interval from parturi-

station where neural and hormonal messages are

tion to first ovulation can be as short as 15 days. The

decoded and translated into appropriate signals

physiological control of each of these events is exerted

to ensure the cooperation of the endocrine system with

by a system of interdependent endocrine organs

the nervous system in regulatory activities. It is able to

that form the hypothalamic–pituitary–gonadal (HPG)

do so because it contains many neurones that are

axis, an important limb of the neuroendocrine

capable of forming and releasing peptide hormones

system.

(neurohormones) that regulate the functions of various

The primary purpose of this chapter is to provide a

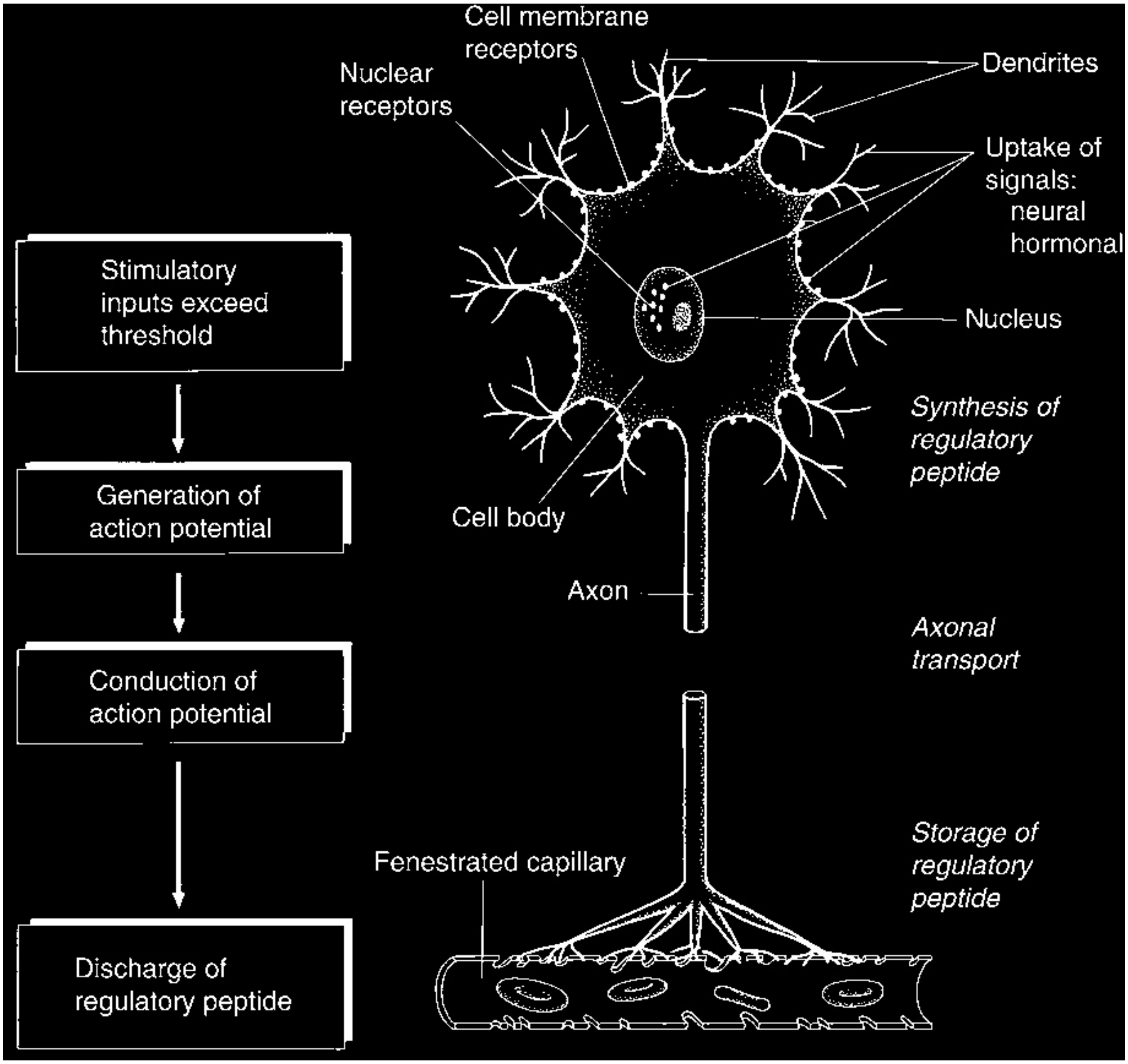
organs, principally via the pituitary gland.

succinct outline of the salient features of the neuroen-

These regulatory peptides are synthesized and pack-

docrine system as it affects reproduction. Why is it con-

aged into granules in the cell body of the neurone



Cell membrane receptors
Nuclear receptors
Dendrites
Uptake of signals: neural hormonal
Nucleus
Stimulatory inputs exceed threshold
Generation of action potential
Conduction of action potential
Discharge of regulatory peptide
Synthesis of regulatory peptide
Cell body
Axon
Axonal transport
Storage of regulatory peptide
Fenestrated capillary

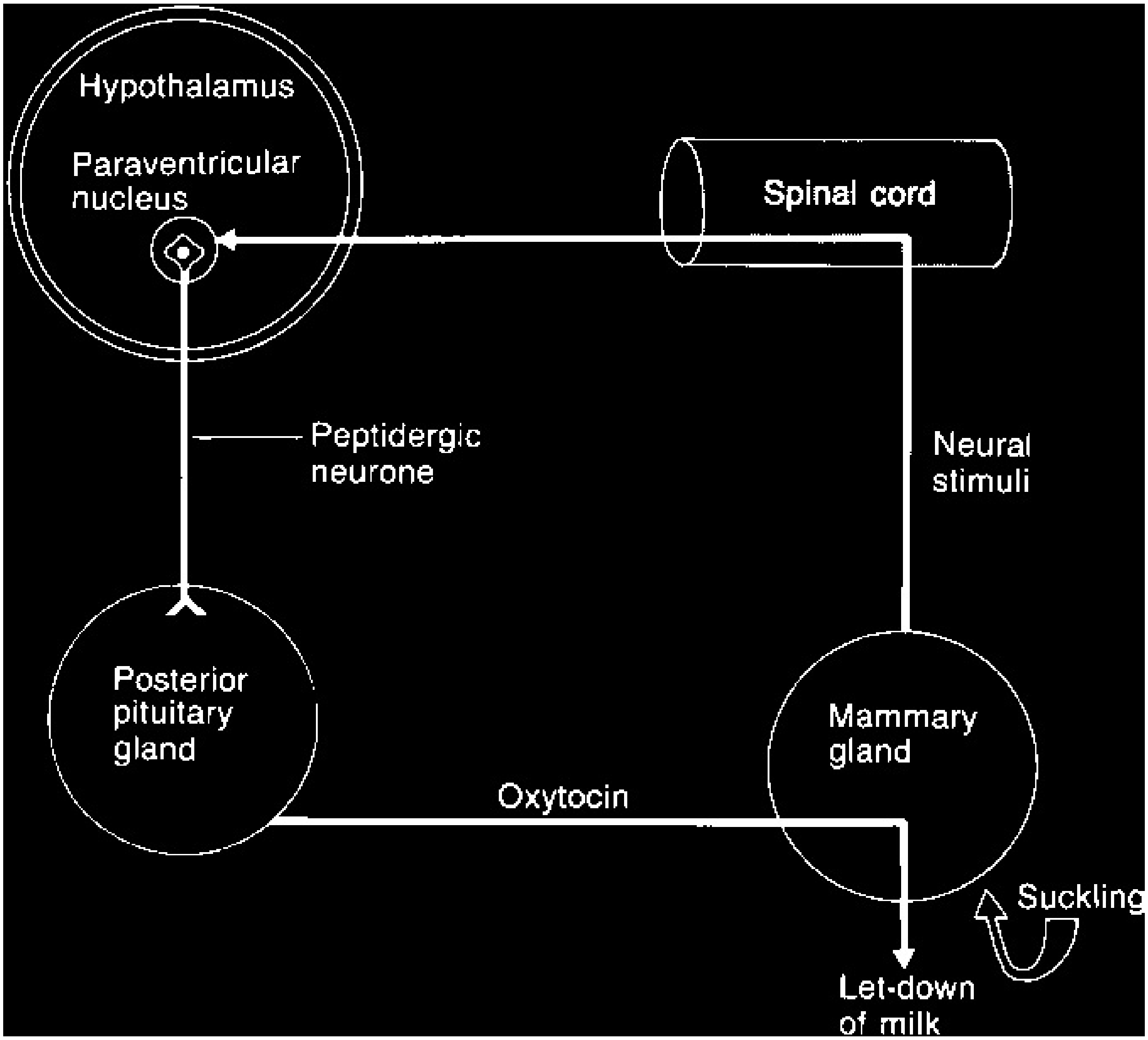


Fig. 33.1

This diagrammatic representation of a typical peptidergic neurone depicts: (i) the uptake of neural signals by dendrites; (ii) the uptake of endocrine signals by specific *receptors located either in the cell membrane (for water-soluble hormones: peptides, proteins) or in the nucleus (for lipid-soluble hormones: steroids, thyroid hormones); (iii) the endocrine response to signals (synthesis, transport and storage of regulatory peptide); (iv) the neural response to signals (generation and conduction of action potential, which is responsible for the discharge of the regulatory peptide).*

before they are transported down the axon to the nerve terminals where they are stored pending release. The peptidergic neurones retain the electrophysiological properties of nervous tissue and they use their electrical activity to release the peptides.

A typical peptidergic neurone (Fig. 33.1) has many hundreds of synapses and through these it receives neural inputs (information) from most parts of the brain. (It also receives information from humoral *inputs; we shall return to this topic later.) The neural and humoral inputs may be stimulatory or inhibitory; at any one moment the response of the peptidergic neurone will reflect its assessment of the current inter-play between the synergistic and conflicting stimuli. When the stimulatory inputs exceed a critical threshold an action potential is generated, the nerve impulse passes down the axon and it causes the release of the (stored) peptide at the nerve terminals. Usually, the nerve terminals are in close apposition to capillaries with highly fenestrated walls that allow the peptide*

Fig. 33.2

Diagrammatic representation of the suckling reflex,

molecules to enter the vascular circulation promptly on

in which neural stimuli elicit an endocrine response.

release.

A simple example to illustrate the physiological phe-

neurones whose cell bodies are located (principally) in

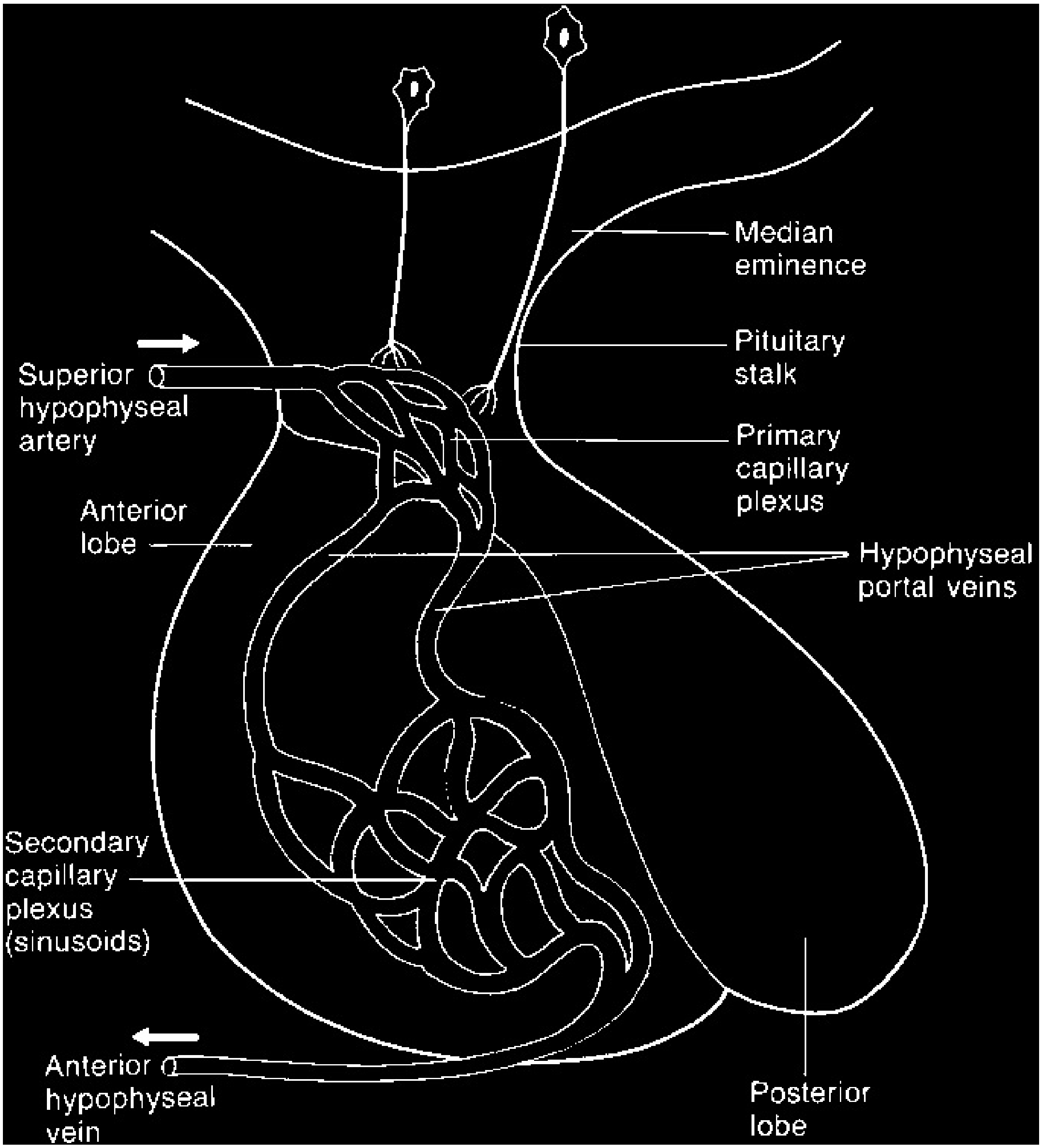
nomena just described is the milk ejection reflex (Fig.

the paired paraventricular nuclei in the hypothalamus

33.2). This reflex depends on a suckling-induced release *and whose axons pass through the pituitary stalk into*

of oxytocin. Oxytocin is produced by peptidergic

the posterior pituitary gland. Suckling evokes sensory



impulses that travel via the spinal cord to the brain where they converge on the paraventricular nuclei and generate the impulses in the peptidergic neurones that lead to the release of oxytocin from the nerve endings in the posterior pituitary gland. The reflex is completed when the oxytocin in the blood perfusing the mammary gland induces ‘let down’ of milk. Conceptually, this is neuroendocrine regulation at its simplest: the neurone that ‘reads’ the afferent sensory message also produces and releases the effector hormone. This is possible only because the posterior pituitary gland, which arises as a downgrowth of neural tissue from the floor of the third ventricle, retains a direct neural link with the hypothalamus.

The anterior pituitary gland

The anterior pituitary gland (adenohypophysis) arises as an upgrowth from the roof of the primitive mouth and, therefore, it does not have a direct neural link with the hypothalamus. A vascular route has to be used to bring the regulatory peptides from the hypothalamus to the adenohypophysis. A specialized arrangement of

Fig. 33.3

The primary capillary plexus, the hypophyseal

the vasculature, the hypothalmo–hypophyseal portal

portal veins and the secondary capillary plexus form the

system, has evolved for that purpose. In contrast to the

hypothalamo–hypophyseal portal system that intervenes

normal sequence of arterioles, capillaries and venules, a

between the superior hypophyseal artery and the anterior

portal system begins and ends with capillaries. In this

hypophyseal vein. This is the route taken by GnRH which is syn-instance, the superior hypophyseal artery gives rise to a

thesized by neurones whose cell bodies lie within the arcuate

plexus of capillaries (the primary plexus) in the region

nucleus of the hypothalamus and whose axons abut onto the

of the median eminence at the top of the pituitary stalk.

external walls of the capillaries in the primary plexus.

From this the blood is drained by the hypophyseal

portal veins, which pass down the pituitary stalk to end

in a secondary plexus (the sinusoidal capillaries) within

the anterior pituitary gland (Fig. 33.3). From there the

plexus, the hypophyseal portal veins and the secondary *blood returns to the general circulation via the anterior*

plexus to the secretory cells of the anterior lobe. It

hypophyseal vein.

stimulates the release of the gonadotrophins, which

In contrast to the posterior pituitary gland, which

enter the general circulation via the draining anterior

does not produce the hormones it releases, the anterior

hypophyseal vein. Other hypothalamic factors may

lobe actually synthesizes the trophic hormones it

exert inhibitory actions in the anterior pituitary gland,

releases into the circulation, including the gona-

e.g. prolactin inhibitory factor (dopamine).

dotrophins: follicle stimulating hormone (FSH) and

luteinizing hormone (LH). However, the release of the

trophic hormones is governed by stimulatory or

inhibitory peptides produced in the hypothalamus. For

Neuroendocrine links

instance, the secretion of FSH and LH is controlled by

a gonadotrophin-releasing hormone (GnRH), which is

Since the peptidergic neurones form the functional

synthesized by peptidergic neurones in the hypothala-

links between the neural and endocrine systems, they

mus and is brought to the anterior pituitary gland

need to be able to receive, decipher and react to signals

via the hypothalamo–hypophyseal portal system. The

generated by either system in response to changes in

axons of the neurones that produce GnRH end in the

the internal and external environments. Neural signals

median eminence, in close apposition to the fenestrated

from other regions of the brain converge on the hypo-

capillaries of the primary plexus. When a nerve impulse

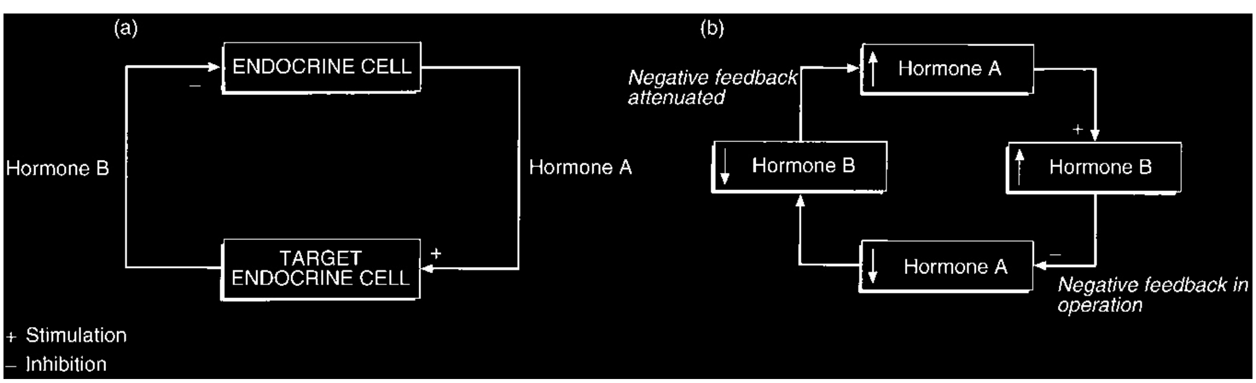
thalamus bringing important cues from the special

induces a discharge of GnRH from the nerve terminals,

senses (sight, sound, smell), various exteroceptors

this hypothalamic factor is transported via the primary

(suckling, mating, pain), interoceptors (stimulation of



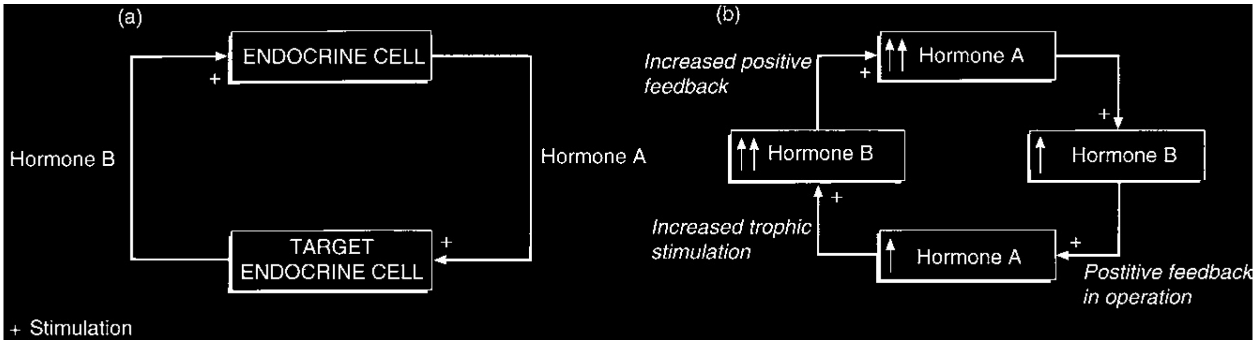


Fig. 33.4

Negative feedback. Example: hormone A, FSH; hormone B, oestrogen. FSH stimulates the production of oestrogen by the granulosa cells of the ovarian follicle. The oestrogen exerts an inhibitory effect on the release of FSH by the pituitary gland. When the oestrogen declines the negative feedback is attenuated and secretion of FSH is increased.

Fig. 33.5

Positive feedback. Example: the gonadotrophins FSH and LH (hormone A) stimulate the secretion of oestrogen (hormone B) by the granulosa cells of the preovulatory ovarian follicle (see Fig. 33.24). The rapidly rising concentration of oestrogen (the 'oestrogen surge') stimulates the hypothalamus and the pituitary gland to release a surge of gonadotrophins that is responsible for ovulation.

Dilution abolishes the positive feedback at source.

the cervix and uterus) and stressors (physical, emo-

within stable normal limits while retaining their respon-

tional, overcrowding). The peptidergic neurones also

siveness to the immediate needs of the body. For

respond to humoral signals, especially to hormones

instance, when the concentration of hormone B in *acting through feedback loops. Again, the input may be*

the circulation rises towards its upper normal limit it

stimulatory (positive feedback) or inhibitory (negative

exerts negative feedback on its trophic hormone. Thus,

feedback). Although there are some important positive

hormone A is prevented from exceeding its upper

feedbacks, e.g. oestrogen prior to ovulation, the major-

normal limit; the concentration of A in the circulation

ity of feedback loops are negative.

declines and, of course, so does the activity of its target

cells. The resultant decline in hormone B attenuates the

negative feedback inhibition (Fig. 33.4b) and the secre-

tion of hormone A is enhanced before it falls below its

Feedback

lower normal limit.

In a positive feedback loop (Fig. 33.5a) hormone B

In its simplest form, a negative feedback loop (Fig.

stimulates rather than inhibits the production of more

33.4a) is a closed system in which hormone A stimulates

hormone A. This is an inherently unstable system in

the production and release of hormone B which, in *that it is liable to generate ever-increasing quantities*

turn, has an inhibitory effect on the cells that produce

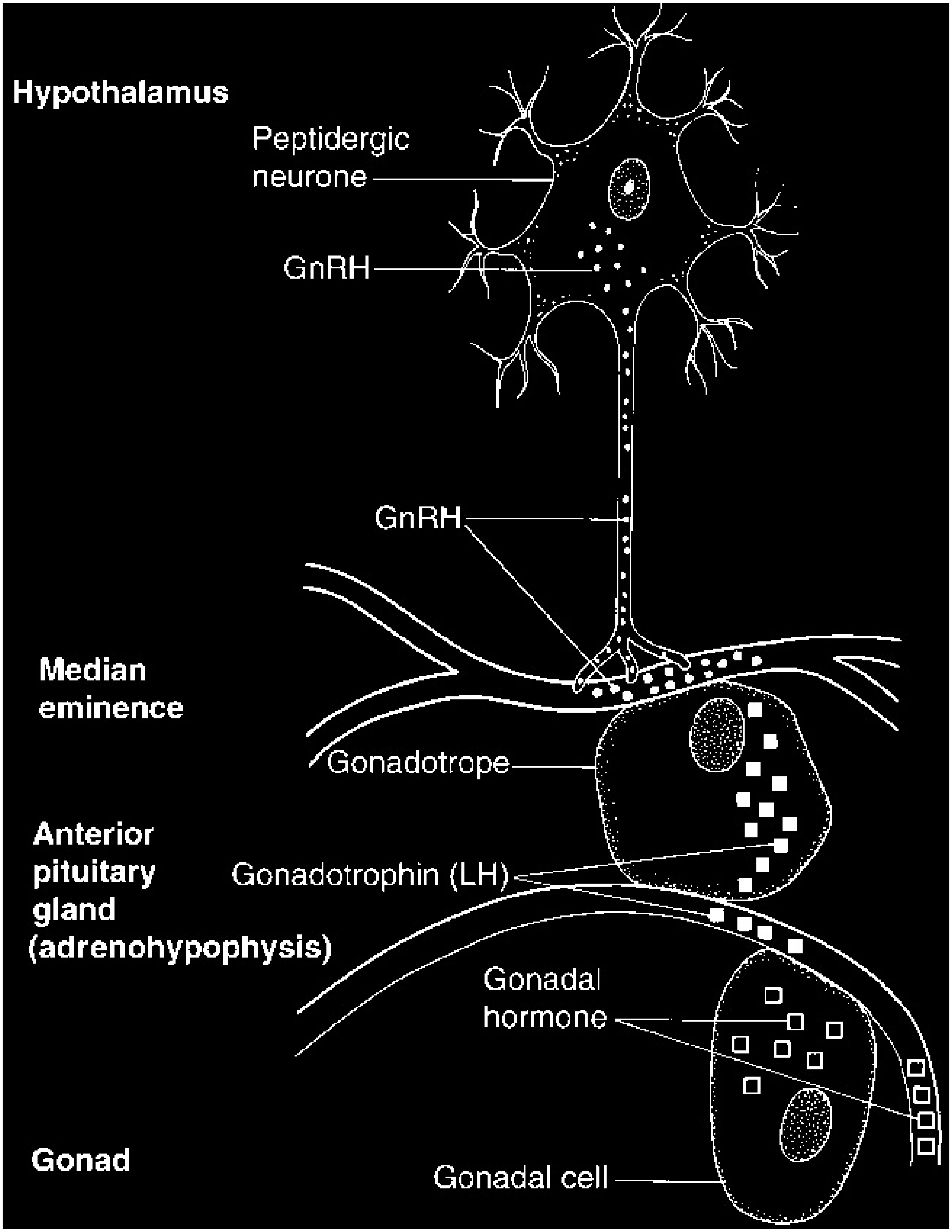
of each of the hormones (Fig. 33.5b); in other words, it

hormone A. Such a loop provides a very efficient mecha-

lacks the checks and balances of a negative feedback

nism by which circulating hormones are maintained

system. However, it is ideal for situations that call for


Hypothalamus
Peptidergic neurone
GnRH
GnRH
Median eminence
Gonadotrope
Anterior pituitary gland (adrenohypophysis)
Gonadotrophin (LH)
Gonadal hormone
Gonad
Gonadal cell

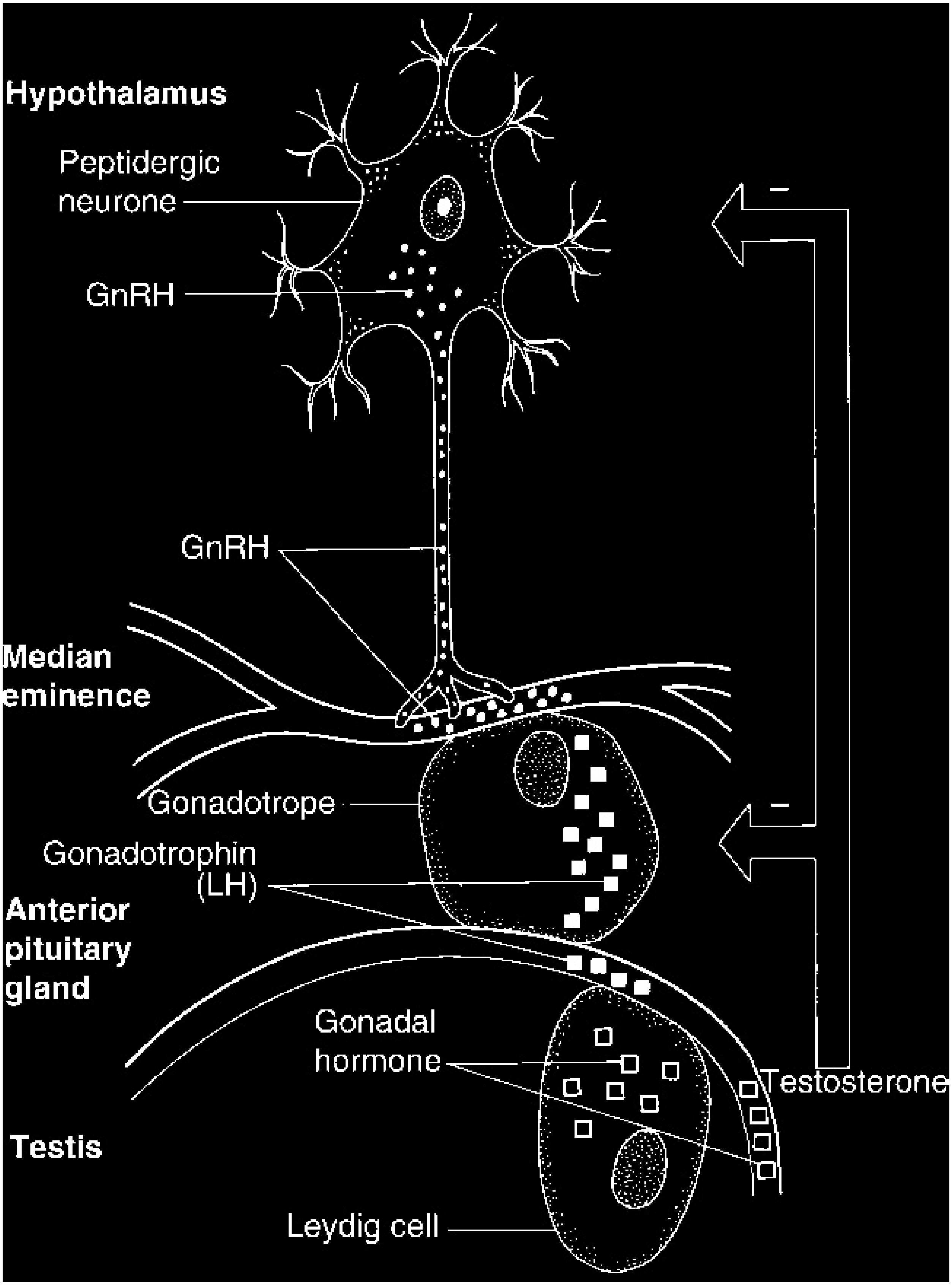

Hypothalamus
Peptidergic neurone
GnRH
GnRH
Median eminence
Gonadotrope
Gonadotrophin (LH)
Anterior pituitary gland
Gonadal hormone
Testosterone
Testis
Leydig cell
–
–

Fig. 33.6

Secretory cells in series: peptidergic neurone

secretes GnRH; gonadotrope secretes LH, FSH; gonadal cell

Fig. 33.7

Long loop negative feedback. LH induces Leydig

secretes testosterone, progesterone or oestrogen.

cells to secrete testosterone; testosterone exerts so-called long loop feedback (i) on adrenohypophysis (suppressing secretion

of LH) and (ii) on hypothalamus (suppressing secretion of

GnRH).

short-term but self-limiting responses. The positive

• Short loop: for example, pituitary gonadotrophins

feedback loop may be a purely hormonal phenomenon;

acting at the level of the hypothalamus (Fig.

for example, the brief but highly significant period of

33.8).

positive feedback by oestrogen that elicits the preovu-

• Ultra-short loop: hypothalamic peptides acting at

latory surge of LH. Other important positive feedback

the level of the hypothalamus (Fig. 33.9).

mechanisms are initiated by neural stimuli from extero-
ceptors, e.g. the suckling reflex, or interoceptors, e.g.
The feedback effect of a particular hormone is not an
stretch receptors in the cervix and vagina during the
intrinsic property of the molecule itself; for instance,
second stage of parturition, that induce reflex release of
although oestrogen is inhibitory (negative long loop
oxytocin. These two reflexes are excellent examples of
feedback), during most of the oestrous cycle it exercises
self-limiting responses; removal of the physical stimu-
an essential stimulatory effect (positive long loop
lus terminates the reflex response almost at once.
feedback) shortly before ovulation. Clearly, a single
The feedback mechanisms involved in the control of
hormone can vary the message it conveys to the
the reproductive tract are complex and involve several
hypothalamus. This raises a crucial question: how do
sets of secretory cells in series (Fig. 33.6). For descrip-
the gonadal steroids, the pituitary gonadotrophins
tive purposes, three types of complex feedback loops
and the hypothalamic peptides encode the signals that

are recognized:

constitute the feedback messages? By definition,

feedback depends on the ability of the target tissues

• Long loop: for example, gonadal hormones acting

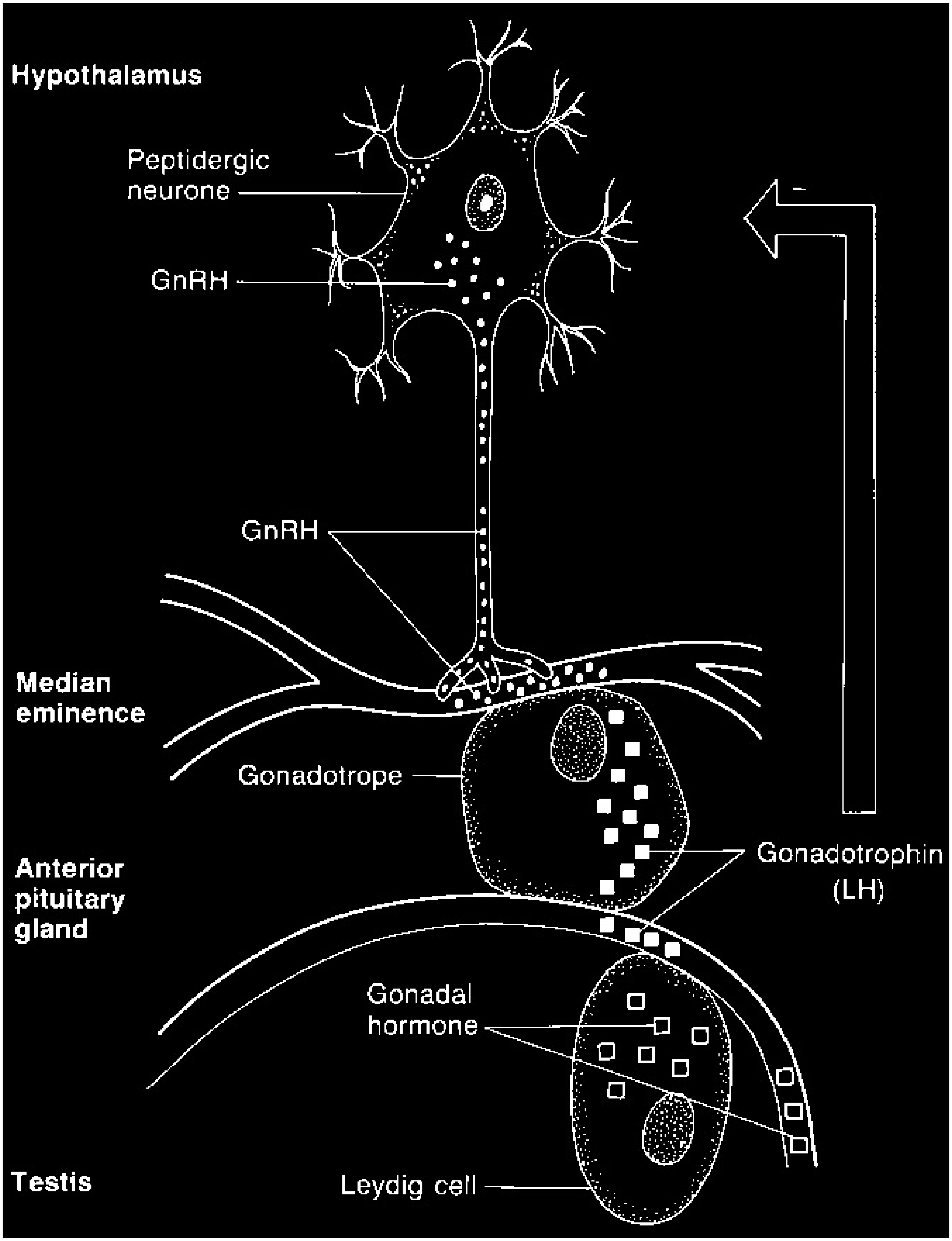
to detect changes in hormone concentrations in the

at the level of the brain or pituitary gland (Fig.

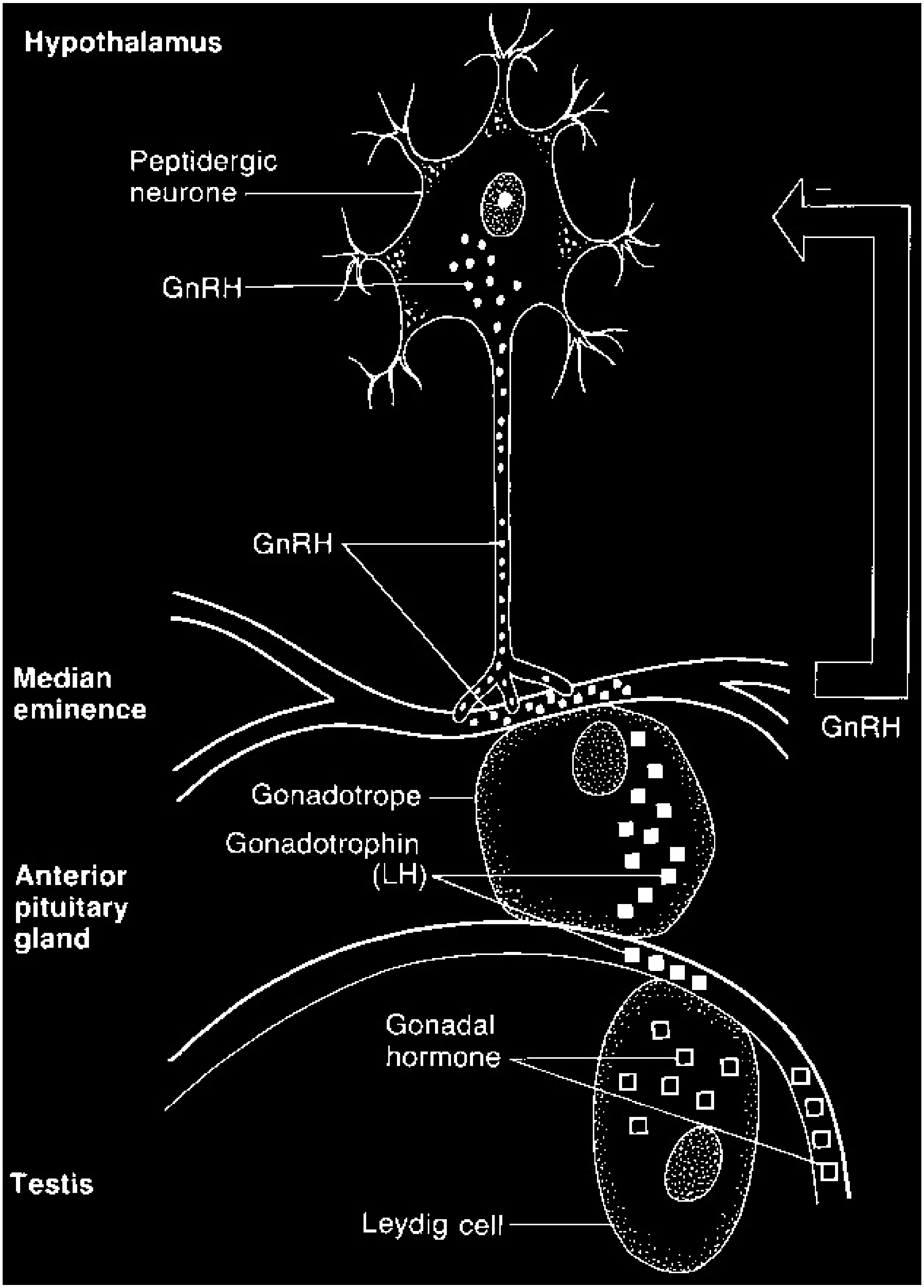
circulation, and to induce the appropriate re-

33.7).

adjustments (further changes). Hence, the system



Hypothalamus
Peptidergic neurone
GnRH
GnRH
Median eminence
Gonadotrope
Anterior pituitary gland
Gonadotrophin (LH)
Gonadal hormone
Testis
Leydig cell
–



Hypothalamus
Peptidergic neurone
GnRH
GnRH
–
Median eminence
GnRH
Gonadotrope
Gonadotrophin (LH)
Anterior pituitary gland
Gonadal hormone
Testis
Leydig cell

Fig. 33.8

Short loop negative feedback. GnRH induces the

Fig. 33.9

Ultra-short loop negative feedback. The hypothala-

gonadotropes to secrete LH; LH exerts negative feedback on the mic hormone (GnRH) regulates its own secretion.

release of GnRH by the hypothalamus.

depends on fluxes rather than constancy as the means

tors may be located in the cell membrane or within the

of communication.

cell, mainly in the nucleus (see Figs 33.1 and 33.11). The

polypeptide hormones, e.g. GnRH, and the glycopro-

tein hormones, e.g. LH, FSH, bind to receptors in the

Endocrine signals: generation

cell membrane (Fig. 33.11a), whereas the lipid-soluble

and reception

gonadal steroids can diffuse through the cell membrane

to react with intracellular receptors (Fig. 33.11b). The

Two basic types of endocrine signals are used: pulses

location of the specific receptors determines the mecha-

and surges (Fig. 33.10). A pulse of a particular hormone

nism by which the target cells express their character-

is a discrete burst of secretion of relatively short dura-

istic responses to a hormone and, in turn, the different

tion and modest amplitude. A surge occurs when a

mechanisms determine the speed at which the final

sequence of frequent pulses, often of high amplitude,

response is elicited.

produces a massive increase extending over a period of

When a gonadal hormone binds to its specific recep-

12–24 hours.

tor in the nucleus of a target cell, it initiates a series

Endocrine signals are detected only by cells that have

of biochemical reactions that takes several hours to

specific receptors to which a particular hormone will

produce the new proteins that elicit the characteristic

bind. When the hormone interacts with the cells that

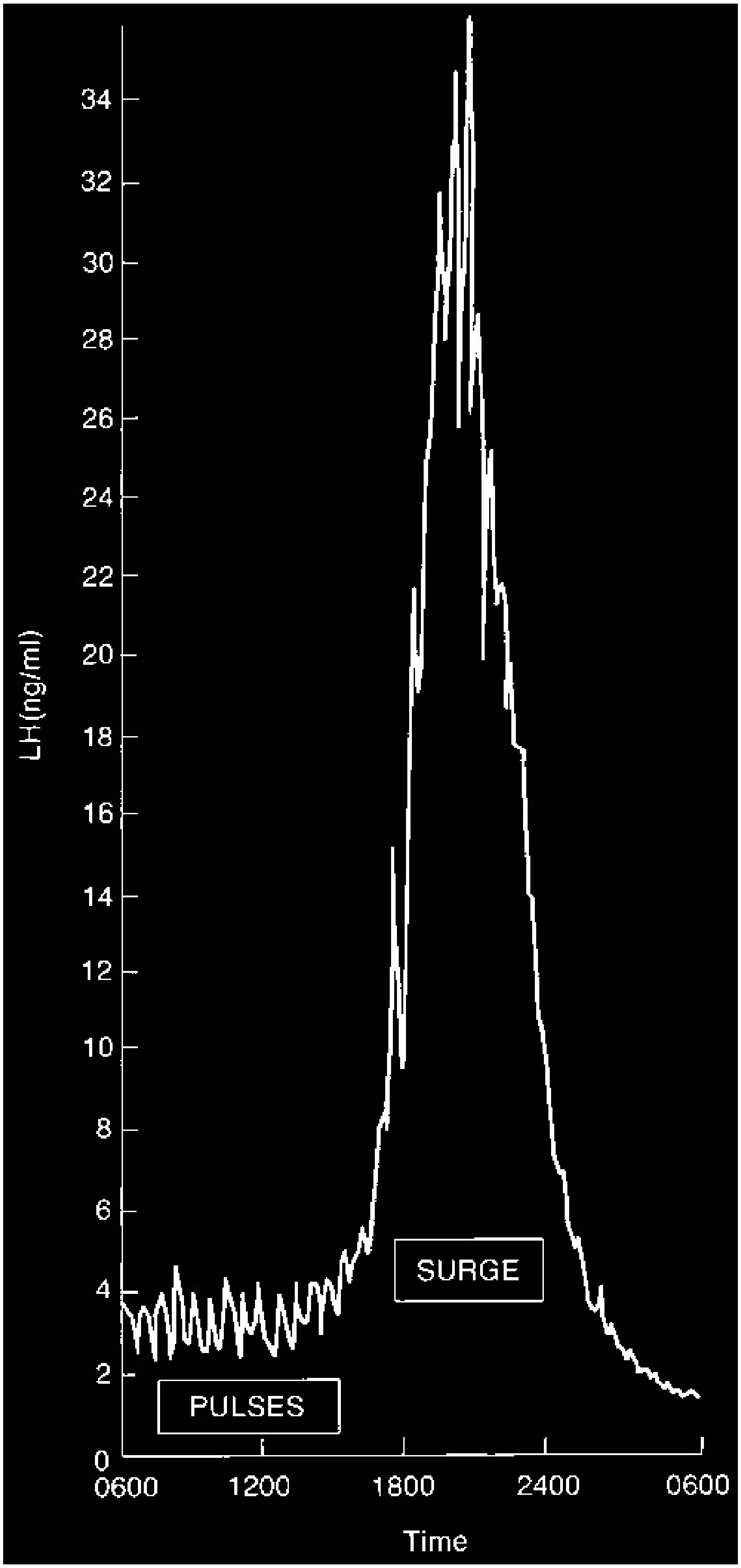
response to that hormone (Fig. 33.11b). By contrast,

produce it we refer to autocrine stimulation; when it

when a gonadotrophin binds to its receptor in the cell

interacts with another cell type located near the pro-

membrane, it elicits the final response much more ducer cell we call it paracrine stimulation; when it rapidly because the resultant cascade of enzymatic enters the blood stream and interacts with target cells activity utilizes enzymes that exist already within the elsewhere we call it endocrine stimulation. The recep- cell. Binding of the hormone (the 'first messenger') to



LH(ng/ml)
34
32
30
28
26
24
22
20
18
16
14
12
10
8
6
4
2
0
SURGE
PULSES
0600
1200
1800
2400
0600
Time

(see p. 492). Alternatively, the hormone stimulus may decrease the sensitivity of the target tissue because it increases the degradation and/or decreases the synthesis of receptors; for instance, GnRH can 'down regulate' its own receptors in the adenohypophysis, especially when the gonadotropes are subjected to constant stimulation rather than pulsatile stimulation by the releasing hormone (see p. 497).

The inherent mode of secretion of hormones in the neuroendocrine system is pulsatile and it is controlled by an oscillator or pulse generator in the hypothalamus. The activity of the pulse generator can be modulated both by neural inputs and by feedback signals from the median eminence, the pituitary gland and the gonads. In turn, the pulse generator will seek to ensure that the characteristics of the signals emanating from the pituitary gland and the gonads are altered so as to elicit the appropriate responses from target tissues in the reproductive tract. In that way the hypothalamus exercises *fine tuning as well as gross control over reproductive events such as puberty, gametogenesis, oestrus, pregnancy, parturition and lactation.*

Before we deal with the neuroendocrine regulation of those processes, it is appropriate to mention three systemic conditions that can constrain the reproductive system: energy balance, stress and neural–immune interactions.

Systemic constraints on reproduction

Energy balance

Although reproduction is critical for the survival of the

Fig. 33.10

Preovulatory surge of LH on day 18 of the oestrous

species, processes that are of more immediate impor-

cycle in a cow. (Redrawn from Rahe et al., 1980).

tance for the survival of the individual take top priority when an animal allocates available metabolic fuels among various energy-consuming activities (Fig. 33. 12). Hence, changes in the availability of metabolic fuels affect reproductive functions, through actions at multi-

the receptor activates an enzyme within the cell mem-

ple sites in the central nervous system, pituitary gland,

brane that acts as a catalyst in a reaction that produces

gonads and other peripheral organs (e.g. liver, skeletal

a 'second messenger', e.g. cyclic AMP, that, in turn,

muscles, adipose tissue). Negative energy balance leads

alters the activities of the enzymes that produce the

to metabolic trade-off in which reproductive activity is

final and characteristic response by the cell (Fig.

curtailed, sometimes suspended. The suspension leaves

33.11a).

the regulatory neuroendocrine apparatus intact; repro-

The sensitivity of a target tissue to a particular

ductive efforts can be resumed when the energy deficit

hormone will vary depending upon the number of spe-

has been repaired.

cific receptors it has available for binding that hormone.

In many simple-stomach species the neural mecha-

At any time, the number of receptors depends on the

nisms that control the pulsatile release of GnRH (and,

balance between degradation and synthesis of recep-

consequently, LH secretion and ovarian function) *tors. A hormonal stimulus may increase the sensitivity*

appear to respond to minute-by-minute changes in the

of a target tissue by increasing the rate of synthesis of

availability of metabolic fuels (Bronson, 1989; Wade &

the specific receptors; a good example of this 'up regu-

Schneider, 1992). The response in ruminants may not be

lation' is the increase in LH receptors induced in the

as immediate but it is significant, nonetheless. Accord-

granulosa cells of the preovulatory follicle by FSH

ing to Roche et al. (2000), cattle are very sensitive to

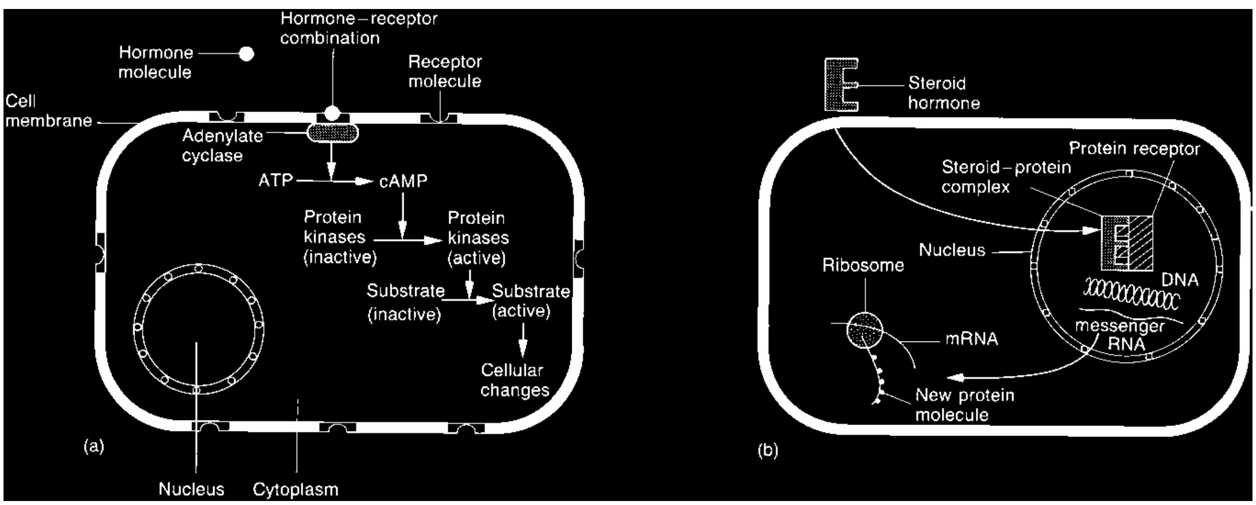


Fig. 33.11

Interaction of hormones with target cells. In (a) a glycoprotein (the 'first messenger') binds with receptors in the cell membrane and activates adenylate cyclase in the membrane. Adenylate cyclase converts ATP to cyclic AMP (the 'second messenger') which, in turn, activates various protein kinases. The *resultant cascade of enzymatic activity produces the characteristic cell response to the endocrine signal. In (b) a steroid hormone enters the nucleus where it binds to its receptor. The receptor–hormone complex binds to a particular region of DNA and activates particular genes. The activated genes promote the synthesis of particular messenger RNA molecules that pass from the nucleus to the cytoplasm where they induce the synthesis of proteins (mainly enzymes) that are responsible for the characteristic actions of that hormone in that cell type.*

Resting metabolism

Storage

Thermoregulation

1

Locomotion

Stress responses

Metabolic

Food

Partitioning

fuels

Lactation

2

Immune responses

Fig. 33.12

Partitioning of energy by a lac-

tating cow. The sizes of the arrows indicate

the order of priorities rather than the quan-

Growth

3

Reproduction

tities of metabolic fuels allocated to the

different activities.

acute nutritional deprivation: after a lapse of three to

of the sympathetic nervous system induces cata-

five days, follicular growth is impeded and ovulatory

bolic responses that mobilize energy, promote its ex-

ability is reduced. Chronic nutritional deprivation

penditure, and leave less available for use by the

results in delayed puberty and, in adult females, it

HPG axis; concurrently, cortisol released by the

causes extended postpartum anoestrus and prolonged

hypothalamic–pituitary–adrenal (HPA) axis acts as a

calving intervals.

counter-regulatory signal at all critical points in the

HPG axis and at target tissues for the gonadal steroids

(see Fig 67.6). Short-term acute stressors active at

Stress (see Chapter 67)

critical times in the reproductive cycle of a female

The effects of stress on reproductive functions are
can disrupt the orderly timed sequence of hormonal
complex: during the stress response increased activity
changes on which reproductive success is predicated. In

such circumstances, failure to establish a pregnancy may
from activated immunocompetent cells can evoke a
be a 'one-off' eventuality without residual effects on the
variety of neural, neuroendocrine, metabolic and
next attempt. On the other hand, stressors that gener-
behavioural responses regulated by the CNS; the effect
ate allostatic load (see Chapter 67) may lead to at-
is akin to activation of the central neural and hormonal
tenuation or suspension of reproductive activities for
components of the stress response (see Chapter 67): the
periods of weeks or months until the counter-regulatory
main routes of communication are via the sympathetic
signals are quenched. In such cases, inhibition of the
nervous system and the HPA axis. The noradrenaline
pulsatile release of GnRH may be the most significant
and glucocorticoids released by the counter-regulatory

action in the context of self-preservation of the organ-

loops invoked by the cytokines can have profound

ism, but inhibition at other critical points in the HPG

biological effects in terms of the expenditure of energy,

axis may be responsible for more persistent carry-over

immunosuppression and interference with the func-

effects during the recovery phase. Recovery of repro-

tions of the HPG axis. Thus, for instance, the cross-talk

ductive efficiency requires that the appropriate bio-

between the brain and the immune system evoked by

chemical features (receptors, G-proteins, transcription

a severe bout of mastitis in early lactation can have a

factors, other signalling proteins, enzymes, metabolic

seriously negative impact on the restoration of cyclic

cascades) be restored and functional at each of the

ovarian activity and fertility.

critical points in the HPG axis. As happens at puberty

and, again, in the early postpartum period, it may

require more than one attempt to fully up-regulate the

***Puberty** (see also Chapter 5)*

normal cascade of the HPG axis and reinstate the *ability to reproduce.*

Puberty, the process by which animals become capable

of producing offspring, is often given a very restricted

definition. According to Short (1984), ‘we generally

Neuro-immune interactions

refer to puberty as that moment at which the female

In recent years it has become increasingly evident that

first comes into oestrus and ovulates, or the male first

the interactions between behavioural, neural, endocrine produces spermatozoa in his ejaculate’. The trouble

and immune processes are as important to our under-

with this widely-held perception of puberty is that it

standing of homeostasis as are the interactions within

concentrates exclusively on the apparent end-point of

each of the individual disciplines. In the present

a protracted and complex physiological process and

context, we focus on the bidirectional network through

suggests that puberty is a discrete event that can be

which the CNS and the immune system exert profound

assigned to a particular day (or moment!). There is the

effects on each other. The nervous system impacts upon *additional problem that the apparent end-point (first*

the immune system through several routes, systemic

release of the gametes) is not necessarily conclusive

and local, including neuroendocrine pathways (e.g. the

evidence that the animal has now reached the stage at

HPA axis), autonomic nerves and systemic nerves. In

which it can reproduce itself; for instance, it is clear that

the reciprocal relationship, cytokines (see Box 33.1)

many heifers may not be capable of doing so until well

after first ovulation.

In fact, the onset of puberty is a gradual process that

Box 33.1.

Cytokines

is in train for several months during which there are sig-

Molecules, proteins or glycoproteins, produced by one or

nificant morphological, physiological and behavioural

more cell types that regulate the activities of other cells. They responses to the progressive expression of both the

bind to specific receptors on the cell membranes of target

steroidogenic and gametogenic activities of the gonads.

cells and, like hormones, they may act locally in autocrine or The essential feature of the process is the maturation of *paracrine fashion, or they may be released into the blood-*

the brain–hypothalamic–pituitary–gonadal axis, which

stream and interact with target cells elsewhere in the body.

culminates in the adult pattern of reproductive activ-

More than 100 cytokines have been identified; they are clas-

ity. The components of the hypothalamic–pituitary–

sified into several categories: interferons, insulin-like growth factors, interleukins, tumour necrosis factors, growth factors, gonadal axis are present before birth and, even at that

transforming growth factors, and so on. Amongst a vast range

stage, each component is capable of responding to

of activities, they participate in haematopoiesis, cell prolif-appropriate hormonal signals. During gestation, steroid

eration, immune responses, inflammation, wound healing,

hormones released from the placenta have an

modulation of cell metabolism. The nervous system can

inhibitory effect on the fetal hypothalamus that

produce cytokines and it can respond to cytokines released

suppresses the activities of the axis. After birth the

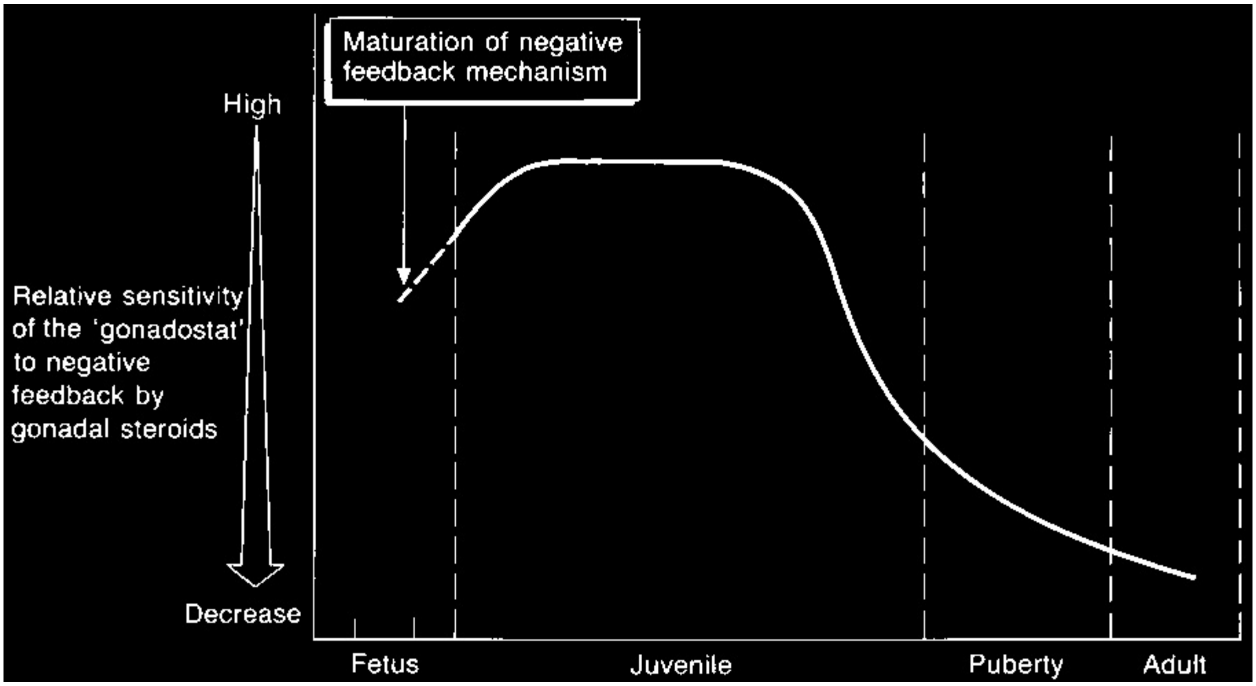
peripherally; for instance, in fever, in sickness behaviour

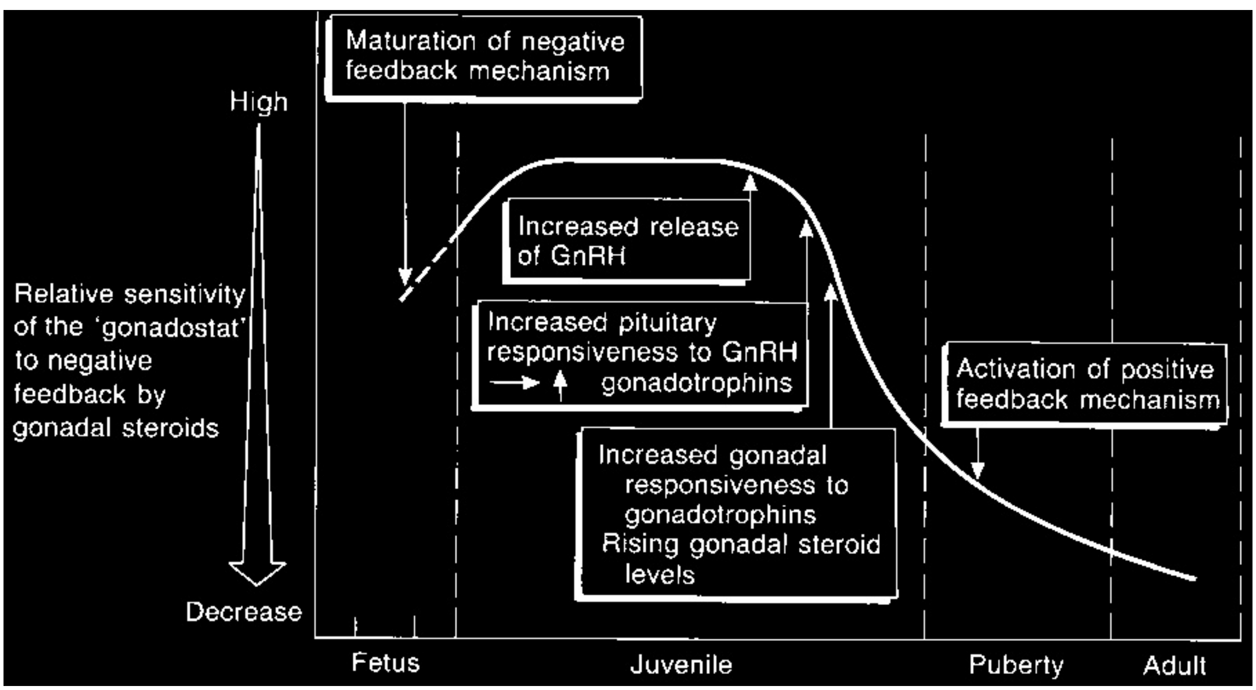
axis becomes an independent regulatory system that

and in modulating neuroendocrine responses – which is the *secretes increased amounts of gonadotrophins and*

context in which we have introduced the term.

gonadal steroids. However, the system is restricted to a





relatively low level of activity (juvenile level); for

gonadotropes to GnRH and to an increase in the

instance, in the female the level of activity is well below

responsiveness of the gonads to the gonadotrophins

that required for ovulation or cyclic ovarian activity.

(Fig. 33.14). Greater quantities of gonadotrophins are

The restraint is due partly to fine sensitivity of the

released from the pituitary gland and, in turn, greater

GnRH pulse generator to negative feedback by

quantities of steroids are released by the gonads. For

gonadal steroids and partly to inhibitory inputs from

instance, in the female the sensitivity of the hypo-

the neural circuits that modulate the activities of the

thalamus to the negative feedback effect of oestrogen

hypothalamus.

declines progressively and, as it does so, the increasing

The transition to sexual maturity is brought about by

quantities of oestrogen from the ovaries can no longer

progressive changes in the neuroendocrine activities of

hold the axis within the juvenile pattern of activity.

the axis in response to a variety of internal and envi-

There is a gradual movement of the regulatory system

ronmental factors. The 'gonadostat' hypothesis postu-

towards the adult pattern (Figs 33.13 and 33.14). Even-

lates that the essential change during the transition to

tually, the ovaries produce a surge of oestrogen that

sexual maturity is a progressive decrease in sensitivity

exerts a positive feedback effect on the pulse generator

of the hypothalamus to the negative feedback effects of

in the hypothalamus (Fig. 33.14) and this induces a

gonadal steroids (Fig. 33.13) so that the frequency of

surge of LH that leads to ovulation.

GnRH pulses is increased progressively. This leads

As our knowledge of these changes expands, there is

to an increase in the sensitivity of the pituitary

increasing evidence that sexual maturity is regulated to

***Fig. 33.13** Maturation of the negative*

feedback system and changes in set

point of the hypothalamic gonadostat

extending from fetal life through puberty

to adulthood (modified from Grumbach

et al., 1974).

Fig. 33.14

The change in set point of the hypothalamic gonadostat (denoted by the dashed and solid lines) and the maturation of the negative and positive feedback mechanisms from fetal life to adulthood (from Grumbach et al., 1974).

a considerable extent by changing patterns of neural
generator is closely coupled with energy balance and
control over the hypothalamus. These alterations in
that it is allowed to progress from the juvenile to the
intrinsic neural activity do not appear to be dependent
adult level of activity in the female only when the ener-
on gonadal hormones; however, they play a crucial role
getic status appears to be adequate to sustain pregnancy
in that they gradually release the GnRH pulse genera-
and lactation. It was anticipated that the hormone
tor from the restraints exercised by the central nervous
leptin, produced by adipose tissues, might prove to be

system during the juvenile period, thus enabling it to

the signal that triggers the onset of puberty: current

respond to the gonadal steroids in the adult manner. It

evidence is that leptin is just one of many permissive

is evident that the classical 'gonadostat' hypothesis does

metabolic factors that allow pubertal development to

not furnish an entirely satisfactory explanation of the

proceed; it may act as a permissive signal to increase

onset of puberty in all its details. Nevertheless, it does

GnRH secretion after the pulse generator has been sen-

provide a conceptual framework that is adequate for

sitized to energy balance by other developmental or

the purposes of this text.

metabolic cues; it is not the trigger for the beginning of

The first ovulation is likely to be silent; it appears

puberty (Urbanski, 2001; Smith et al., 2002).

that the hormonal requirements for the expression

Selective culling is an integral part of efficient

of oestrus are small quantities of progesterone from a

management of the dairy herd. It can be practised suc-

regressing corpus luteum followed by a surge of oestro-

cessfully only when the stockperson has available an

gen from the preovulatory follicle – a sequence that

adequate number of high-quality heifers due to calve

is absent at the time of first ovulation. Thus, the first

down at the appropriate time. This requires careful

oestrus observed by the stockperson indicates that the

management of the prepubertal animal to ensure that

process of puberty is well advanced but it does not

the reactivation of the hypothalamic pulse generator is

provide a precise date for the 'moment' of puberty.

not delayed unduly by environmental influences, prin-

The earliest possible maturation of the individual

cipally nutritional factors and subclinical diseases.

components of the reproductive axis (and, therefore,

Similarly, young bulls intended for breeding purposes

of the axis itself) is determined by genes, i.e. there are

require careful management during the juvenile period

inherent breed variations in the onset of puberty.

because the onset of puberty in the male is also influ-

However, in all breeds this process is subject to delays

enced by a variety of factors (including breed, season *caused by a variety of endogenous and exogenous influ-*

of birth, energy intake and liveweight gain) that affect

ences, some of which can be manipulated by the stock-

the reactivation of the hypothalamic GnRH pulse

person to ensure that the heifer is ready for breeding at

generator.

the desired time. The principal environmental factors

that influence the onset of puberty are: season of birth,

level of nutrition, growth rate, photoperiod, high am-

Male physiology

bient temperatures, intercurrent diseases and presence

of the male.

In the male, puberty is associated with changes in the

Specific reference to these factors will be made in the

pattern of LH secretion, a gradual increase in the con-

clinical segment of the text. For the moment, suffice

centration of testosterone in the blood, rapid growth of

it to say that, as a general guideline, the stockperson

the testes and the initiation of spermatogenesis. In

should devise a management strategy in the knowledge

essence, the adult pattern of GnRH release is attained *that the onset of puberty is a labile process that is con-*

and the testes proceed to fulfil two primary functions:

ditioned by competition between the reproductive

the synthesis and release of androgens (steroidogene-

system and the other body systems of the growing

sis) and the production of spermatozoa (gameto-

animal for energy and specific nutrients. Reproduction,

genesis). In most male mammals, these functions are

particularly in the female where it involves pregnancy

performed best at temperatures somewhat lower than

followed by lactation, is an energy-consuming process

body core temperature.

to which Nature assigns a relatively low priority for the

In the bull the testes are located in the pendulous

prepubertal animal. Evidence is accumulating from

scrotum, where they are attuned to function at 3–4°C

work on a number of species that inadequate intake of

below core temperature. The three principal mecha-

energy or nutrients can depress or abolish the activities

nisms by which the scrotal temperature is reduced are

of the GnRH pulse generator in the juvenile animal.

as follows:

This has been attributed, variously, to deficiencies in

body weight, in rate of growth, in fat content or in

(1)

Precooling of the arterial blood supply as it passes

fat : lean ratio. There is no agreement on the particular

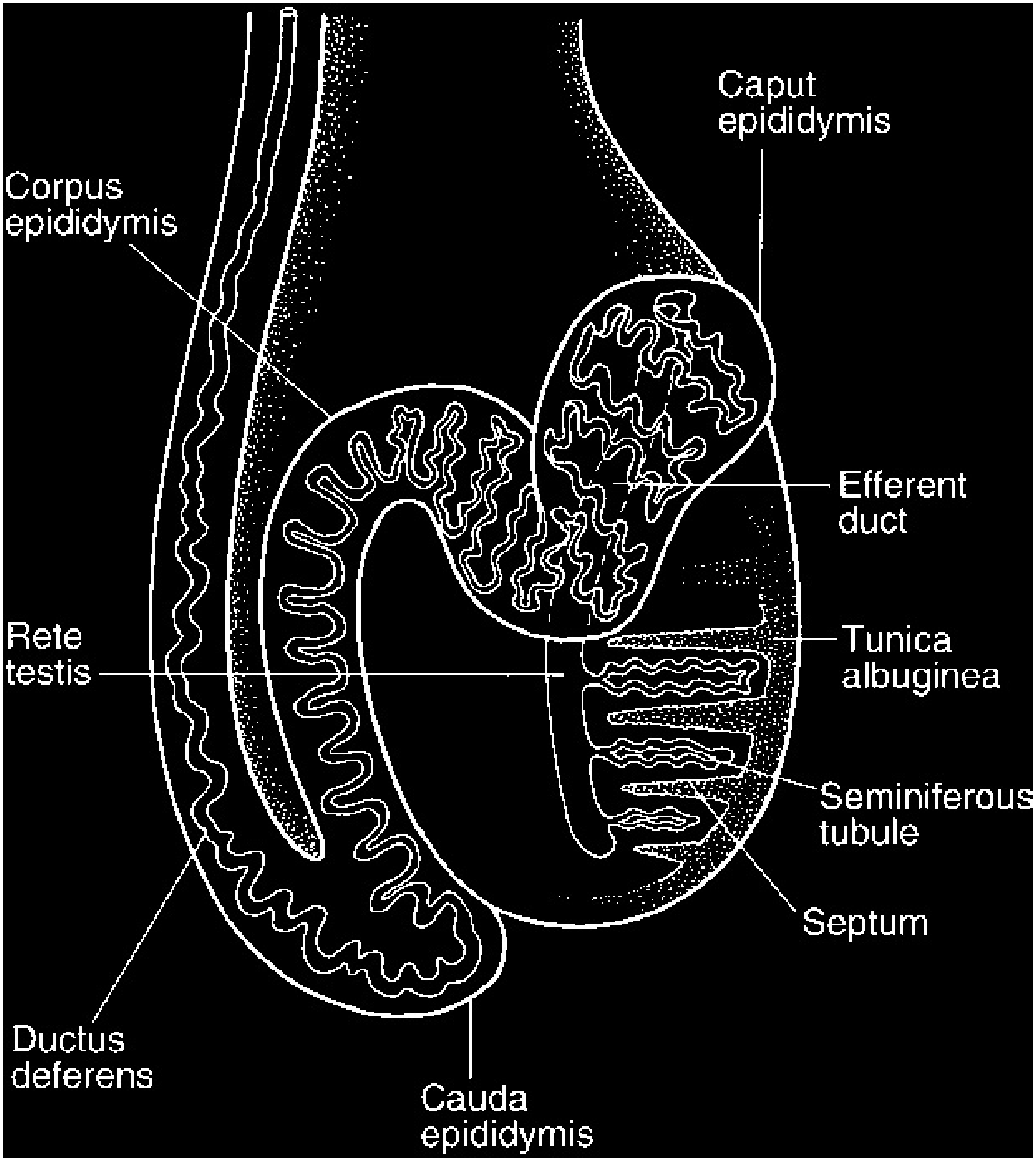
through the vascular cone in the spermatic cord.

cue(s) that inhibit(s) the pulse generator but there is

The vascular cone consists of a coiled segment of

general acceptance of the thesis that the function of the

the spermatic artery that is surrounded by the



pampiniform plexus of the spermatic vein.

the germ cells during their migration from the base to

Because of this anatomical arrangement the arte-

the luminal surface. The plasma membranes of adjacent

rial blood and the venous blood are flowing in par-

Sertoli cells form specialized interepithelial tight junc-

allel but in opposite directions; this allows for an

tions that extend entirely around the circumference of

efficient countercurrent exchange of heat between

each cell (Fig. 33.17). These junctions constitute the

the two vessels. The net result is that the arterial

epithelial component of the blood–testis barrier that

blood delivered to the testes is several degrees

precludes the passage of many substances from the

below body core temperature.

blood or interstitial fluid into the lumen of the seminif-

(2)

Sweating from the many sweat glands in the

erous tubule. They also divide the intercellular spaces

scrotal skin.

into two compartments: the basal compartment that

(3)

Physical contact with cold ground or other cold

contains the undifferentiated germ cells and the *objects.*

adluminal compartment that provides the appropriate

microenvironment for the more differentiated germ

In very cold weather, the temperature at the base of

cells (see below).

the scrotum may be up to 7°C below core values but the

The basal surface of the Sertoli cell has specific recep-

bull can attempt to curtail the drop in temperature by

tors for FSH. The cells respond to the gonadotrophin

drawing the scrotum closer to the (relatively) warm

by secreting (i) a nutrient fluid that sustains the germ

body wall by contracting the cremaster and dartos

cells in the intercellular spaces, (ii) androgen-binding

muscles.

protein that binds and transports testosterone to the

The gametogenic function of the testes is much more

epididymis and (iii) inhibin that modulates the secre-

heat sensitive than the steroidogenic function; for

tion of FSH by negative feedback at the pituitary gland

instance, a retained testicle in a cryptorchid animal

(Fig. 33.18). Sertoli cells also have receptors for andro-

(‘rig’) may secrete androgens but the seminiferous

gens; it is known that testosterone can maintain the

tubules will remain infantile in structure and they will

functional integrity of the Sertoli cell when FSH is

not produce spermatozoa. The retained testicle has a

withdrawn.

propensity to develop neoplasms (see p. 182).

Sertoli cells are resistant to relatively high levels of

heat, ionizing radiation and many toxins (e.g. cadmium,

nitrofurans, cytotoxins) that destroy differentiating

Morphology of the testis

germ cells.

The testis is surrounded by a thick fibrous capsule, the

tunica albuginea, from which septa project inwards to

divide the substance of the testis into lobules (Fig.

33.15). Each lobule contains one to four highly convo-

luted seminiferous tubules and interstitial tissue that

fills the spaces between the convolutions.

The interstitial tissue contains blood vessels, lym-

phatic vessels, nerves and the steroid-secreting Leydig

cells.

The seminiferous tubules are about 200 mm in diameter and they may be up to 70 cm long; they open at both ends into the rete testis (Fig. 33.15). The tubules contain two populations of cells: (i) a fixed population of non-proliferating somatic cells, the Sertoli cells, and (ii) a migratory population of proliferating, differentiating germ cells (Fig. 33.16).

Sertoli cells

The Sertoli cells have been described as the 'backbone' of the tubule. They are columnar cells that rest on the basement membrane and extend the full depth of the epithelial layer; they envelop the developing germ cells in deep recesses in their lateral walls and, ultimately, in their luminal surfaces. The Sertoli cells continually alter shape to accommodate the morphological changes in

Fig. 33.15

Outline morphology of the testis.

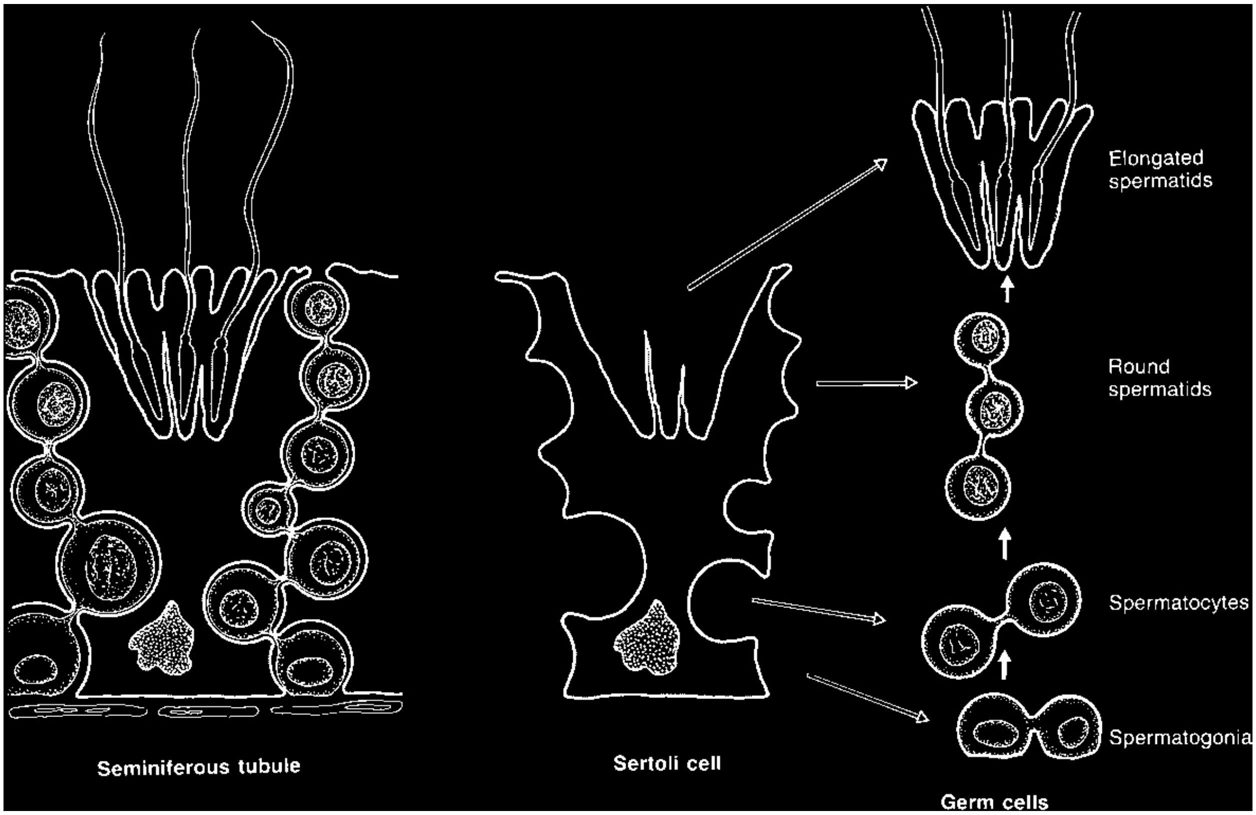


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Fig. 33.16

The histology of the seminiferous tubule. The diagram depicts the Sertoli cell and the germ cells in intimate contact as they are in vivo and, also, separately to show the outlines of the individual cells. (Adapted from Fawcett, 1994.) Germ cells

still attached to the Sertoli cell; the final stages take

place at the luminal surface. The conversion of the sper-

A detailed description of the process of spermato-

matid to the spermatozoon does not involve cell divi-

genesis (see Table 33.1) is beyond the scope of this

sion, merely morphological reorganization (referred to *text. Suffice it to say that the spermatogonia are the*

as spermiogenesis). The principal changes are conden-

stem cells and that they begin the process by undergo-

sation of the nucleus and acquisition of the acrosome

ing a number of mitotic divisions in the basal compart-

in the head region, reorganization of the mitochondria

ment. These divisions produce a pool of cells that

in the middle piece, development of the tail and loss of

are joined to each other by intercellular bridges

excess cytoplasm that moves caudally and is shed as the

(Fig. 33.19).

residual body, which is phagocytosed by the Sertoli cell.

Cohorts of spermatogonia from this pool are moved

The intercellular bridges are lost with the residual

to the adluminal compartment while one spermatogo-

bodies and each spermatozoon now is a separate cell,

nium from the group remains behind in the basal com-

that soon escapes from the luminal surface of the

partment. It enters a resting phase during which it is

Sertoli cell (spermiation). When the fully developed

highly resistant to ionizing radiation and toxic agents.

spermatozoon is released into the lumen of the semi-

This will be the stem cell from which the next cycle of

niferous tubule it is non-motile. It is transported pas-

spermatogenesis will begin (two weeks later). In the

sively from the tubule into the rete testis and thence to

meantime, the newly arrived cells at the base of the

the epididymis. Motility is acquired during passage

adluminal compartment proceed to undergo meiosis as

through the epididymis.

primary spermatocytes (first meiotic division) and sec-

In summary, during spermatogenesis the germ cells

ondary spermatocytes (second meiotic division). The

advance through three major processes:

haploid secondary spermatocytes are still attached to

each other by intercellular bridges and after a short

(1)

Proliferation of stem cells by mitosis in the basal

period each of them divides to yield two spermatids. As

compartment.

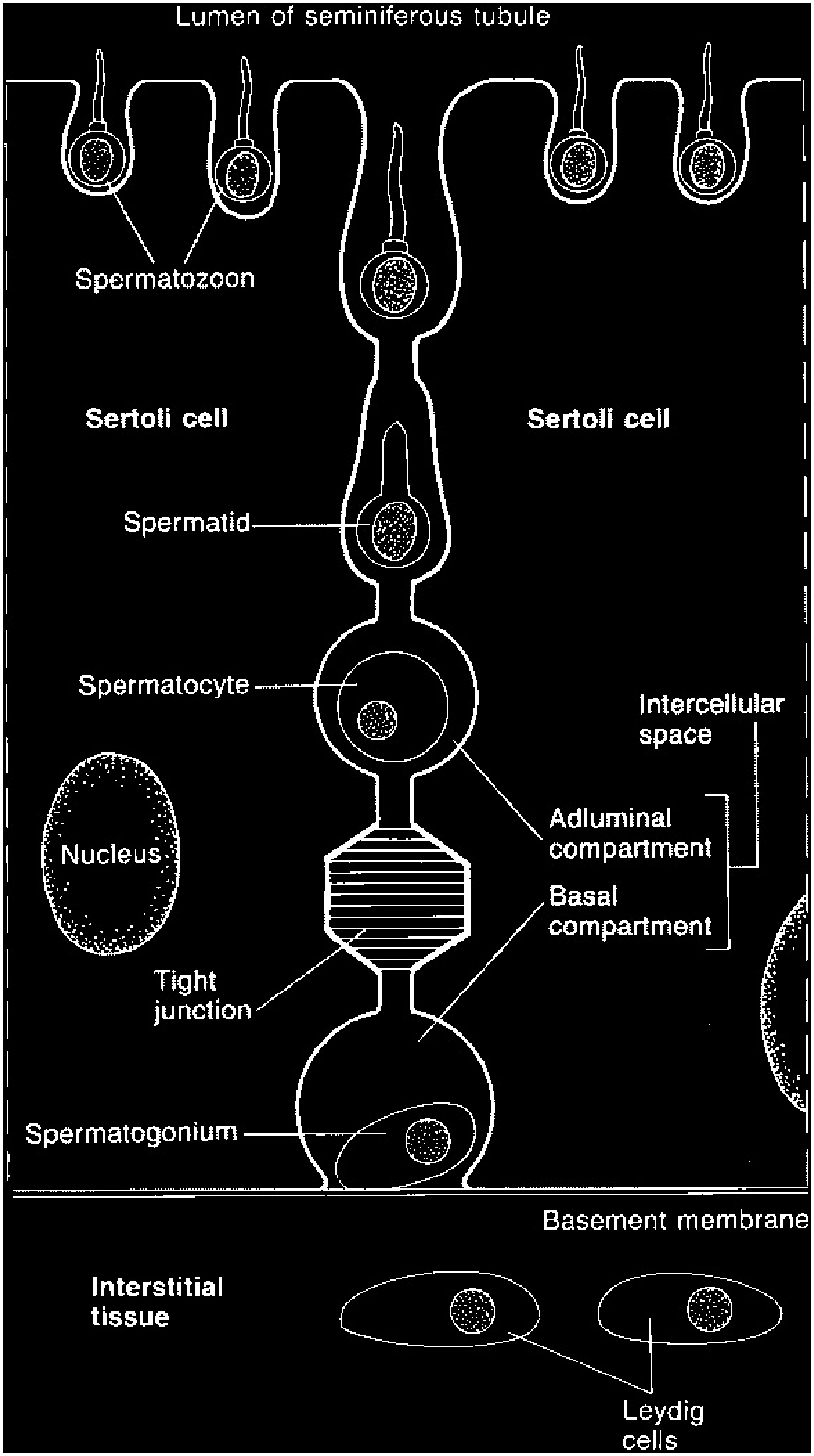
the process of spermatogenesis proceeds the germ cells

(2)

Reduction of the chromosome number by meiosis

move progressively towards the lumen of the tubule,

in the adluminal compartment.



Lumen of seminiferous tubule
Spermatozoon
Sertoli cell
Sertoli cell
Spermatid
Spermatocyte
Intercellular space
Nucleus
Adluminal compartment
Basal compartment
Tight junction
Spermatogonium
Basement membrane
Interstitial tissue
Leydig cells

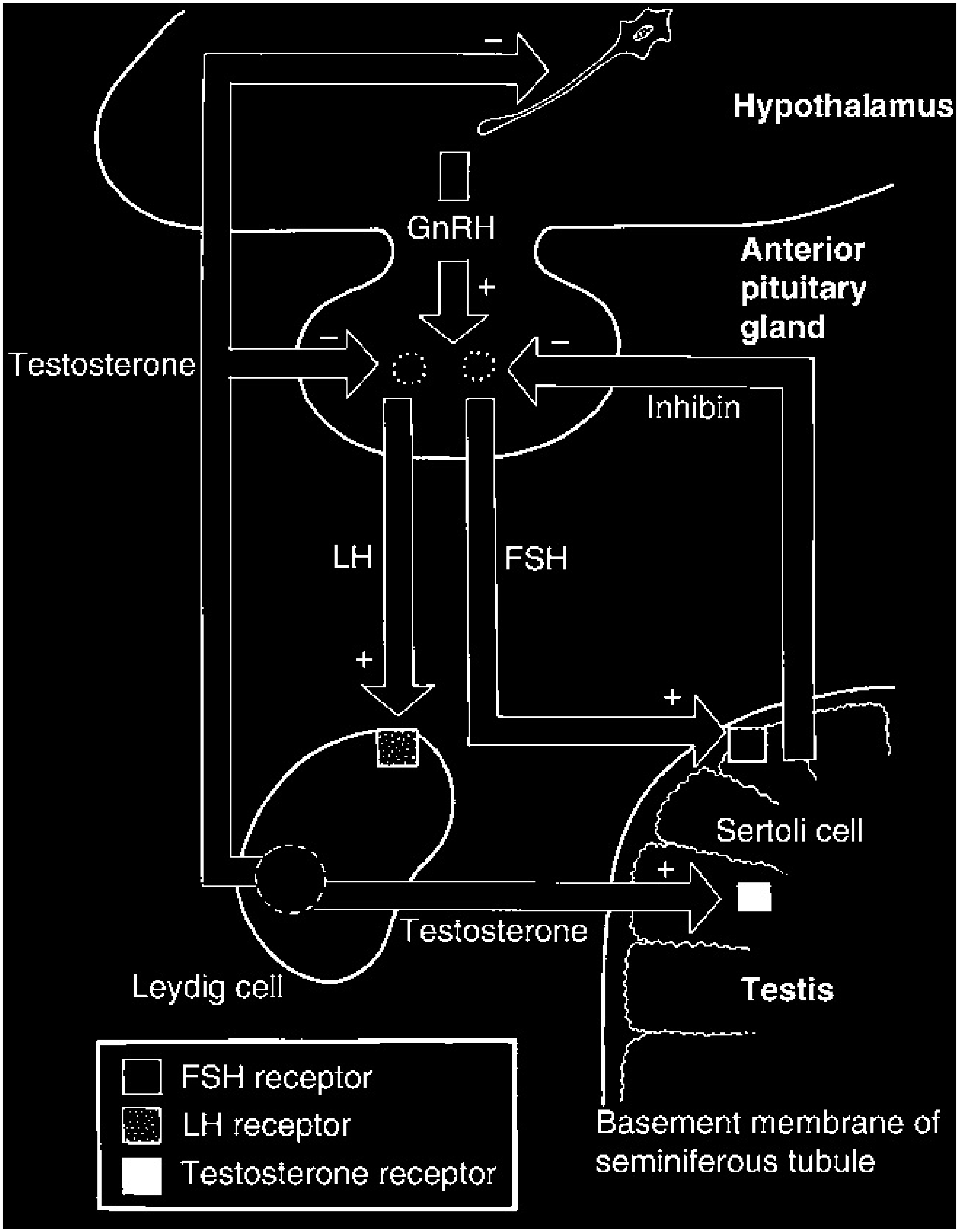

Hypothalamus
GnRH
+
Anterior pituitary gland
Testosterone
−
−
Inhibin
LH
FSH
+
+
Sertoli cell
+
Testosterone
Leydig cell
Testis
FSH receptor
LH receptor
Testosterone receptor
Basement membrane of seminiferous tubule

Fig. 33.18

Hormonal interactions in the hypothalamic–

pituitary–testicular axis.

Table 33.1

Principal stages in the development of spermato-

zoa (spermatogenesis).

Fig. 33.17

The relationship between the germ cells and Sertoli

cells during spermatogenesis.

Cell type

Number of chromosomes

Spermatogonium

2n

Primary spermatocyte

2n

(3)

Morphological transformation of a conventional

Secondary spermatocyte

n

cell (the spermatid) into the very specialized struc-

Spermatid

n

ture of the spermatozoon (spermiogenesis) in the

Spermatozoon

n

adluminal compartment.

This sequence of mitotic, meiotic and packaging events

requires 56 days for completion in the bull. It is a very

orderly sequence in which each of the component cells

will be in train in the seminiferous epithelium at any

has a fixed lifespan so that cellular differentiation pro-

moment. Furthermore, since both the intervals between

ceeds at a fixed rate. The spermatogonium that reverts

the commencement of the cycles and the rates of

to the resting phase remains quiescent in the basal com-

progress of the cells through spermatogenesis are con-

partment for 14 days (equivalent to 25 per cent of the

stant, a histological examination of a cross-section of a

entire cycle) before it enters mitosis and begins the next

seminiferous tubule will reveal a characteristic set of

spermatogenic cycle. The cells derived from the new

cell associations at any one time. In most mammals the *cycle advance in a similar orderly fashion behind the same set of cell associations is seen at all points in the cells from the previous cycle as they move progressively circumference of the tubule (this represents the 'cycle towards the luminal surface. In fact, this arrangement of spermatogenesis'); however, adjacent segments means that four successive cycles of spermatogenesis of the tubule tend to have a different set of cell*

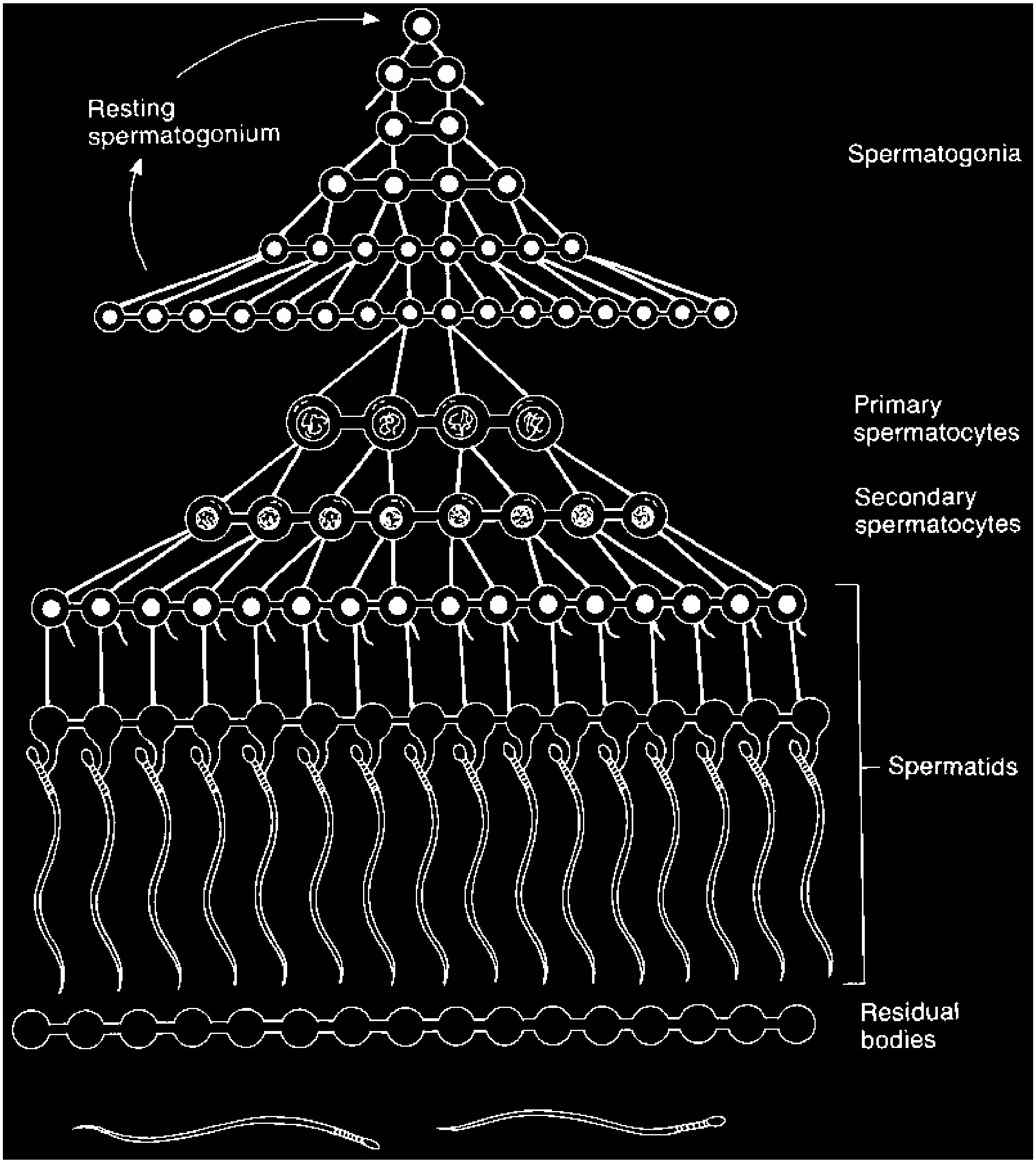


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Fig. 33.19

The process of spermatogenesis.

(Reproduced from Fawcett, 1994.)

associations, each either in advance of or behind

the head of the sperm and allowing the lytic enzymes

its neighbours (this constitutes the 'wave of

to escape through the resultant pores (see p. 499).

spermatogenesis').

Some of the progeny of the original spermatogonia do

Neuroendocrine control

not complete the full course; large numbers (perhaps 20

per cent) of differentiating germ cells die without reach-

The steroidogenic functions and the gametogenic func-

ing maturity and these are removed by the Sertoli cells.

tions are segregated anatomically: androgen synthesis

by the Leydig cells in the interstitial spaces and

spermatogenesis within the seminiferous tubules (Fig.

The spermatozoon

33.17). Both functions are controlled by the pituitary

The essential features of the mammalian spermatozoon

gland through the secretion of the gonadotrophins.

are depicted in Fig. 33.20. Only one structure warrants

Luteinizing hormone binds to specific receptors on the *further comment at this juncture: the acrosome, an*

cell membranes of Leydig cells and they respond by

organelle that undergoes significant morphological

secreting androgens (principally testosterone), which in

change as an essential prelude to fertilization. The acro-

turn inhibit LH secretion by negative feedback. When

some contains a number of lytic enzymes (particularly

the concentration of testosterone in the blood declines

hyaluronidase, neuraminidase and acrosin); it has been

sufficiently the 'brake' on LH secretion is released and

described as a modified lysosome and, like all lyso-

the resultant rise in LH in the circulation induces the

somes, it has a bilaminar structure. The inner acrosomal

Leydig cells to secrete testosterone (Figs 33.18 and

membrane is adherent to the nuclear membrane, while

33.21). The negative feedback effect of testosterone on

the outer acrosomal membrane underlies the cell mem-

LH secretion is exercised at the level of the hypoth-

brane. When the ejaculated spermatozoon undergoes

alamus (influencing the secretion of GnRH) and at

the acrosome reaction in the female genital tract, the

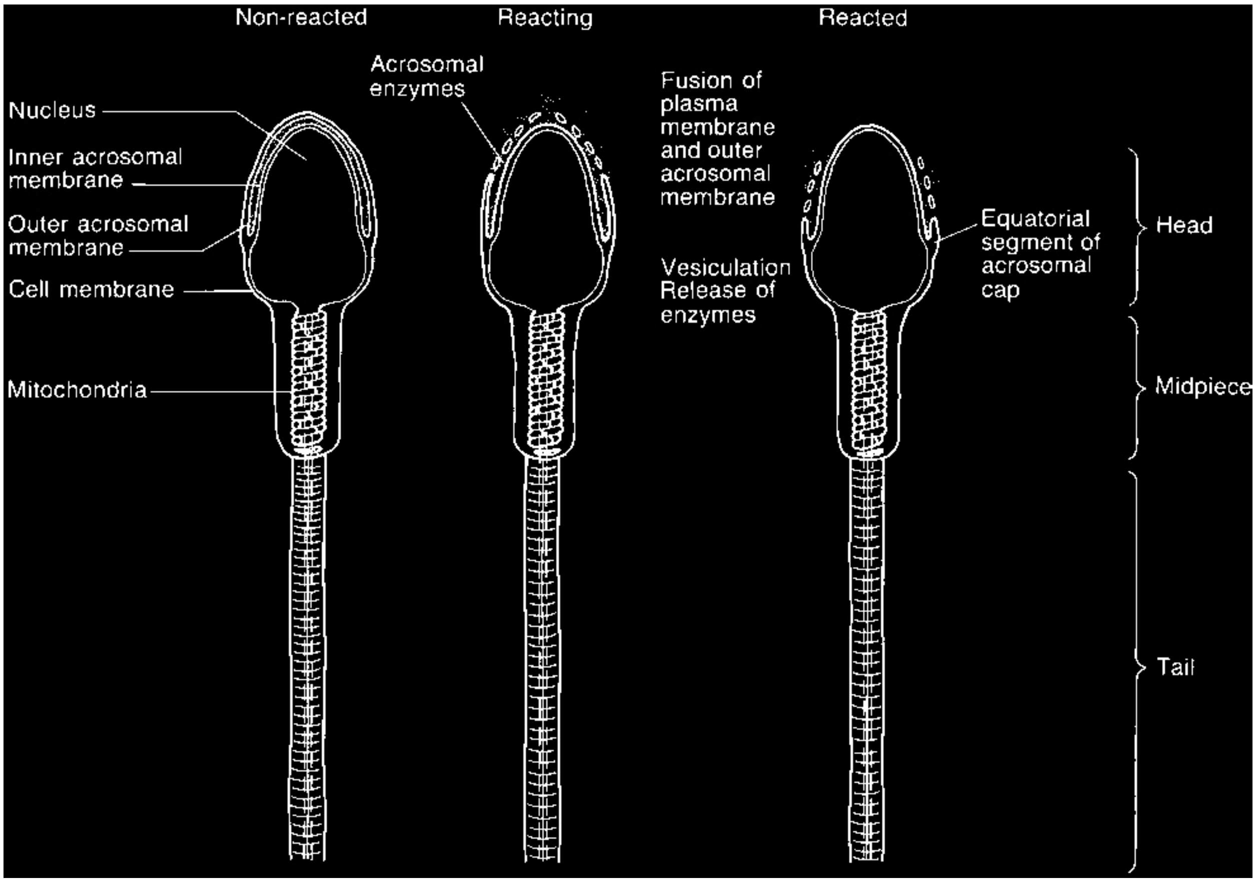
the pituitary gland (modulating the responsiveness of

outer acrosomal membrane forms point fusions with

the gonadotropes to GnRH). In this manner the

the cell membrane creating a sequence of vesicles over

hypothalamic–pituitary–Leydig cell axis maintains the



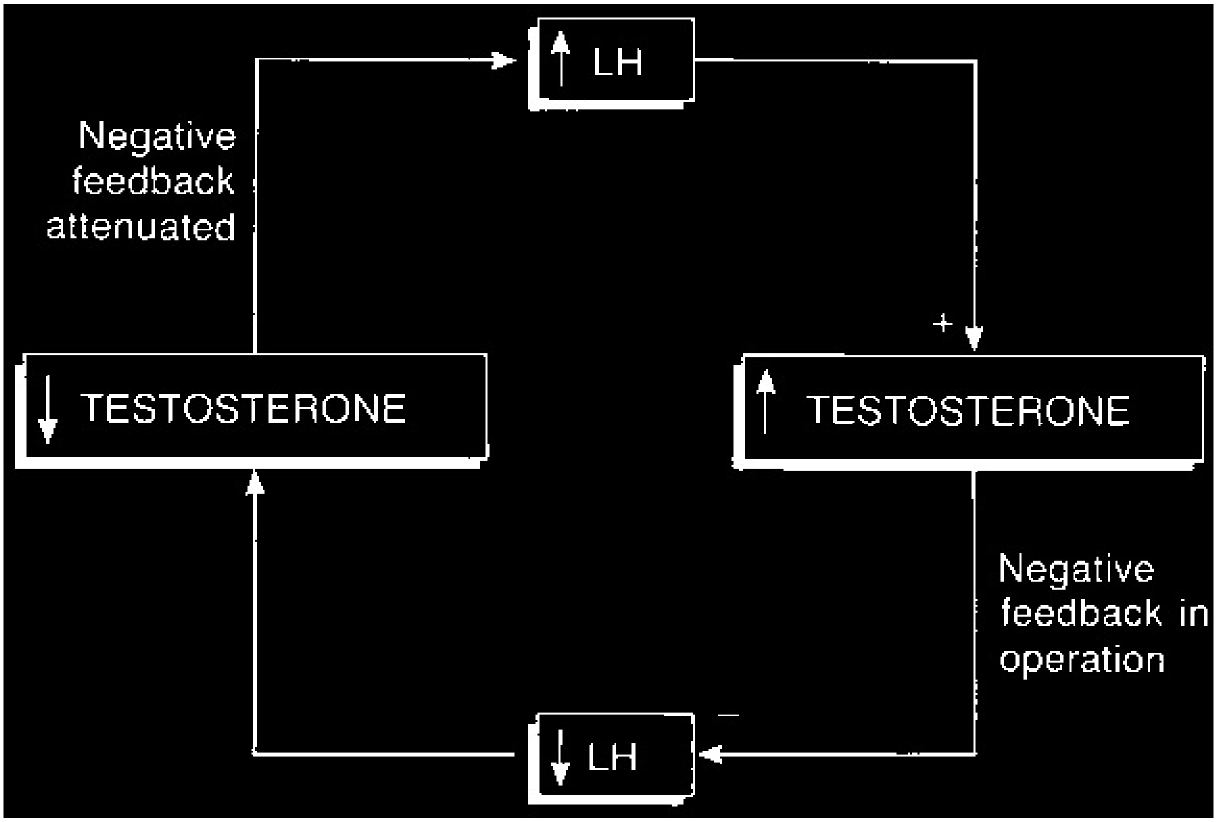


Fig. 33.20

The spermatozoon

undergoing the acrosome

reaction.

There is no doubt that an intact hypothalamic–

pituitary–testicular axis is essential for normal testicu-

lar function; however, apart from the fact that FSH is

essential for the initiation of the process in immature

animals, it is unclear what specific roles in the process

of spermatogenesis are played by the individual *hormones that constitute the axis. On the basis of*

information available in the literature, the following

deductions have gained wide acceptance:

• Differentiating germ cells lack hormone receptors

and, therefore, they are not affected directly by the

hormones.

Fig. 33.21

The reciprocal relationship between the concentra-

• Sertoli cells have specific receptors for FSH and for

tions of testosterone and LH in the general circulation.

androgens but not for LH.

• Testosterone is required for the first mitotic division

of the stem cell in the basal compartment.

• Testosterone is necessary for the reduction division

concentration of testosterone in the general circulation

of the primary spermatocyte.

within normal limits.

• FSH is essential for the final steps in the maturation

Sertoli cells respond to FSH by secreting fluids and

of the spermatids.

proteins that sustain the differentiating germ cells. Fol-

• There is controversy as to whether or not testos-

licle stimulating hormone is absolutely essential for the

terone is required for the earlier steps in the matu-

initiation of spermatogenesis in immature animals but

ration of the spermatids.

once the normal germinal epithelium has been estab-

• It is likely that all the other steps in spermatogene-

lished FSH does not appear to be essential for the start

sis can proceed without the specific intervention of

of each successive spermatogenic cycle. Another action

a particular hormone.

of FSH is to stimulate the conversion of testosterone to

oestradiol by the Sertoli cells. The Sertoli cells also

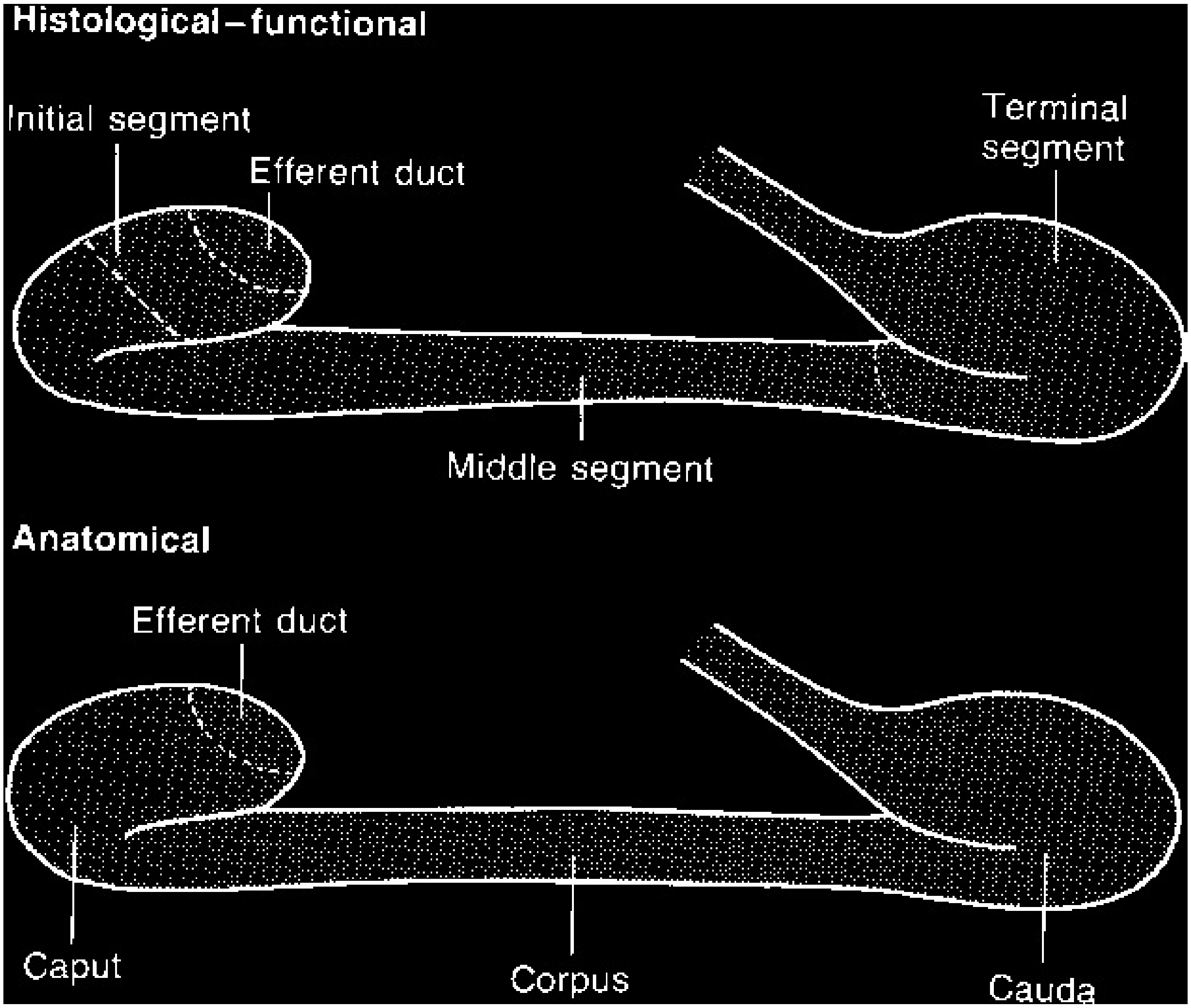
Thus, FSH and testosterone exercise direct actions on

secrete inhibin, a polypeptide that inhibits the release

the seminiferous tubules, while LH does so indirectly

of FSH by the pituitary gland (Fig. 33.18).

via the production of testosterone.



bull is an exception in that the bulk of the water has been absorbed by the efferent ducts before the contents reach the epididymis. The secretions from the epithelial cells of the initial and middle segments induce significant alterations in the functions and composition of most of the component parts of the spermatozoon. The principal functional changes are the acquisition of pro-

gressive motility and the ability to fertilize an egg. Fine structural changes have been observed in the plasma membrane, the acrosomal membranes, the nucleus and the tail. Changes in the composition of the plasma membrane appear to be central to the process of maturation of the spermatozoon as it passes through the epididymis; in particular, its protein composition is altered either by adsorption of components from the epididymal fluid or by modification or loss of existing components in response to enzymatic activity of the

Fig. 33.22

The regions of the bovine epididymis.

epididymal fluid. It is important to note that these biochemical changes are associated with the acquisition of the ability to fertilize but they do not complete the process of maturation – this will occur only after the

It should be noted that even where specific hormonal

ejaculated spermatozoa have been capacitated within

stimulation is essential, the hormone serves to ensure

the female genital tract (see p. 499).

that the event occurs but it does not alter the rate of

Ejaculated spermatozoa have species-specific recep-

progress of spermatogenesis, which is a feature that is

tors that bind to the zona pellucida of the egg. The

determined by genes rather than by hormones.

spermatozoa acquire these receptors in the epididymis,

under the influence of testicular androgens.

The ability of the epididymis to facilitate maturation

The epididymis

of the spermatozoa and to maintain the viability of the

When spermatozoa are transported from the rete testes

mature spermatozoa in the cauda is critically depend-

through the efferent ducts to the initial segment of the

ent on testicular androgens. Obviously, some of the

epididymis they are neither motile nor capable of fer-

testosterone reaches the epididymis in the arterial

tilization. They acquire these attributes during passage

blood but it is probable that most of it comes via

through the epididymis.

the efferent duct system bound to androgen-binding

The epididymis is a highly convoluted tubule lined by

protein. The epithelial cells of the epididymis have *specialized epithelium and surrounded by connective*

androgen receptors and they rapidly convert the testos-

tissue, which incorporates concentric layers of smooth

terone to dihydrotestosterone, which then regulates

muscles that increase in thickness from the initial

epididymal functions. It has been clearly established

segment to the terminal segment. Anatomists describe

that the maturation of spermatozoa is regulated by

the epididymis as consisting of three parts (Figs. 33.15,

dihydrotestosterone rather than by testosterone.

33.22): the caput (head), the corpus (body) and the

Movement of spermatozoa through the middle

cauda (tail). A more recent histological–functional clas-

segment is by continuous peristaltic contractions of

sification has designated at least eight regions in the epi-

the smooth muscles that surround the epididymal

didymis of the bull, but for the purposes of this text it

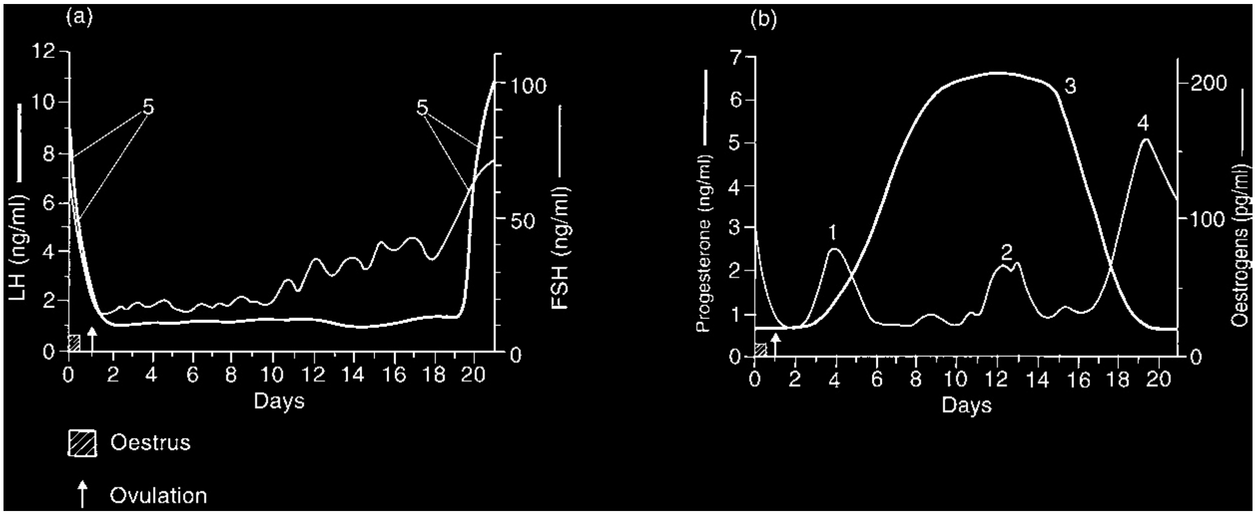
tubule. The rate of transport in this segment is not

is sufficient to refer to the three principal segments used

influenced by ejaculation and in the bull it is estimated

in that scheme: the initial segment, the middle segment

to take two to three days. It follows that the fertility of
and the terminal segment (Fig. 33.22). The efferent
sperm should not be depressed even when the bull is
ducts empty into the initial segment, which is special-
ejaculating frequently. By contrast, the muscles sur-
ized for the bulk reabsorption of water and electrolytes.
rounding the terminal segment are relatively inactive
The middle segment, which includes most of the caput
except when they are stimulated to contract during
and corpus, is responsible for the sperm maturation.
ejaculation; it follows that frequency of ejaculation can
The terminal segment, largely the cauda, stores the
have a significant effect on the duration of storage of
mature spermatozoa pending ejaculation.
potentially fertile spermatozoa and on the numbers of
In many species the initial segment is the principal
fertile sperm available for ejaculation at a particular
site for absorption of water from the luminal fluids. The
time.



Seminal plasma

principal secretions (oestrogens and progesterone). For

problems associated with the oestrous cycle see

The fluid portion of the ejaculate is called the seminal

Chapter 35.

plasma. It consists of the testicular and epididymal

secretions in which the spermatozoa are suspended

when they pass from the cauda epididymis into the vas

Oestrus

deferens plus the secretions from the various accessory

It has been shown that behavioural oestrus results from

glands, which are added as the spermatozoa are pro-

exposure of the anterior hypothalamus to both proges-

pelled along the vas deferens and the urethra during

terone and oestrogen in physiological concentrations

ejaculation. The seminal vesicles contribute fructose,

and in the proper temporal sequence. Progesterone on

the primary source of energy for the spermatozoa.

its own inhibits oestrus. Furthermore, in the absence of

Prostaglandins in the seminal fluid may assist transport

priming by progesterone, physiological concentrations

of spermatozoa within the female tract by stimulating

of oestrogen fail to elicit the signs of oestrus; thus, in the contraction of smooth muscle. The bull ejaculates 1–15

pubertal heifer the first preovulatory follicle produces

ml of semen containing 0.8–2.0 ¥ 109 spermatozoa/ml.

a surge of oestrogen that feeds back positively on the

(Infertility in bulls is dealt with in Chapter 38

pulse generator and induces an effective ovulatory

and some aspects of artificial insemination in Chapter

surge of LH, but it does not induce behavioural oestrus.

39.)

In the adult cow the normal sequence is a high con-

centration of progesterone (P4) for 10–14 days followed *by a rapid decline in P4 and an immediate increase in*

Female physiology

oestrogen from the growing preovulatory follicle (Fig. 33.23). This sequence results in behavioural oestrus that appears to be coupled with the preovulatory surge of

Oestrous cycle

LH so that ovulation occurs approximately 24 hours

By definition, the oestrous cycle is the interval between

after the onset of oestrus.

the onset of two successive periods of sexual receptiv-

The duration of oestrus may vary from 8 to 30 hours

ity (oestrus). Both the expression of oestrus and the

and the behavioural signs may recur frequently

duration of the cycle are the result of cyclic changes in

throughout the period or they may be evident during

the ovaries that involve two temporary endocrine struc-

two shorter periods at the beginning and end with a

tures (the ovarian follicles and corpora lutea) and their

quiescent period between them ('split oestrus').

Fig. 33.23

Changes in concentrations of gonadotrophins (a) and ovarian steroids (b) in *peripheral plasma during a 21-day oestrous cycle in the cow. During most of the cycle progesterone (P4) secreted by the corpus luteum (CL) is the dominant hormone, exercising strong negative feedback on the hypothalamic–pituitary axis. However, the tonic concentrations of gonadotrophins released during the luteal phase induce two waves of follicles that are associated with small peaks of oestrogen (1, 2). When the CL regresses, the concentration of P4 declines (3) and oestrogen concentration climbs to a peak, the oestrogen surge (4), which triggers a surge of gonadotrophins (5) that induces ovulation.*

Length of the cycle

Box 33.2.

Some regulators of follicular growth.

The cow is a polyoestrous animal and, if she is not preg-

From the pituitary gland

nant, she will tend to return to oestrus repeatedly

Follicle stimulating hormone (FSH)

throughout the year at intervals of 18–24 days (mean =

Luteinizing hormone (LH)

21 days). By convention, the day of oestrus is desig-

Prolactin (PRL)

nated day 0 and the length of the cycle is calculated

Ovarian steroids

from that baseline.

Androgens

There can be considerable variation (within the

Oestrogens

normal range) in the length of the oestrous cycle: even

Progesterone

successive cycles in the same cow may vary by several

Other regulatory factorsa

days. Most of this variation is due to differences in the

Inhibin

duration of the luteal phase of the ovarian cycle, i.e. in

Activin

the functional lifespan of the individual corpus luteum.

Insulin-like growth factor

Luteal regression may begin as early as day 15 or as late

Insulin

as day 19 of normal (20–24-day) cycles.

Follistatin

Vascular endothelial growth factor

Prostaglandins

Regulation of the cycle

a Chosen from among the scores of factors isolated from intrafollicu-From a neuroendocrine perspective, the oestrous cycle *lar/extrafollicular sites. They have important extra-ovarian actions but is controlled by the secretory activities of three princi-are listed here in recognition of autocrine and paracrine activities during follicular growth.*

pal components: peptidergic neurones in the hypo-

thalamus, gonadotropes in the adenohypophysis and

steroid-secreting cells in the ovaries. It is clear that ulti-

mate control is exercised by the hypothalamus through

characteristic cyclic changes in the pattern of GnRH

responds to the gonadotrophins and it secretes a range

release, which are reflected in the circulating levels of

of regulatory factors (Box 33.2), including steroid hor-

FSH, LH, oestrogens and progesterone. Nevertheless,

mones (principally, oestradiol and progesterone) and

from the perspective of the practising veterinarian it

the polypeptide inhibin; it also facilitates the matura-

would appear as if it is the ovary that times the events

tion of the oocyte – but that is not a topic within the

of the oestrous cycle. That perception will have been

remit of this essay.

reinforced as a result of recent developments in ultra-

In its simplest form, the primordial stage, the follicle

sound technology that have given the clinician visual

consists of an oocyte surrounded by squamous pre-
access to the morphological changes in the female
granulosa cells. The resting primordial follicles are
genital tract throughout the reproductive life of the
thought to be under constant inhibitory influences to
cow; it is likely that it will be strengthened by this pres-
remain dormant. In due course, either due to a decrease
entation, which emphasizes the central importance of
in inhibitory influences or to positive stimuli by some
the inherent rhythmicity with which cohorts of follicles
paracrine or endocrine factors, growth is initiated in a
emerge from the pool of resting follicles. In essence, the
cohort of primordial follicles. This process of recruit-
following text describes how the responses of the HPG
ment begins long before puberty and is recurrent
axis determine the fate of the oocytes that are brought
throughout reproductive life. The fate of a recruited fol-
forward every seven to ten days in anticipation of being
licle depends on whether or not the mutual interactions
chosen to perpetuate the species.
between the component parts of the HPG axis can

shepherd it to ovulation. Those follicles that fall by the

wayside on the long path to ovulation undergo atresia;

Follicular development and its control during the

obviously, that is the fate of all follicles recruited before

oestrous cycle

puberty; it is also the fate of most of the follicles

Basic pattern: Each ovary has a large pool of oocytes, recruited after puberty.

each contained within a follicle. The follicle is the basic

In the adult ovary, most of the follicles progress

functional unit of the female gonad; although it spends

slowly through several developmental stages to reach

much of its lifespan in a dormant state, it does have a

the antral stage after four months or so, at which point

brief period of progressive growth and development

the follicle has acquired the histological features

that ends in either ovulation or degeneration (atresia).

depicted in Figure 33.24. There is evidence that follicles

During this active phase it is an essential component

can develop to the preantral stage in the complete

of the hypothalamic–pituitary–gonadal (HPG) axis. It

absence of gonadotrophins; thereafter, they are

Theca externa

Theca interna

Basement membrane

Antrum containing

follicular fluid

Granulosa cells

Fig. 33.24

The ovarian follicle has four distinct

layers: the theca externa, the highly vascular

Cumulus oophorus

theca interna, the basement membrane and

the avascular granulosa cell layer. The base-

Oocyte

ment membrane prevents direct access of

Zona pellucida

capillaries to the granulosa cell layer.

First wave

Second wave

Ovulatory wave

Loss of

Loss of

Ovulation

dominance

dominance

Dominance

Dominance

Dominance

15

(Static)

(Regressing)

10

Fig. 33.25

A model explaining the terms

(Growing)

associated with each wave of follicular

Emergence

Deviation

development during the oestrous cycle of

Subordinate

heifers. Based on ultrasound analysis,

Diameter (mm)

5

most heifers have one (first wave) or two

waves (first wave, second wave) of follicu-

lar development during the luteal phase

and a single wave of development (ovula-

1

Cohort

Cohort

Cohort

tory wave) during the follicular phase.

Selection

Selection

Selection

(From Ireland et al., 2000, reproduced with

1

12

21

permission of the American Dairy Science

Days of the oestrous cycle

Association.)

gonadotrophin-dependent. FSH can stimulate growth *recorded as the first day on which a 4 mm or 5 mm fol-*

of the follicle up to about 9 mm in diameter, while LH

licle is detected by ultrasonography as the largest in a

is required for further growth and for ovulation. In

new cohort of growing follicles. Over the next two or

fact, the HPG axis provides the hormonal milieu that

three days all of the emergent follicles grow at a similar

regulates the passage of the antral follicle through a

rate but then there is an abrupt divergence of in-

complex sequence of processes known (‘in the trade’)

dividual growth rates (deviation; Fig. 33.26): growth

as emergence, deviation, selection and dominance, and

continues unabated in one follicle, now grown

ovulation or atresia (Webb et al., 1999; Ireland et al., to approximately 8 mm in diameter and destined to

2000).

become dominant; in the subordinate follicles it comes

The inherent pattern of follicular growth in cattle is

to a halt and, soon, is followed by regression (Ginther

wave-like (Fig. 33.25); it is set long before puberty and

et al., 2001). About 8 hours before the beginning of *it persists during oestrous cycles, throughout most of*

deviation, the granulosa cells in the future dominant

pregnancy and during the early anoestrum of the post-

follicle acquire LH receptors. LH stimulates increased

partum period. In practice, the emergence of a wave is production of oestradiol and of insulin-like growth

16

(a)

FSH (–)

(n = 33 waves)

FSH

14

Follicular

Dominant

factor (s)

12

follicle

10

Subordinate

8

follicle

rowth

Diameter (mm)

g

Continued

6

8 h

Divergence

4

Atresia

0

1

2

3

4

5

6

7

8

Number of days from emergence

Fig. 33.27

Simplified model of deviation. The future dominant

follicle emerges approximately 8 hours before the future largest 14

(b)

13

subordinate follicle. Under the influence of FSH the two follicles (n = 19 waves)

FSH concentration (ng/ml)

grow at the same rate so that the larger follicle retains its initial 12

12

advantage up to the point of deviation (marked by asterisk). As FSH

the follicles grow they secrete increasing quantities of oestradiol and inhibin, both of which diminish the secretion of FSH until 10

11

there is insufficient to sustain the growth of subordinate follicles; they regress. However, changes in the dominant follicle, such as 8

10

increased responsiveness to LH and the stimulatory activity of Diameter (mm)

IGF-1, enable it to survive and enlarge in the presence of low 6

9

concentrations of FSH. (After Wiltbank et al., 2000.)

4

8

reduced to what is the ‘species-specific ovulatory

–2

–1

0

1

2

3

4

quota': in cattle, usually one follicle, occasionally two.

The beginning of the selection phase cannot be identi-

Number of days from deviation

fied by ultrasonography but the end of the phase is

Fig. 33.26

Deviation. The patterns of growth in the dominant

coincident with the onset of dominance, which can be

follicle and the largest subordinate follicle from the day of emer-identified.

gence. (a) The growth rates gradually diverge. (b) Before devi-Normally, each wave has a span of seven to ten days

ation, the growth rates did not differ significantly. The

from emergence to ovulation or to the onset of atresia

concentration of FSH reached a nadir on the day of deviation.

in the dominant follicle. The dominant follicle has

(Reproduced from Ginther et al., 1996 with permission of the the functional capacity to trigger the neuroendocrine

Society for the Study of Reproduction.)

cascade that culminates in ovulation but its fate is deter-

mined by the frequency of pulsatile LH secretion at the

factor 1 (IGF-1). Systemically, the high levels of oestra-

point of decision, essentially according to the phase of

diol and inhibin released by the dominant follicle sup-

the cycle: the high frequency during the follicular phase

press release of FSH from the pituitary gland; there is

enables it to ovulate; the low frequency during the

inadequate concentration of FSH to sustain the smaller

luteal phase or during postpartum anoestrum results in

follicles and they become atretic (Figs 33.26 and 33.27).

atresia; an intermediate frequency (e.g. when there is

Within the dominant follicle, oestradiol and IGF-1

suboptimal concentration of progesterone) is associ-

increase the sensitivity of the granulosa cells to FSH,

ated with extended dominance, which may have a dele-

thus enabling that follicle to respond to (and thrive on)

terious effect on the competence of the oocyte. The next *the low concentration that contributed to the onset of*

wave cannot emerge until after the dominant follicle

atresia in the subordinate follicles. If the largest follicle

has begun to regress.

is ablated before deviation, the next largest follicle will proceed to dominance. Thus, the follicular wave has two

Cyclic pattern: Usually, the bovine oestrous cycle has phases (Fig. 33.28): the growth phase (initiated by FSH)

either two waves (modal days of emergence: days 0, 10)

and the dominance phase (initiated when FSH is close

or three waves (modal days of emergence: days 0, 10,

to its nadir; LH dependent).

16) of follicular growth, each emerging about a day

Dominance is a consequence of selection, the process after a transient peak in serum concentrations of

that results in the number of growing follicles being

FSH. During the luteal phase both progesterone from

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Growth phase

Dominance

which the new dominant follicle goes on to ovulate

12

phase

approximately three days later (Fig. 33.28), by which

(a)

3.2 Oestradiol concentration (pg/ml)

time it has grown to 16–20 mm in diameter.

2.8

Dominant

10

follicle

Largest

2.4

subordinate

The phases of the oestrous cycle

follicle

2.0

8

Follicular phase: Each of the growing follicles has two 1.6

populations of steroid-secreting cells: theca interna cells

1.2

6

and granulosa cells (Fig. 33.29a). The cells of the theca

Diameter (mm)

Oestradiol

0.8

interna have specific receptors for LH and they respond

0.4

to this gonadotrophin by synthesizing androgens

4

0.0

(androstenedione and testosterone) that diffuse across

the basement membrane into the granulosa cell layer.

0.7

1.1

During the early stages of folliculogenesis the granulosa

(b)

1.0 LH concentration (ng/ml)

cells have receptors for FSH and they respond to this

0.6

gonadotrophin by converting the thecal androgens to

LH

0.9

oestrogen (Fig. 33.29b). As the follicles grow under the

0.5

0.8

trophic influences of both FSH and oestrogen, the gran-

0.7

ulosa cells acquire increased numbers of FSH receptors

0.4

FSH

0.6

and oestrogen receptors and they secrete increasing

quantities of oestrogen-rich follicular fluid (Fig. 33.29c).

0.5

0.3

Follicular oestrogen passes into the circulation and

0.4

FSH concentration (ng/ml)

Deviation

exerts negative feedback on the release of FSH from the

0.2

0.3

pituitary gland: while the concentration of FSH is in

–48 –40 –32 –24 –16 –8

0

8

16 24 32

decline, the dominant follicle is selected and the subor-

Number of hours from follicle deviation

dinate follicles regress (Figs 33.26, 33.27). The dominant

follicle maintains FSH at low concentrations and

Fig. 33.28

The follicular wave has a growth phase and a

becomes dependent on LH for continued growth and

dominance phase. (a) Diameters of the dominant follicle and of secretion of oestradiol (Fig. 33.30). LH stimulates the

the largest subordinate follicle before and after deviation; also, secretion of sufficient oestradiol to induce oestrus and to

the contemporary concentrations of circulating oestradiol. (b) evoke the oestrogen surge that exerts a positive feedback

The contemporary concentrations of circulating FSH and LH.

on the hypothalamic–pituitary axis (Figs 33.30, 33.31).

(Reproduced from Kulick et al., 1999 with permission from Elsevier Science.)

The frequency of the GnRH pulse generator increases,

the sensitivity of the adenohypophysis to GnRH is

increased by a self-priming action of the GnRH and the

*the corpus luteum and oestrogen from the cohort of
pituitary gland releases the preovulatory surge of LH.
growing follicles (>5 mm) restrain the hypothalamic–
The response of the dominant follicle to LH is both mor-
pituitary axis by negative feedback. The frequency
phological (growth, ovulation, formation of the corpus
of the pulse generator is reduced to one pulse of
luteum) and secretory (oestrogen, progesterone).
GnRH every 4–8 hours and the concentrations of
Ovulation is critically dependent on the timing, fre-
gonadotrophins in the peripheral circulation are insuf-
quency, and amplitude of the hormonal changes just
ficient to induce ovulation. As a result, neither of the
described. For instance, an inappropriate pattern of LH
dominant follicles in the first two waves can ovulate;
secretion could lead to atresia or to undue persistence
all of the follicles in the two waves undergo atresia.
of the dominant follicle (with detrimental effects on the
Luteolysis, which is required to remove this inhibi-
quality of the oocyte). The crucial hormonal event that
tion, occurs spontaneously when the uterus, under the*

initiates the ovulatory process is the switch from nega-
trophic influence of progesterone followed by oestro-
tive feedback by progesterone and oestrogen to posi-
gen and oxytocin, produces sufficient prostaglandin F2a
tive feedback by oestrogen (Figs. 33.30, 33.31); again,
(PGF2a) to kill the corpus luteum (see p. 495). The
the timing and rate of change of the oestrogen surge are
resultant fall in progesterone concentrations releases
critical: any significant deviation in either feature can
the GnRH pulse generator, which increases its fre-
result in delayed ovulation or anovulation.
quency to one pulse every hour (approximately). The
concentrations of FSH and LH rise in the peripheral
Luteal phase: After ovulation, the basement membrane
circulation, stimulating the cohort of follicles that initi-
between the theca cells and the granulosa cells breaks
ates the follicular phase of the cycle and from within
down and the avascular granulosa cell layer is invaded

(a)
Basement

(b)

membrane

Theca

Oestrogen

LH

interna

Granulosa

cells

Androgen

LH receptors

FSH

FSH receptors

(c)

LH

FSH

LHR

FSHR

Theca

Granulosa

cells

cells

+

+

+

5

+

+

FSHR

ER

Mitosis

IGF-

Aromatase

1

+

+

+

+

+

+

6

6

Androgens

2

4

4

3

5

Oestrogens

Fig. 33.29

Formation of oestrogen by ovarian follicles: (a) depicts the structure of the follicular wall; (b) illustrates the essential features of the production of oestrogen: LH stimulates the synthesis of androgens by the theca cells, FSH stimulates aromatases within the granulosa cells to convert the androgens to oestrogens; (c) depicts the biochemical events in the growing follicle between emergence and divergence: (1) LH stimulates theca cells to produce androgens; (2) FSH activates aromatase in granulosa cells to convert the androgens to oestrogen; In the granulosa cells, oestradiol (3) stimulates mitosis and (4) up-regulates receptors for FSH (FSHR) and for oestradiol (ER); (5) synthesis and secretion of IGF-1 by granulosa cells are stimulated by oestradiol and FSH; (6) IGF-1 further stimulates mitosis and aromatase activity in granulosa cells. Outcome: growth of the follicle and expansion of the antrum due to the combination of increased numbers of secretory granulosa cells with increased numbers of FSH and oestrogen receptors per cell.

by connective tissue septae that carry theca cells and

specifically, serum progesterone at luteal phase concen-

blood vessels. The granulosa cells and the theca cells dif-

trations for a few days before it subsides, followed by

ferentiate into luteal cells that secrete progesterone;

serum FSH at normal preovulatory concentrations.

they can also synthesize and secrete oestrogen, oxytocin

Failure of this sequence or inappropriate serum con-

and relaxin. The invading blood vessels undergo exten-

centrations of either hormone seem to affect the life-

sive branching and deliver a very large blood flow to

span of the corpus luteum (short luteal phase, prolonged

support the very high metabolic rate of the mature

luteal phase) and/or its capacity to secrete progesterone

corpus luteum; so rich does the vasculature become that

(inadequate luteal phase), phenomena that are

endothelial cells comprise more than half of the con-

common after the first ovulation at puberty or after

stituent cells – in due course, these cells play a pivotal

calving. It is not known how the (prefollicular phase)

role in the process of luteolysis (see below).

progesterone exerts its influence on the activities of the

Luteinizing hormone is the principal luteotrophin in

next corpus luteum; it is possible that the FSH could do

the cow; under normal circumstances, tonic secretion of

so through its role in the induction of LH receptors on

LH maintains the functional corpus luteum until PGF2a *the granulosa cells of the preovulatory follicle.*

from the uterus causes luteolysis at the end of the cycle.

The corpus luteum grows progressively in size until

It is important to realize that ‘normal circumstances’

days 16–18 of the oestrous cycle. Histologically, the

include the correct antecedent hormonal pattern:

mature corpus luteum is seen to contain two mor-

LH surge

Ovulation

+

FSH surge

9

+

8

Low FSH

Positive

feedback

Oestrogen surge

FSH

3

6

LHR

–

–

R

LH

4

5 Aromatase

LH R

7

IGF-

+

5

+

1

+

3

Negative

+

Mitosis

5

feedback

RE

E2

E

R

2

FSH

FSH

Oestradiol (E2)

R

2

FSH

Oestradiol (E

R

2)

Inhibin

FSH

R

Inhibin

Fig. 33.30

Dominant follicle becomes the ovulatory follicle. When luteolysis occurs, the LH *pulses attain the frequency that is required to progress the dominant follicle to ovulation. FSH induces mitosis and stimulates aromatase activity in granulosa cells and they secrete oestradiol and inhibin: within the follicle, oestradiol binds to receptors (ER) in granulosa cells in which it (1) up-regulates ER and receptors of FSH(FSHR), stimulates aromatase activity, mitosis and secretion of IGF-1: systemically, both oestradiol and inhibin depress FSH*

secretion by the pituitary gland (negative feedback). (2) Granulosa cells have high number FSHR [see (4) in Figure 30.29]. (3) The low levels of FSH continue to induce mitosis and to stimulate aromatase activity in granulosa cells (thus producing oestradiol and enlarging the antrum). FSH (4) and oestradiol (1) stimulate granulosa cells to secrete more IGF-1 – which, in turn, (5) enhances the steroidogenic and mitotic actions of FSH and oestradiol on granulosa cells, and enhances the steroidogenic action of LH on theca cells. FSH

(6) in creases the number of LH receptors (LHR) on granulosa cell. The cell division and the secretory activity accelerate the expansion of the dominant follicle: it may be 16 to 18 mm in diameter at the preovulatory stage. The rapid increase in secretion of oestrogen induced by the activities of LH, FSH and IGF-1 leads to a surge of oestrogen (7) which evokes, by positive feedback (8), coincident surges of the gonadotrophins (large surge of LH, smaller surge of FSH) and, consequently, ovulation (9).

phologically distinct populations of parenchymal cells:

to the recognized luteotrophin (LH) and luteolysin

small luteal cells (10–20 mm) and large luteal cells

(PGF2a). Receptors for LH are numerous on the small

(20–35 mm). All of the small cells are derived from

cells but they are scanty or absent on the large cells.

thecal cells and, until the sixth day of the oestrous cycle,

Therefore, LH stimulates the small cells to secrete prog-

nearly all of the large cells are derived from the granu-

esterone but it has no such effect on the large cells.

losa cells. After day six, some small luteal cells differ-

Despite this and the numerical predominance of small

entiate into large luteal cells, so that the large cells are

luteal cells throughout the luteal phase, it is generally

of mixed origin and the proportion of large cells

agreed that most of the progesterone is secreted by the

increases as the corpus luteum matures (from less than

large luteal cells. Progesterone is secreted as pulses at

2 per cent at days 3 to 5 to almost 5 per cent at days 10

a frequency that is different from that for LH. This does

to 18).

not diminish the importance of LH as the principal

It is significant for the clinical management of the

luteotrophin in the cow: LH does not have direct

oestrous cycle to realize that the small luteal cells and

control over the quantities of progesterone secreted by

the large luteal cells differ in their abilities to respond

the large cells but it does exert an important indirect

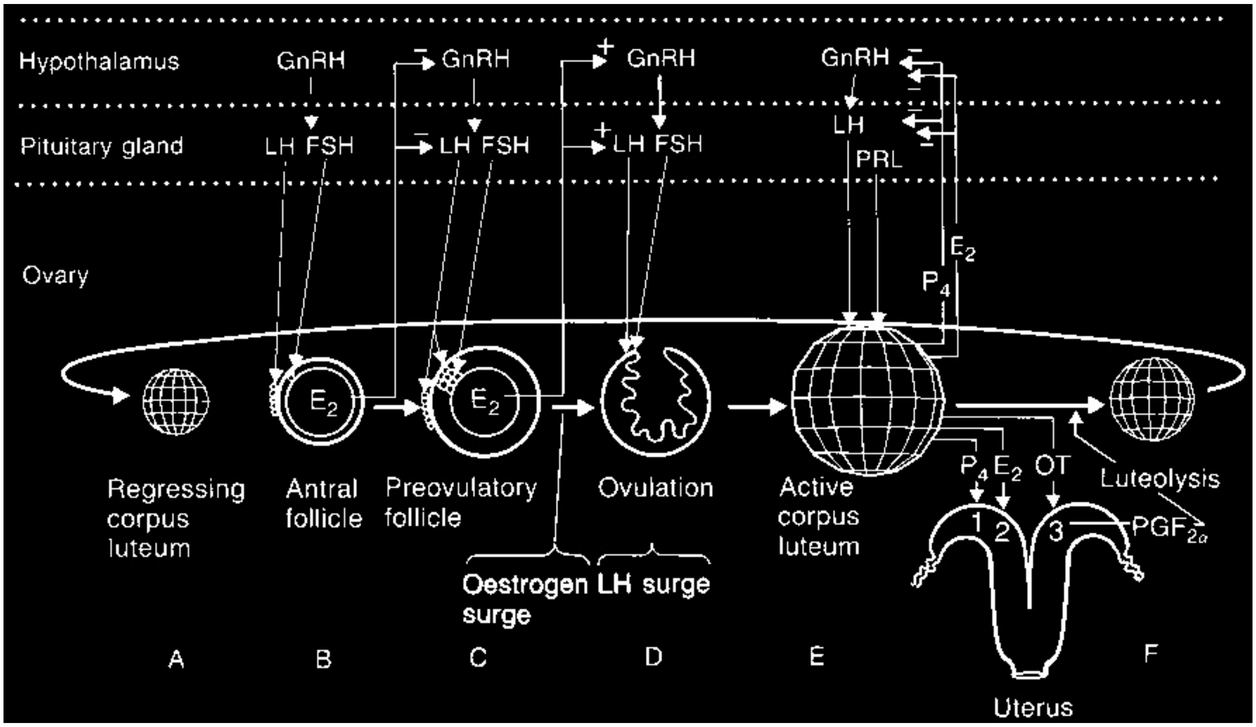

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Fig. 33.31

Interrelationships between the hypothalamus, pituitary gland, ovary and uterus during the oestrous cycle. When the corpus luteum (CL) regresses at the end of a cycle (A), the hypothalamus and pituitary gland are released from the strong negative feedback exerted by progesterone (P4) throughout the luteal phase of the cycle. FSH and LH stimulate the growth and secretory activity of a dominant ovarian follicle (B) that secretes increasing quantities of oestradiol (E2). The initial low concentrations of E2 have a negative feedback effect until the preovulatory follicle produces a surge of oestrogen (C) that exerts a positive feedback and results in a surge of LH that causes ovulation (D). A new CL develops under the trophic influence of both LH and, perhaps, prolactin (PRL). It secretes P4 and E2 that reassert a strong negative feedback effect on the hypothalamic–pituitary axis. In addition, the P4 causes an accumulation of fatty acid precursors in the endometrium (1). After day 10, E2 induces the synthesis of prostaglandin from the stored precursors (2). Finally, oxytocin (OT) causes the release of the PGF2a (3), which is transferred from the uterus to the ipsilateral ovary by a countercurrent mechanism (see Fig. 33.32) and induces luteolysis (F). (See Fig. 33.23 for changes in concentrations of the hormones in the peripheral plasma.)

control by regulating the differentiation of small cells transported in the venous blood to the lungs where into large luteal cells, a process during which the approximately 65 per cent of it is degraded into its inac- steroidogenic activities of the cells seem to be turned tive metabolite, PGFM, in one passage. However, some on fully and permanently. On the other hand, receptors PGF2a is brought directly from the uterus to the adja- for PGF2a are numerous on large luteal cells but are cent ovary by means of a counter current mechanism absent from the small cells. Since the secretion of (Fig. 33.32) that transfers the luteolytic agent from the progestrone by the young corpus luteum (days 3 to 5) uterine vein to the ovarian artery. Thus, in the cow, is invested almost entirely in the small cells, it is not sur- PGF2a may act partly by the systemic route to augment prising that it is refractory to the luteolytic action of the local counter-current transfer (McCracken et al., PGF2a. The luteolysin becomes effective when the large 1999).

luteal cells assume responsibility for most of the secre-

Prostaglandin F2a is released from the uterus in

tory activity.

pulses and there is evidence that the minimum

It is well known that during the first four or six days

requirement for normal regression of the corpus luteum

of the oestrous cycle exogenous oxytocin can inhibit the

at the end of the oestrous cycle (i.e. effective luteolysis

growth of the corpus luteum and block its secretory

by endogenous PGF2a) is a pulse lasting one hour

activity. This is possible because the small luteal cells

repeated about every six hours over a period of 24–30

have specific receptors for oxytocin and interaction

hours. (By contrast, after day 5 of the oestrous cycle the

between the receptors and the peptide leads to inhibi-

corpus luteum can be removed by a single injection of

tion of the LH-stimulated secretion of progesterone by

exogenous luteolysin, in an appropriate dose.)

the small cells. In the mature corpus luteum the large

The timing and magnitude of PGF2a release from the

luteal cells synthesize oxytocin and it has been sug-

uterus is determined by the sequential interactions of *gested that this peptide may play a significant role in*

progesterone, oestradiol and oxytocin. The central and

local 'large-cell-to-small-cell communication' during

peripheral actions of oestradiol are critical for luteoly-

prostaglandin-induced luteolysis.

sis to occur (Binelli et al., 2001). During the early part Prostaglandin F2a is formed in the endometrium. It

of the oestrous cycle the endometrial cells have many

leaves the uterus in the uterine vein and most of it is

receptors for progesterone and coupling of the steroid

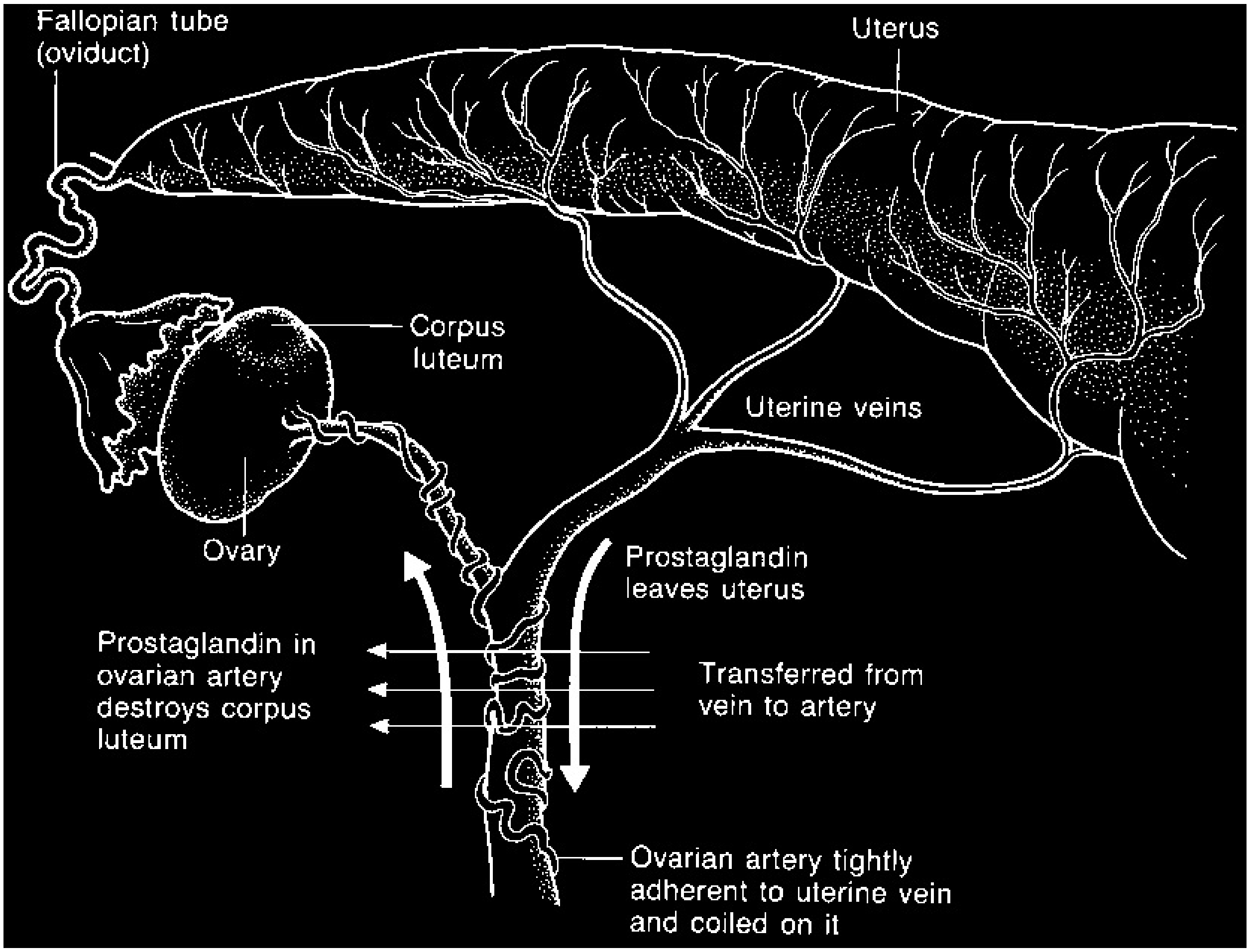


Fig. 33.32

The transfer of PGF2a from the

uterus to the ovary by a counter current

mechanism.

with its receptors effectively blocks the production of

tion of progesterone by the small luteal cells. Oxytocin,

PGF2a; however, it causes an accumulation of fatty acid

which is formed in the large luteal cells and has specific *precursors in the endometrium. After about 10 days the receptors on the small luteal cells, is an obvious candi- action of progesterone on the hypothalamus and on date messenger. Recent studies (Meiden et al., 1999) the endometrium begins to decline (possibly due to assign the pivotal role to endothelin 1 (ET-1), a peptide progesterone-induced loss of its own receptor: 'down synthesized and released by the resident endothelial regulation'), permitting oestrogen to effect changes cells. The proposal is that PGF2a elicits the release of both centrally and peripherally. Centrally, oestradiol ET-1 from the endothelial cells and of oxytocin from from developing ovarian follicles appears to alter the the large luteal cells; ET-1 acts on the steroidogenic frequency of the hypothalamic oxytocin pulse genera- cells to reduce their progesterone output; both PGF2a tor, which produces a series of intermittent episodes of and ET-1 induce vasoconstriction and consequent oxytocin secretion; peripherally, it promotes the forma- hypoxic conditions; ET-1 secretion is enhanced both by tion of endometrial receptors for oestradiol and oxy-*

hypoxia and by oxytocin (Fig. 33.33). For structural

tocin. In the endometrium, coupling of oestradiol with

regression it is envisaged that ET-1 initiates a cascade

its receptors increases the synthesis of PGF2a from the

of events leading to recruitment and activation of

fatty acid precursors, while coupling of oxytocin (from

phagocytic cells that release cytokines responsible for

the hypothalamus and from the corpus luteum) with its

programmed cell death.

receptors leads to immediate pulsatile secretion of

It is obvious that the functional corpus luteum plays

PGF2a (McCracken et al., 1999). It is probable that the a primary role in the control of the oestrous cycle, a fact

duration of the pulses is determined by the rapid down

that is central to all regimes that aim to control the

regulation of oxytocin receptors (within one hour) and

cycle. In the past, the practice was to remove it manu-

that the frequency of the pulses reflects the regenera-

ally per rectum, a procedure to be condemned. The

tion time of the oxytocin receptors in response to

mature corpus luteum (CL) is a very vascular organ;

oestradiol (six hours).

manual expression causes haemorrhage which will give

PGF2a causes a significant reduction in luteal blood

rise to local adhesions, if it is not fatal. The CL can be

flow and it couples with specific receptors on the large

removed by administration of exogenous luteolytic

luteal cells. However, the other steroidogenic cells, the

agents. It is insensitive to exogenous PGF2a during the

small luteal cells, do not have receptors for PGF2a and

first four days of the cycle, but between day 5 and day

it has to be assumed that some type of intercellular

16 the administration of PGF2a or an analogue will

communication between the large cells and the small

cause rapid luteolysis followed, within a few days, by

cells is involved in terminating the LH-induced secre-

oestrus and ovulation.

Messenger

Mechanisms by which luteal secretions are altered

Large luteal cells

Progesterone decreased

Oxytocin increased

PGF2

Arterioles: vasoconstriction

Progesterone decreased

(hypoxia)

+

Luteal cells

Progesterone decreased

+

+

Arterioles: vasoconstriction

Progesterone decreased

ET-1

(hypoxia)

Oxytocin increased

+

+

Luteal cells

Progesterone decreased

Fig. 33.33

Schematic representation of the

putative role of endothelin-1 (ET-1) in func-

Oxytocin

Arterioles: vasoconstriction

Progesterone decreased

+

(hypoxia)

ET-1 secretion increased

*tional luteolysis in cattle***.**

Pharmacological regulation of the oestrous cycle

due recognition of these observations. A single bolus of

(see also Chapter 42)

exogenous GnRH is likely to be effective only when a

preovulatory follicle is present already.

The pharmaceutical industry has provided an array

During the luteal phase of the oestrous cycle the

of natural and synthetic hormones – GnRH, gonado-

corpus luteum acts as an effective 'brake' on the pulse

trophins, steroids, prostaglandins – that can be used to

generator: pulse frequency is reduced so that circulat-

regulate the oestrous cycle. The use of these agents for

ing gonadotrophins are maintained at tonic concen-

specific purposes will be described when we deal with

trations and the dynamic surges required to cause

the clinical conditions in which they have been found

ovulation cannot occur. Luteolysis removes the brake,

to be effective. Nevertheless, it is appropriate at this

the pulse frequency increases and ovulation occurs

juncture to emphasize a few basic principles that should

within four or five days. Hence, there are two methods

be borne in mind when the clinician is contemplat-

by which control over the length of the cycle and

ing the use of reproductive hormones for therapeutic

ovulation can be achieved: the use of a luteolytic agent

purposes.

to kill the corpus luteum of the current cycle or the use

The GnRH generator imposes a pulsatile mode of

of a progestogen to create an 'artificial' luteal phase,

secretion on the hypothalamic–pituitary–ovarian axis.

which will be followed by ovulation shortly after with-

The component parts of the axis respond to hormonal

drawal of the progestogen. These methods can be used

signals that are encoded in the frequency and, to a lesser

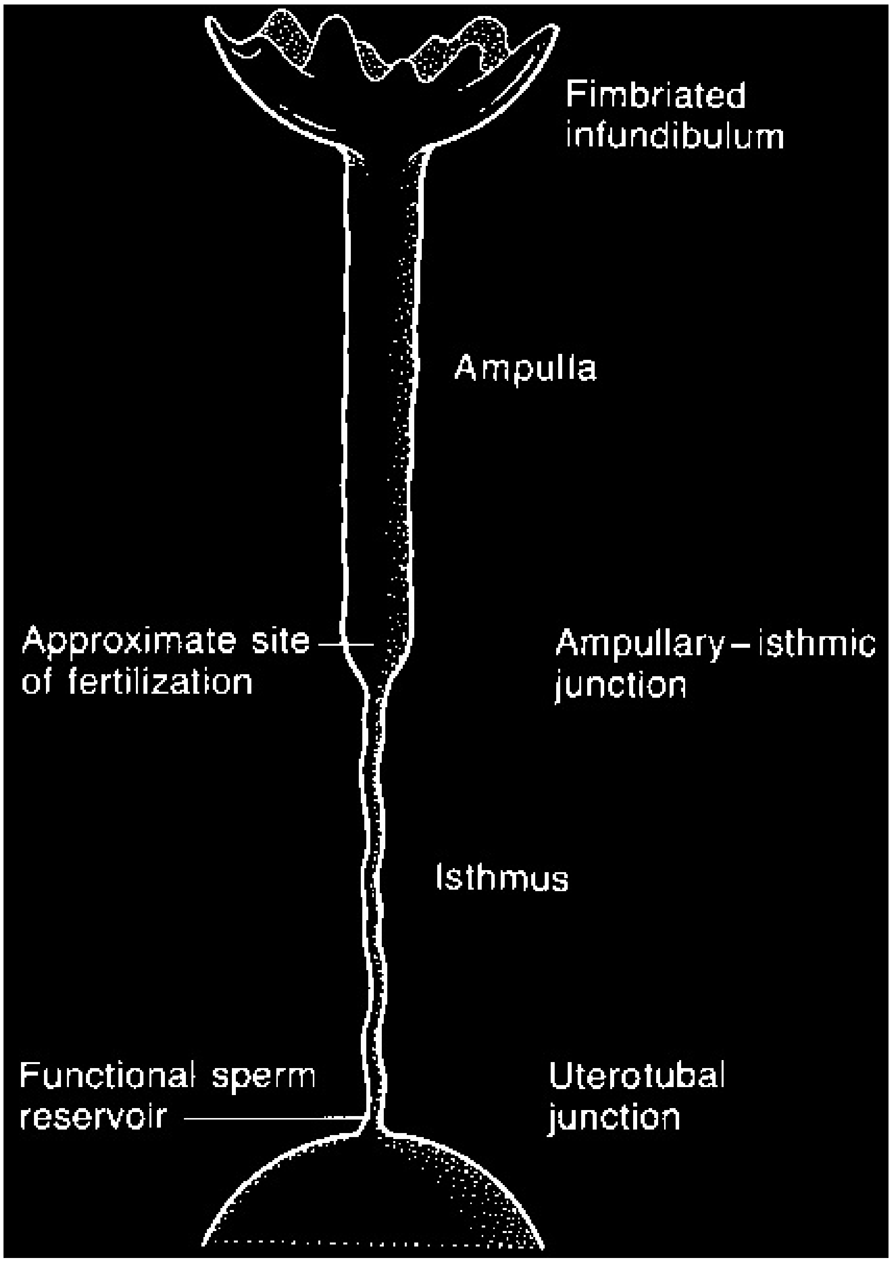
separately or in combination. Since prostaglandin does
extent, the amplitude of the pulses. However, these
not kill the very young corpus luteum (less than five
target tissues may not be able to decode a hormonal
days after ovulation), the usual recommendation is to
stimulus that is either non-pulsatile or pulsatile at non-
give two injections 11 days apart (see p. 682).
physiological frequencies. As an example, repeated
To date, neither of these methods has fully satisfied
small pulses of exogenous GnRH will induce pulsatile
the requirements of the industry. Ideally, synchroniza-
releases of gonadotrophins and these responses will be
tion of oestrus should make it possible to achieve high
enhanced by the self-priming action of GnRH. On the
rates of pregnancy to a single insemination at a pre-
other hand, continuous infusion of GnRH or intermit-
dictable interval after treatment, without the need for
tent infusions of GnRH at markedly non-physiological
detection of oestrus. Recent studies of the dynamics of
frequencies will soon lead to complete refractoriness of
follicular waves have revealed that the prime require-

the pituitary gland to the continued stimulation (see

ment is ‘to have a recently selected dominant follicle of

p. 477). Therapeutic regimes should be planned with

short duration dominance at the end of a progestagen



or PGF2a treatment regimen' (Roche et al., 1999). Thus, the objective of current research efforts is to validate a

regimen that will regulate both the luteal and follicular

components of the periovulatory phase.

As mentioned, the response of the corpus luteum to

an exogenous luteolysin depends on the stage of its

development, and even when it is fully responsive the

intervals from treatment to oestrus and ovulation can

vary by some days depending on the stage of develop-

ment of the dominant follicle at the time of treatment.

For instance, if the current largest follicle is no longer

functionally dominant, clinical response will be delayed

until the dominant follicle of the next wave does the

business up to a week later. Scientists have shown that

it is possible to manipulate follicular waves to deliver

ovulation within a time span that would satisfy the level

of predictability required to make fixed-time insemina-

tion a viable proposition. However, the problem

remains that some of the procedures that have been

employed under 'laboratory conditions' do not lend

themselves to ready application under field conditions.

Fig. 33.34

Schematic diagram of the uterine tube (oviduct,

One such approach involved transvaginal ultrasound-

Fallopian tube).

guided ablation of all follicles greater than 5 mm (day

0) followed by PGF2a (day 4) and LH or GnRH (day 5):

all of 23 treated heifers ovulated within the same

24-hour period, 19 within the same 12-hour period

(Bo et al., 2002). Presumably, the next task is to replace (oestrogens and progesterone) released in the correct

surgical ablation by a pharmacological regimen that will

concentrations and in the proper sequence. Therapeu-

selectively consign the current cohort of emerging

tic procedures that significantly alter the relative con-

follicles to immediate atresia, permitting the emer-

centrations or sequence of the hormones can disrupt

gence of a new cohort, one of which then can be driven

the transport mechanisms, which in some instances may

by exogenous hormones to ovulation within a pre-

cause the loss of gametes or of the conceptus.

dictable time span. It is known that the physiological

The transport of spermatozoa is not an entirely

activities of the follicle are modulated by a range of

passive process: the motility of the male gametes makes

molecules produced locally within the follicle (growth

a significant contribution to the successful completion

factors, activins, inhibins, cytokines etc.: Box 33.2). The

of the hazardous voyage from vagina to oviduct during

paracrine or autocrine actions of those molecules

which the vast majority of the spermatozoa are lost,

may hold the keys to precise manipulation of ovarian

partly as a result of phagocytosis but largely by expul-

function.

sion to the exterior in cervical mucus. It appears from

the literature that two distinct populations of sperma-

tozoa arrive in the oviduct:

Pregnancy

• Those that are transported rapidly but are inca-

Transport of gametes in the female genital tract

pable of fertilizing the ovum; and

• Those that are transported more slowly to the func-

Fertilization takes place in the oviduct, close to the

tional sperm reservoir, are viable and are capable
junction of the isthmus and the ampulla (Fig. 33.34).
of undergoing capacitation and the acrosome reac-
Transport of the ovum from the ovary is achieved by
tion, two processes that are essential if a spermato-
muscular and ciliary activity and flow of fluids in the
zoon is to acquire the capacity to fertilize an ovum.
ovarian bursa and ampulla of the oviduct. After natural
mating, spermatozoa have to traverse the cervix, the
Spermatozoa have been recovered from the ampulla
uterus and the uterotubal junction. Again, muscular
of the oviduct within 3–5 minutes after mating. This
activity and flow of fluids are largely responsible for the
rapid transport is due to muscular contractions in the
transport of the male gametes. The appropriate muscu-
female genital tract. During oestrus, the contractions
lar activities, secretion and flow of fluids in the female
begin at the cervix and move towards the oviduct; at
genital tract are regulated by the ovarian hormones
the end of oestrus the direction of the contractions is

reversed. Most of the spermatozoa that reach the

The acrosome reaction (Fig. 33.20) involves multiple

oviduct during the initial rapid transport phase are

point fusions between the plasma membrane and the

damaged or dead and they do not include the sperm

outer acrosomal membrane over the front half of the

that fertilizes the ovum. It has been suggested that these

sperm head. The fusions give rise to a series of small

non-viable spermatozoa may play a significant physio-

vesicles formed by fragments of both membranes. The

logical role, by releasing products that elicit local mus-

vesicles are separated by small pores through which the

cular and secretory responses that facilitate transport

acrosomal enzymes escape. There is controversy as to

and sustenance of the gametes.

whether or not the escaping enzymes aid the passage of

According to Hunter and Wilmut (1984), viable

the spermatozoa through the cumulus oophorus in the

spermatozoa are transported more slowly: heifers

cow. As the reaction proceeds, the pores enlarge at the

mated early in oestrus took 8–12 hours to establish an *expense of the vesicles so that the vesicles have been*

adequate population of viable spermatozoa in the

lost by the time the sperm penetrates the zona pel-

oviduct. Then the gametes were sequestered, in a rela-

lucida. When one of the advancing spermatozoa

tively quiescent state, in the caudal 2 cm of the isthmus

reaches the perivitelline space, it fuses with the plasma

for a further 18–20 hours before they began a progres-

membrane of the ovum and its genetic material is

sive migration towards the site of fertilization. Thus, the

incorporated into the conceptus at fertilization.

caudal isthmus served as the functional sperm reservoir,

The fusion of the egg and the sperm triggers a series

the immediate source of viable spermatozoa at the time

of reactions that prevent polyspermy by making both

of ovulation. It is known that both the temperature and

the zona pellucida and the plasma membrane of the

the oxygen tension are lower in that segment of the

ovum impenetrable to other spermatozoa.

isthmus than they are in the ampulla and it is thought

It is often stated that capacitation requires a 6-hour *that these factors may be responsible for the depressed*

sojourn in the female tract. However, it is unlikely that

motility of the spermatozoa in the reservoir up to the

the processes would be synchronized to ensure that all

time of ovulation. At ovulation, the temperature and

the surviving spermatozoa would have been capacitated

oxygen tension are elevated in the lumen of the caudal

at a fixed minimum time after deposition in the female

isthmus, the sequestered spermatozoa begin to exhibit

tract. Asynchrony in the time to capacitation would

activated motility (hyperactivation) and they migrate to

appear to be more advantageous in that it would allow

the site of fertilization. Hyperactivation is in response

for small populations of potential fertilizing spermato-

to the 'pick-up' of follicular fluid and the ovum by the

zoa to be available sequentially over a period spanning

oviduct.

several hours before and after ovulation. Indeed, there

is evidence that only 10–20 per cent of bovine sperma-

tozoa have undergone capacitation and the acrosome

Capacitation and the acrosome reaction

reaction within three hours of insemination, while other

The spermatozoa deposited in the female reproductive

spermatozoa do so several hours later. Again, the

tract are not immediately capable of fertilizing an

inappropriate use of exogenous hormones may hamper

ovum. During transport through the tract they undergo

capacitation and the acrosome reaction.

physiological changes that make them competent to

penetrate the zona pellucida and fuse with the ovum,

Maternal recognition of pregnancy

i.e. they undergo capacitation. It is thought that during

capacitation the spermatozoon loses some proteins it

Normally, the conceptus enters the uterus about 72

has acquired, by adsorption or incorporation into the

hours after ovulation, at the 8–16 cells stage. The cells

plasma membrane, during exposure to epididymal fluid

(blastomeres) form a solid mass (morula) still con-

or seminal plasma. This does not cause any visible

tained within the zona pellucida. By day 7 or 8, fluid

change in the morphology of the spermatozoon but it

secreted by the blastomeres accumulates in a central *does alter the physical and chemical properties of the*

cavity (blastocoele) and the zygote is now called a

plasma membrane, permitting an influx of calcium ions

blastocyst. The cells have been arranged into two dis-

required for the induction of the hyperactivated form

tinct populations (Fig. 33.35):

of motility and for the acrosome reaction. The hyper-

• The flattened trophoblast cells that form the wall of

activated motility endows the capacitated spermatozoa

the blastocyst and ultimately will forms the chorion.

with strong thrusting power that facilitates migration

• A group of cells that forms the inner cell mass at

from the isthmus to the ampulla and subsequent

one pole beneath the trophoblast cells and is des-

passage through the zona pellucida. The acrosome reac-

tined to form the fetus.

tion is an essential prerequisite for fertilization – a sper-

matozoon with an intact acrosome cannot penetrate the

The blastocyst hatches from the zona pellucida on

ovum.

days 9 to 11 and on day 13 it begins to elongate so that

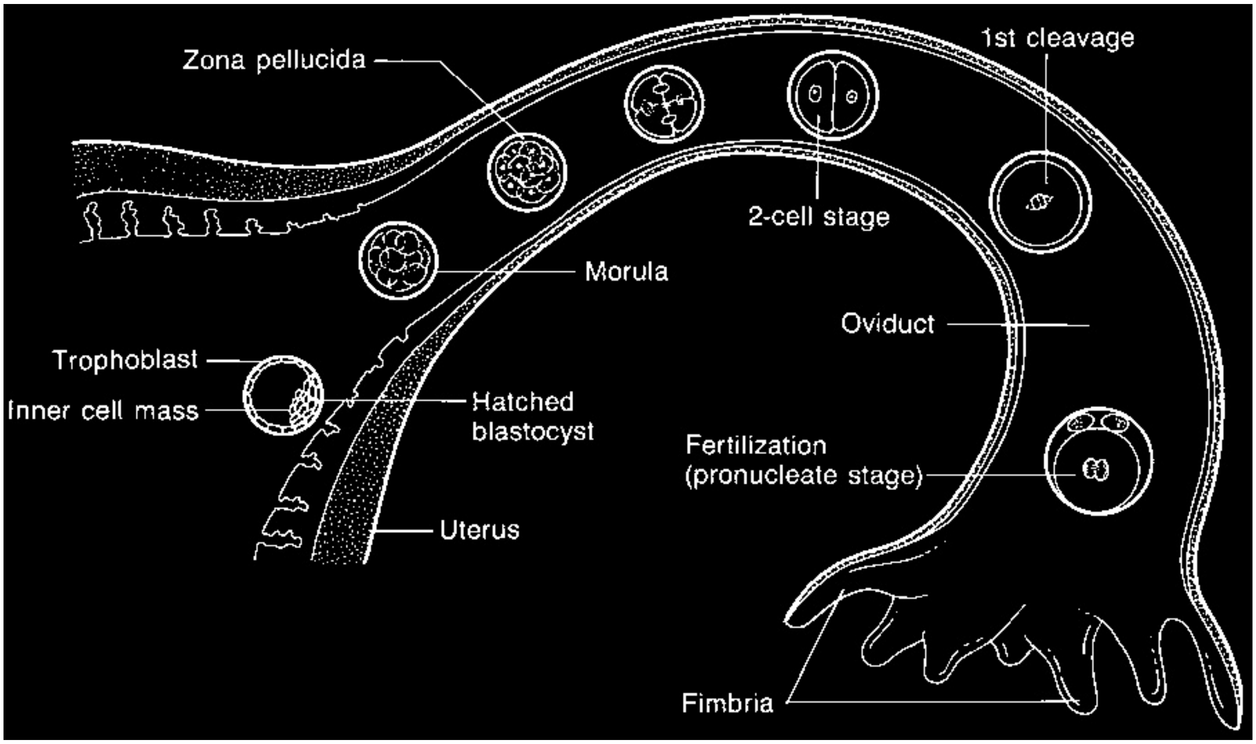


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Fig. 33.35

Schematic diagram to illus-

trate the changes in the conceptus

during transport down the uterine tube

and into the uterine lumen (after

McLaren, 1984).

during the third week it occupies most of the pregnant

endometrium. The size of the blastodermic vesicle may

(ipsilateral) horn and a portion of the non-pregnant

be critical: a small conceptus may not secrete sufficient

(contralateral) horn. The process of attachment begins

IFN-t to prevent luteolysis. Putative luteotrophic

at day 19 or 20 when there are definite areas of adhe-

factors include a lipid-like substance released by the

sion between the trophoblastic epithelium of the con-

conceptus between day 13 and day 18 of pregnancy and,

ceptus and the endometrial epithelium; implantation is

possibly, PGE2 from the endometrium.

completed between days 35 and 42. The conceptus plays

Later in this text we shall pay serious attention to

an important role in prolonging the functional lifespan

the effects of nutritional status on the resumption of

of the corpus luteum, an essential requirement for the

normal ovarian and uterine functions after calving;

maintenance of pregnancy. The critical period for the

therefore, it seems appropriate to mention at this junc-

extension of the lifespan of the corpus luteum in

ture that the survival of the early conceptus may be put

the cow is between day 15 and day 17; if there is an

at jeopardy when the dam is fed excess protein in the

elongated conceptus present at that time, the mother

diet. The resultant production of large quantities of *will ‘recognize’ that she is pregnant and the luteolytic*

ammonia in the rumen leads to elevated concentrations

pulsatile pattern of PGF2a

release from the

of urea in the blood which, in turn, so alters the ionic

endometrium will be attenuated or abolished.

composition of uterine and tubal secretions that the pH

Since maternal recognition of pregnancy precedes

is incompatible with the survival of the conceptus. Prob-

the physical attachment of the conceptus to the

lems of embryonic loss are dealt with in Chapter 36.

endometrium, it is evident that the utero-ovarian regu-

latory mechanisms that ‘rescue’ the corpus luteum are

Maintenance of pregnancy

responding to a biochemical dialogue between the con-

ceptus and the maternal tissue that is initiated by a

Once the normal conceptus–endometrial–ovarian

variety of signal factors released into the uterine lumen

regulatory axis of pregnancy has been established, the

by the preimplantation conceptus.

uterus comes under long-term control by progesterone.

The bovine conceptus can synthesize a number of In the cow, a fully functional corpus luteum is essential products (steroids, prostaglandins, peptides, proteins) to maintain pregnancy up to day 235; thereafter, the that may interact with the maternal utero-ovarian axis. adrenal glands seem to be able to secrete sufficient There is evidence to suggest that the conceptus releases progesterone to maintain pregnancy in ovariectomized different signal factors at different times and that the cows. The placenta contributes little to the circulating relative importance of each of these factors may change concentrations of progesterone at any time during during these early days of pregnancy. A hypothesis pregnancy. The principal luteotrophin is LH; there is consistent with current information is that the bovine little evidence that prolactin plays any significant role conceptus initiates both antiluteolytic and luteotrophic (McCracken et al., 1999). The corpus luteum maintains activities. The main signal is the secretion of interferon- the plasma progesterone concentration above 10 ng/ml tau (IFN-t) which reduces the secretion of PGF2a by the from the second week of gestation until term. Proges-

terone exercises a 'block' on the uterine muscle in that
release increased amounts of cortisol. The cortisol
it depresses the amplitude of contractions, suppresses
induces the placenta to release increased quantities of
the reactivity to oxytocin and PGF2a and prevents the
oestrogens into the maternal circulation, and both the
development of synchronous coordinated contractions
cortisol and the oestrogens act on the endometrium to
that might expel the fetus prematurely. It does not
increase the output of PGF2a, which causes luteolysis.
abolish the spontaneous contractility of the myometrial
Thus the oestrogen:progesterone ratio has been
cells. Problems of fetal loss are dealt with in Chapter
switched strongly in favour of oestrogen and the
37.
inhibitory effect of progesterone on the uterine muscle
has been abolished. The oestrogens promote uterine
contractility by stimulating the synthesis of contractile
Parturition

protein and of receptors for both oxytocin and PGF2a, Since parturition depends on coordinated rhythmic and by facilitating the formation of gap junctions contractions of the myometrium as well as involuntary between adjacent myometrial cells. Gap junctions are contractions of the abdominal muscles and 'softening' intercellular structures that link cells and allow them to of the birth canal, the final preparation for delivery of exchange ions and electrical impulses. In the parturient the fetus must involve removal of the progesterone uterus they provide the routes through which electrical block. This is achieved by significant changes in the activity is propagated; in other words, they provide the hormonal profile coupled with the acquisition of gap structural basis for a functional syncytium that permits junctions by the myometrial cells.

synchronization of myometrial contractions. Thus, the The hormonal changes are initiated by the fetus, trig- switch to oestrogen domination at full term enables the gered by the recognition of 'stress' by the fetal hypo- uterine muscle to develop spontaneous rhythmical *thalamic–pituitary axis (Fig. 33.36). This results in the*

contractions. The transition of the myometrium from a

release of ACTH that stimulates the fetal adrenal to

quiescent state to an active state has been termed

Fetus

Hypothalamus

Corticotrophin-releasing factor (CRF)

Pituitary gland

Adrenocorticotrophin (ACTH)

Adrenal gland

Cortisol

Fig. 33.36

Hormonal control of parturition.

Placenta

Progesterone

The hormonal changes are initiated when the

fetal hypothalamic–pituitary–adrenal axis

Oestrogen

releases increased amounts of cortisol. The

Prostaglandin

cortisol induces the placenta to release *increased quantities of oestrogens. The*

oestrogen : progesterone ratio is switched

strongly in favour of oestrogen and the

inhibitory effect of progesterone on the

Mother

uterine muscle (‘progesterone block’) is

Uterus

Softening of cervix

abolished. The oestrogens promote uterine

Gap junctions in myometrial cells

contractility by stimulating the synthesis of

x

contractile protein and of receptors for both

Myometrial contractions

e l f

oxytocin and PGF2a and by facilitating the for-

e

Pressure on cervix and vagina

r

mation of gap junctions between adjacent

s’

myometrial cells. Gap junctions enable the

no

uterine muscle to develop spontaneous

Pituitary gland

s

s

rhythmical contractions. The more powerful

Oxytocin

u

F e r g

contractions during parturition are generated

in response to PGF2a, augmented during the

Abdominal muscles

second stage of labour by oxytocin. (From

Contractions (pelvic reflex)

Hartigan, 1995.)

'activation'; the activated myometrium is capable of

concentrations of progesterone and oestrogen in the

generating high-frequency, high-amplitude contractions

circulation exert a prolonged negative feedback on *in response to mechanical or biochemical stimuli. The the maternal hypothalamic–pituitary–ovarian axis. The more powerful contractions during parturition are principal long-term effect of this inhibition is a pro- generated in response to PGF2a, augmented during the gressive decline in the amount of LH in the pituitary second stage of labour by oxytocin. Both of these hor- gland, accompanied by a greatly diminished response of mones influence smooth muscle activity by regulating the pituitary gland to GnRH, a low concentration of LH the concentration of calcium ions in the myometrial in the circulation and relatively quiescent ovaries. The cells. The concentration of free Ca2+ in myometrial cells inherent wave-like pattern of follicular growth is not increases about three-fold during contraction, through lost: it is in train within a few days after parturition, influx from extracellular sources and release from intra- with the intrinsic periodicity of seven to ten days. cellular stores. A deficiency of calcium in a pregnant However, the selected dominant follicle may not be female at full term is associated with atony of the* *able to trigger the neuroendocrine process that leads to*

uterine muscle and a tendency to prolapse of the uterus.

oestrus and ovulation. Hence, immediately after

Softening of the birth canal is achieved by the

calving, the cow has a period of anoestrum, the length

cascade of hormones: a rise in oestrogen concentrations

of which can be influenced by age, season, nutritional

followed by the activities of relaxin and PGF2a. Partu-

status, dystokia, milk yield, suckling, uterine pathology

rition can be induced after about day 255 of gestation

or subclinical disease.

by a single injection of a synthetic glucocorticoid that

simulates the effects of fetal cortisol, or after 270 days

Re-activation of the

by PGF2a. Retained placenta can be a problem with

hypothalamic–pituitary–ovarian axis

either method.

The primary objective of the neuroendocrine adjust-

Tocolysis: Myometrial activity is inhibited by agents

ments in the early postpartum period is to reinstate

(such as b-adrenergic agonists and relaxin) that

the ovaries as fully functional components of the

increase the intracellular levels of cAMP or cGMP, thus

hypothalamic–pituitary axis and to restore the pituitary

interfering with the interaction of free calcium ions with

stores of LH to their normal levels so that the pituitary

contractile protein.

gland can respond to pulses of GnRH by releasing

Drugs that stimulate b2-adrenoceptors of the myome-

pulses of LH of sufficient frequency and amplitude to

trial cells have been used to relax the uterine muscle in

stimulate follicular maturation; in general, this is

non-pregnant cows undergoing embryo transfer and in

achieved by day 10 postpartum. In addition, the cow has

pregnant cows at full term to delay parturition (tocoly-

to cope with the myriad of endogenous and exogenous

sis) or to facilitate obstetrical operations such as

stressors that might interfere with her ability to

fetotomy, caesarean section or replacement of uterine

progress the dominant follicle to its physiological

prolapse. The duration of the tocolysis depends on the

destiny as a preovulatory follicle. The fate of the first-

pharmacological effects of the agent and on the posi-

wave dominant follicle has a significant impact on the

tion of the fetus at the time of treatment. For instance,

duration of the interval to first ovulation: for instance,

clenbuterol causes an outflow of calcium ions from the

Beam and Butler (1999) reported the interval as 20 days

myometrial cells and that renders the cells unrespon-

for those that ovulated (46 per cent of their cows), 51

sive to oxytocin for some hours. When a single thera-

days for those that regressed (31 per cent of cows) and

peutic dose of clenbuterol is given early in stage one of

48 days for those that formed follicular cysts (23 per

labour it can delay parturition for 5–8 hours, but if it is

cent of cows).

given in stage two after the cervix has been fully dilated

Metabolic factors play key roles in the resumption of

the delay may be as short as an hour or two. It has been

reproductive activity (Fig. 33.37). Following parturition,

reported that when uterine contractility returns, the

the high producing dairy cow is unable to increase dry

treated animal tends to have an 'easier' calving; it is *matter intake as fast as is necessary to meet the*

suggested that this is due to greater widening and

increased nutrient demands for lactation; body reserves

softening of the birth canal.

of fat and protein are mobilized to meet the deficit; in

the circulation, the concentrations of non-esterified

fatty acids and triglycerides are elevated, while the

Physiology of the postpartum period

concentrations of glucose, insulin, and IGF-1 are dimin-

During pregnancy, the mechanisms for the synthesis

ished (Fig. 33.37) and the interval to first ovulation is

and release of GnRH by the hypothalamus and those

extended. According to Beam and Butler (1999), the

for the release of the gonadotrophins by the pituitary

interval from calving to the nadir of negative energy

gland appear to remain intact and functional. The high

balance has just as much significance for fertility as does

E2

*

IGF-1

Response

E2

Insulin

to LH

LH surge

Fig. 33.37

A schematic model describing

dominant follicle development (circles) and

FSH

function in relation to changing metabolic

and reproductive hormones, and energy

Atresia

balance (EB), during the first follicular wave

postpartum in dairy cows. The first-wave

follicle either ovulates (*) or undergoes

IGF-1

E2

atresia. LH pulse frequency is modulated

by the day of the EB nadir and, to a lesser

extent, the level of EB. The large upward

arrows indicate increased insulin-like *growth factor-1 (IGF-1) and insulin leading*

to improved responsiveness to LH and

greater oestradiol (E2) production by the

Calving

LH

EB NADIR

dominant follicle. (From Beam & Butler,

1999, reproduced with permission of the

Society for Reproduction and Fertility.)

EB LEVEL

the depth of the nadir. Available evidence seems to

normal duration but with reduced concentrations of

confirm that the modal interval to first ovulation has

progesterone. Another group that may constitute

become longer in recent years.

approximately 50 per cent of either the dairy herd or

It is suspected that the negative energy balance may

the beef herd has been reported to have a short luteal

be a factor in the pathogenesis of abnormal cycles

phase of five to ten days' duration during which the

(short luteal phase, prolonged luteal phase, follicular

corpus luteum secretes reduced amounts of proges-

cysts) in cows that have returned to oestrus. The mech-

terone (Lamming et al. , 1981). These corpora lutea are anisms by which the negative energy balance can inhibit

not killed by the usual luteolytic process: their ability to

ovarian activity are complex. For instance, there is some

synthesize progesterone is lost prematurely. The tran-

evidence that it may suppress LH pulse frequency; the

sient low levels of progesterone after the first ovulation

low levels of insulin and IGF-1 may retard the growth

may have a significant (but, as yet, unidentified) effect

of the dominant follicle; the steroidogenic activity of the

on hypothalamic function and they almost certainly

dominant follicle may be so reduced that it is incapable

play a role in ensuring that oestrus is expressed before

of exerting the positive feedback on the hypothalamus

the second ovulation.

and the pituitary gland that is required for ovulation; if

As mentioned above, a variety of factors can delay

the follicles that ovulate are small, they may form small

the onset of oestrous cycles. Although the events *corpora lutea that are incapable of secreting optimal*

leading to normal stores of LH in the pituitary gland

concentrations of progesterone. It has been reported

are relatively independent of the suckling stimulus

that cows that experienced deep negative energy

and environmental stressors, the events leading to an

balance over the first 10 days postpartum subsequently

increased frequency of LH pulses are susceptible to

had subnormal progesterone concentrations in their

inhibition by such factors.

third oestrous cycles.

In general, milked dairy cows ovulate earlier in the

postpartum period than do suckling dairy cows or beef

cows. For instance, Lamming's group at Nottingham has

Oestrous cycles in postpartum cows

reported that milk progesterone profiles on 505 milked

The first ovulation may or may not be associated with

dairy cows indicated a mean calving-to-first-ovulation

oestrus; estimates of silent ovulation range from 40 to

interval of 24 days compared with approximately 60

70 per cent. Frequently, oestrus is not observed until the *days for 365 suckled beef cows. Suckling depresses the*

end of the first full-length interovulatory period. The

frequency of LH pulses, probably because it induces a

first preovulatory surge of LH may be followed in some

release of endogenous opioids that inhibit the normal

cows by a complete cycle with a normal luteal phase.

pulsatility of the hypothalamic–pituitary axis. There are

However, other cows may have an initial cycle of

high concentrations of prolactin in the circulation of

lactating cows but, according to Lamming et al. (1981), been suggested that a very early ovulation from the ipsi-there is no evidence that hyperprolactinaemia plays a

lateral ovary in an infected cow may increase the risk

significant role in the suckling-induced inhibition of

of development of pyometra (Hartigan et al. , 1974).

ovarian activity. The potency of the suckling stimulus

It is perfectly 'normal' for bacteria to invade the

declines with time after parturition. The duration of the

bovine uterus during the first few days after parturition.

period of inhibition can be influenced by other envi-

Bacteriological studies have revealed that a very wide *ronmental factors, such as poor nutrition (e.g. when*

range of micro-organisms, both pathogens and commen-

cows lose one unit or more in body condition score in

sals, gain entry but repetitive sampling showed that when

early lactation) or season at calving (photoperiod?).

parturition was uncomplicated the contamination of the

For instance, cows that calved during January to June

uterus was transient and that the isolates varied from

took significantly longer to resume ovarian activity than

one sample to the next. At the end of the fourth week

did those that calved during July to December

postpartum only 30 per cent of the cows had

(Lamming et al. , 1981).

bacteria in the uterus, mostly non-pathogens (Griffin

et al. , 1974). Under optimal conditions, most cows have eliminated the pathogenic contaminants before cyclic

Uterine involution

ovarian activity begins. On the other hand, cows that

It should be emphasized that the uterus exercises some

experience dystokia,

traumatic damage to the

control over the activities of the ovaries by way of a endometrium or retention of placental membranes are local utero-ovarian axis and that uterine pathology can less efficient in dealing with pathogens. There is a signif- put a brake on the ovarian contribution to the larger icant reduction in the efficiency of phagocytic cells in the neuroendocrine axis. Synthesis and metabolism of endometrium and uterine lumen and, as a result, poten- PGF2a are elevated in the bovine uterus during the early tial pathogens may persist and induce endometritis or postpartum period and this is reflected in the presence metritis. Again, in the majority of cows the endometritis of a major metabolite (PGFM) in the blood at that time. tends to be short-lived; the combination of phagocytosis, There is accumulating evidence that ovarian function local antibody production and myometrial contractions does not resume until the concentration of this metabo- that are normal features of the involutionary period lite has fallen below a critical threshold. There appears effect clearance of the micro-organisms and resolution to be a significant negative correlation between the *of the endometritis. However, it is important to stress duration of elevated concentrations of PGFM after that infusion of irritants (antibiotics, iodine) that inhibit calving and the time required for completion of uterine phagocytosis, extensive intra-uterine manipulation that involution (Lindell & Kindahl, 1983). Persistent uterine damages the endometrium or an early ovulation that infections prolong the period of high concentrations of causes the onset of a precocious luteal phase may permit PGFM and the time to uterine involution. A problem a pathogenic micro-organism to become established may arise in the infected cow that ovulates very early within the uterus, particularly if the concentration of in the postpartum period because these continuously PGFM is still high. In such circumstances the elevated concentrations of prostaglandin are not suffi- prostaglandin produced by the uterus is inadequate to cient to induce luteolysis and a mutual interdependence cause luteolysis. The result is that the defence mecha- between the infection and the corpus luteum may be nisms of the host are depressed by the progesterone*

*established, thus rendering the cow liable to develop
from the corpus luteum and the pathogens cause contin-
pyometra. However, the majority of cows do not
uing damage to the endometrium, thus preventing the
ovulate until after the microbial population of the
release of a luteolytic dose of prostaglandin. At this
uterus has been reduced to transient contaminants, a
stage, the pathogen and the corpus luteum have estab-
process that may be enhanced by the fluctuating levels
lished a mutual interdependence that predisposes to the
of oestrogens released from the follicles that begin to
development of pyometra. The vicious circle can be
grow in the ovaries as early as the first week postpar-
broken by exogenous prostaglandin. The important
tum and at intervals of seven to ten days thereafter.
point is that inappropriate medication early in the post-
During the second week after parturition the pool of
partum period can interfere with the physiological
antral follicles in the ovaries is increased both in dairy
progress of involution and induce long-term pathologi-
cows and in beef cows; the increase in numbers is*

cal consequences.

largely due to the development of medium-size follicles

If a cow enters the second week postpartum without

(4–8 mm in diameter), particularly evident in the ovary

clinical evidence of an active inflammatory response, it

contralateral to the previous pregnancy. This predomi-

is unnecessary – and it may be unwise – to resort to

nance of the contralateral ovary seems to persist for

intrauterine antibacterial therapy: the drug may cause

about four weeks, with the result that the majority of

physical damage to the regenerating mucosa and –

first ovulations are from the contralateral ovary. It has

perhaps just as important – it may dampen the local

immune response to micro-organisms that may chal-

reports of long-term (up to the third cycle) deleterious

lenge that system later, when the cow is inseminated.

effects on embryo survival in cows that experienced

If purulent endometritis/metritis develops it does not

deep negative energy balance during the first 10 days

abolish ovarian activity immediately and totally. Ini-

after calving. Were the carry-over effects due to a loss

tially, it causes prolonged cycles, usually with silent ovu-

of developmental competence that resulted in embryo

lations for some months before anoestrum supervenes.

mortality and suboptimal luteotrophic stimuli, or were

Obviously, the best prospects of full recovery to fertil-

they due primarily to deficient luteal function that

ity will depend on diagnosis and treatment before the

made the uterine microenvironment suboptimal for the

link between the hypothalamic–pituitary axis and the

conceptus?

ovaries has been severed.

We have mentioned that ingestion of excess protein

For problems seen in the postpartum period consult

leads to elevated blood urea levels, lower pH of uterine

Chapter 34.

fluids and lower fertility. The pregnancy wastage has

been attributed to the deleterious effect of acidic

uterine fluid on embryos (Butler,

2000) but

Uterine environment after resumption of

O'Callaghan and Boland (1999) took a different view:

cyclic ovarian activity

on the basis of experiments involving reciprocal

The quality of the luminal microenvironment of the

embryo transfers, they suggested that the effects on

female genital tract has a significant impact on fertility.

embryo quality are due to alterations in the tubal

The fluids secreted by the oviducts and by the uterus

microenvironment or in the follicle rather than in the

are the media in which the gametes are transported and

uterus.

sustained; the spermatozoa are capacitated, hyperacti-

The iatrogenic introduction of micro-organisms can

vated and acrosome-reacted, the ovum is fertilized and

seriously diminish the quality of the uterine microenvi-

the conceptus is transported and sustained while it

ronment during the breeding season. The uterus has a

develops into the elongated blastodermic vesicle that

higher degree of susceptibility to bacterial infection

implants in the uterus. The appropriate secretions, mus-

during the luteal phase than it has during oestrus. This *cular activity and flow of fluids are governed by oestro-*

is because the migration of neutrophils into and

gen and progesterone released from the ovaries in the

through the endometrium is inhibited by progesterone,

correct concentrations, at the correct times and in a

which also depresses the phagocytic activity of the cells

specific sequence. Therefore, any factor that alters the

once they have arrived in the endometrium. Therefore,

delicate balance of ovarian hormones during the

the clinician should exercise great care to avoid the

oestrous cycle is a potential hazard to pregnancy, even

introduction of contaminated or irritant material into

when a normal fertile cow is bred to a highly fertile bull.

the uterus during the luteal phase. For the same reason,

The composition of the tubal and uterine fluids

cows should not be inseminated at mid-cycle or after

changes on regional and temporal bases – specifically

conception. Persisting bacterial endometritis in a cyclic

to meet the needs of the gametes and of the conceptus:

cow could induce embryo loss because (i) it damages

in particular, the changing needs of the conceptus as it *the endometrium so that it is not possible to establish*

progresses from a single cell zygote to an elongated

an efficient interface for the transfer of nutrients; (ii) it

vesicle. It follows that the preimplantation conceptus is

induces embryo mortality or retards expansion of the

vulnerable to damage by anything that disrupts the

blastocyst which then fails to secrete enough IFN-t to

hormonal balance or otherwise alters the secretions.

maintain the corpus luteum and/or (iii) it releases suf-

However, it is not easy to disentangle the complex inter-

ficient PGF2a to induce premature luteolysis.

relationships between the various actions of the hor-

Problems of the postpartum period are dealt with

mones, the secretory and muscular responses of the

in Chapter 34, with endometritis being discussed from

tubular tract, and the viability and developmental com-

p. 521.

petence of the oocyte. For instance, there are several

highly sensitive junctures at which short-term acute

stress might interfere with the maturation of the oocyte,

Take-home concepts for the clinician

fertilization, embryogenesis or implantation; it would
be virtually impossible to ascertain whether the preg-
Readers must be aware that this overview of the basic
nancy wastage was due primarily to low developmental
elements of reproductive physiology in cattle is a sim-
competence of the zygote or to an inappropriate
plified account of some highly complex phenomena; the
uterine microenvironment that was unable to sustain a
aspiration has been to provide the broad concepts that
fully competent conceptus. Frequently, it would be just
ought to inform the diagnostic and therapeutic efforts
as difficult to identify the cause of the acute stress. A
of the clinician. So, what is the conceptual framework
similar cause-and-effect conundrum attaches to the
for the major themes presented here?

Overall control of reproductive activities is vested in
sale in the local store has been produced by cows that
the HPG axis, within which the dominant role is played
are ‘hormone-laden’?
by the hypothalamus, literally the nerve centre that

coordinates and responds to the relevant neural,

endocrine and immunological inputs. It exercises

References

control through the actions of a pulse generator that is

responsible for the pulsatile release of GnRH which, in

Beam, S.W. & Butler, W.R. (1999) Effects of energy balance turn, regulates the release of the gonadotrophins that

on follicular development and first ovulation in postpartum

determine the nature, intensity and timing of events in

dairy cows. Journal of Reproduction and Fertility, ***Supple-the genital tract. For instance, it is the frequency and,***

ment 54, 411–24.

to a lesser extent, the amplitude of LH pulses that

Binelli, M., Thatcher, W.W., Mattos, R. & Baruselli, P.S. (2001) regulate the timing of ovulation. The pulsatility is

Antiluteolytic strategies to improve fertility in cattle.

modulated by feedback, by energy balance and by stress; Theriogenology, 56, 1451–63.

to take a practical example, it is likely that ovulation

Bo, G.A., Baruselli, P.S., Moreno, D., Cutaia, L., Caccia, M., will be suppressed when an animal is in negative energy

Tribulo, R., Tribulo, H. & Mapletoft, R.J. (2002) The

control of follicular wave development for self-appointed

balance and/or is stressed by other environmental

embryo transfer programs in cattle. Theriogenology, 57, challenges.

53–72.

During the transition period the high-producing cow

Bronson, F.H. (1989) Mammalian Reproductive Biology.

is exposed to a plethora of stressors (both intrinsic and

Chicago University Press, Chicago.

extrinsic), is relatively immunosuppressed and, once lac-

Butler, W.R. (2000) Nutritional interactions with reproductive tation begins, is in significant negative energy balance;

performance in dairy cattle. Animal Reproduction Science, in such circumstances, reproduction has a relatively low

60–1, 449–57.

priority in the partitioning of energy and it is likely that Fawcett, D.W. (1994) A Textbook of Histology. Chapman and the resumption of cyclic ovarian activity will be delayed.

Hall, London.

Of course, the deleterious effect of the energy deficit on

Ginther, O.J. (1996) Selection of the dominant follicle in cattle.

LH pulses is a major factor in the suppression of oestrus

Biology of Reproduction, 55, 1187–94.

Ginther, O.J., Beg, M.A., Bergfelt, D.R., Donadeu, F.X. & Kot, and ovulation, and in the low pregnancy rates to first

K. (2001) Follicle selection in monovular species. Biology of service; however, the fact that approximately half of the

Reproduction, 65, 638–47.

mated cows calve to first service should convince us that

Griffin, J.F.T., Hartigan, P.J. & Nunn, W.R. (1974) Non-specific there are other contributing factors that tip the balance

uterine infection and bovine fertility I and II. Theriogenol-away from a satisfactory level of herd fertility. Thus,

ogy, 1, 91–106; 107–14.

management of the breeding programme demands

Grumbach, M.M., Roth, J.C., Kaplen, J.L. & Kelch, R.P. (1974) attention to hygiene and the physical facilities, to body

In Control of the onset of puberty (ed. by M.M. Grumbach, condition score, to feeding practices and to veterinary

G.D. Grove & F.E. Meyer), p. 158. Wiley, New York.

care throughout both the transition period and the

Hartigan, P.J. (1995) Cattle breeding and infertility. In Animal breeding season. The prime objective is to minimize the

Breeding and Infertility (ed. by M.J. Meredith), pp. 86–186.

allostatic load so that functions of HPG axis are not put Blackwell Science, Oxford.

Hartigan, P.J., Langley, O.H., Nunn, W.R. & Griffin, J.F.T.

at hazard by the coping strategies of an overburdened

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cow (see Chapter 67).

dairy cows in Ireland. Irish Veterinary Journal, 28, 236–41.

If there is a need to induce ovulation, the relevant

Hunter, R.H.F. & Wilmut, I. (1984) Sperm transport in the

conceptual framework derives from the inherent

cow: peri-ovulatory redistribution of viable cells. Repro-

pattern of follicular waves that makes a cohort of newly duction Nutrition Development, 214, 597–608.

recruited follicles available every seven to ten days.

Ireland, J.J., Mihm, M., Austin, E., Diskin, M.G. & Roche, J.F.

Treatment should be administered at the appropriate

(2000) Historical perspective of turnover of dominant folli-

stage in a current wave or, as has been done by inves-

cles during the bovine estrous cycle: key concepts, studies,

tigators pursuing the aspiration to eliminate the need

advancements, and terms. Journal of Dairy Science, 83, for detection of oestrus after induced ovulation, in a

1648–58.

new wave that has emerged after surgical ablation of

Kulick, L.J., Kot, K.,Wiltbank, M.C. & Ginther, O.J. (1999) Follicular and hormonal dynamics during the first follicular

the current wave (Bo et al. , 2002). The latter experiment wave in heifers. Theriogenology, 52, 913–21.

is an exciting application of basic physiological infor-

Lamming, G.E., Wathes, D.C. & Peters, A.R. (1981) Endocrine mation but it does prompt a rhetorical question: if an

patterns in the post-partum cow. Journal of Reproduction

effective pharmacological regimen capable of chemical

and Fertility, Supplement 30, 155–70.

ablation of cohorts of recruited follicles is devised and

Lindell, J.O. & Kindahl, H. (1983) Exogenous prostaglandin is then used widely on a whole-herd basis, how is the

F2a promotes uterine involution in the cow. Acta Veterinaria consumer likely to respond to the news that milk on

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83 , 2998–3007.

maximize fertility in cattle. Journal of Reproduction and

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management of postpartum cows. Animal Reproduction

Science, 60–1, 703–12.

Chapter 34

The Postpartum Period

I.M. Sheldon, D.C. Barrett and H. Boyd

Introduction

508

tion or abnormal ovarian function causes subfertility

Uterine involution

508

which results in substantial economic loss for the cattle

Regeneration of the uterine epithelium

509

industry. Retained fetal membranes, endometritis and

Elimination of bacterial contamination

509

cystic ovarian disease, for example, delayed conception

Return of ovarian cyclicity

509

by 25, 31 and 64 days, respectively compared with cows

Monitoring the postpartum period

511

with a normal postpartum period (Borsberry &

Herd records

511

Dobson, 1989).

Individual clinical cases

511

History

511

The events that comprise the postpartum period are

Clinical examination

511

uterine involution, regeneration of the endometrium,

Principal factors affecting the postpartum period

512

elimination of bacterial contamination of the uterus

Enhancement of the postpartum period

513

and the return of ovarian cyclical activity. The initial

Postpartum lesions of the genital tract

513

stimulus for these changes to occur is the expulsion of

Lacerations and haemorrhage

513

the fetus along with the associated membranes and

Uterine prolapse

514

fluids at calving.

Retained fetal membranes

515

Pneumovagina and urovagina

519

Vaginitis

519

Acute puerperal metritis

519

Uterine involution

Endometritis

521

Pyometra

524

Postpartum anoestrus

525

Uterine involution is the return of the genital tract after

Cystic ovarian disease

526

calving to normal non-pregnant dimensions. This

Prevention of postpartum disease problems

526

involves physical shrinkage, necrosis and sloughing of

Breeding decisions and the management of the pregnant

caruncles, and the regeneration of the endometrium.

and periparturient cow

526

There is considerable loss of tissue, with the

Therapy immediately postpartum

527

mean weight of the uterus decreasing from about 13 kg

Conclusions

527

before parturition to about 1 kg during a 30-day period

(Kaidi et al. , 1991). The uterus and cervix contract

rapidly immediately after calving and it is often difficult

Introduction

to insert a hand through the cervix 24 hours

postpartum; the cervix only admits two fingers by 96

The postpartum period is the time during which the

hours postpartum. Uterine involution occurs in a

genital tract recovers after parturition, and returns to a

decreasing logarithmic scale with the greatest change

normal state ready for the next pregnancy. Despite a

during the first few days after parturition (Fig. 34.1).

trend for extended lactation for higher genetic merit

By 10 to 14 days postpartum the entire genital tract is

dairy cows producing high milk yields, the majority of *palpable per rectum in normal animals, although the*

farmers still select an earliest service date, or voluntary

previously gravid horn can still be identified because it

waiting period, between 40 and 60 days after calving.

is longer and has a greater diameter than the con-

Similarly, in seasonally calved herds, a short period for

tralateral horn. Although the time required for com-

recovery following pregnancy is often essential for

plete involution is 40 to 50 days, the changes in uterine

those animals that calve during the later part of the

diameter are almost imperceptible after 20 days post-

season. Monitoring the uterus and ovaries in the post-

partum. Involution is delayed by postpartum disease

partum period is important because delayed uterine

including milk fever, retained fetal membranes and

involution, the presence of postpartum uterine infec-

uterine infection.

Box 34.1.

Uterine defence mechanisms.

200

180

• Intrauterine neutrophils

160

• Physical barriers of the vulva and cervix

• Persistent uterine contractions and involution

140

• Caruncular sloughing (to expel adherent bacteria)

120

• Secretory immunoglobulins

100

• Cell mediated immunity

80

• Intrauterine pH (rises at oestrus to 7.0, from 6.4 during

dioestrus, which reduces bacterial growth)

60

• Resident vaginal bacterial flora

40

Uterine horn diameter (mm)

20

0

5

10

15

20

25

30

Day postpartum

uterus. The postpartum environment of the uterine

lumen supports the growth of a variety of aerobic and

Fig. 34.1

The mean external diameter of the previously gravid

anaerobic bacteria. Many of these bacteria are simple

(䊉) and non-gravid (䊊) uterine horns between 7 and 28 days

contaminants in the uterine lumen and are removed by

postpartum.

a range of uterine defence mechanisms (Box 34.1).

In one study, 93 per cent of the uteri obtained at an

abattoir within 15 days of calving yielded bacteria on

Regeneration of the

aerobic and anaerobic culture of lumenal swabs and

uterine epithelium

endometrial tissue (Elliot et al. , 1968). The number of uteri from which bacteria were isolated had declined to

Following the loss of the allantochorion there is necro-

78 per cent by 16 to 30 days, 50 per cent at 31 to 45 days

sis of the uterine caruncle and this has usually sloughed

and 9 per cent by 46 to 60 days postpartum. In the live

by day 12 postpartum. Sloughing of the uterine carun-

animal, there is a constantly fluctuating bacterial flora

cles contributes significantly to the rapid reduction in

in the first 7 weeks postpartum due to spontaneous

weight of the involuting postpartum uterus because

contamination, clearance and recontamination. How-

the caruncles account for over half of the weight of the

ever, uterine infection is commonly associated with

uterus. The sloughed caruncles form the lochial dis-

Escherichia coli, Arcanobacterium pyogenes, Fusobac-charge, along with the remains of fetal fluids and blood

terium necrophorum and Prevotella (formerly Bac-from the ruptured umbilicus. The lochia is usually a

teroides) species. Indeed, A. pyogenes, F. necrophorum yellow to brown, viscous fluid without an unpleasant

and Prevotella species have been shown to act syner-

odour. The uterus of normal animals contains one to

gistically to enhance the likelihood of uterine disease

two litres of lochia immediately postpartum and the

and increase the risk of clinical endometritis and its

greatest discharge is in the first two to three days; it has

severity.

virtually disappeared by 14 to 18 days after calving.

There is initially regeneration of the endometrium in

the intercaruncular areas and then by centripetal

Return of ovarian cyclicity

growth of the cells over the caruncle. Epithelial regen-

eration is complete by about day 25 postpartum, but the

During the bovine oestrous cycle, ovarian follicular

deeper layers of tissues are not fully restored until 6 to

development occurs in a wave pattern starting with the

8 weeks postpartum. Whilst these epithelial changes are

emergence and recruitment of two to six follicles of 4

taking place the caruncles are shrinking. By 40 to 60

to 6 mm diameter (Savio et al. , 1988). One of these

days postpartum the caruncles are only 4 to 8 mm diam-

follicles is selected to continue to grow and become the

eter and 4 to 6 mm high, compared with 40 to 70 mm

dominant follicle, whilst the remaining follicles become

diameter and 25 mm high at calving.

atretic and regress (Fig. 34.2). Each follicular wave is

preceded by an increase in circulating FSH concentra-

tion (Adams et al. , 1992). Selection of the dominant fol-Elimination of bacterial

licle results in oestradiol production, and negative

contamination

feedback on FSH, with the follicle subsequently becom-

ing LH dependent (Ginther et al. , 1996). Early luteal At calving, the vulva is relaxed and the cervix dilated,

phase progesterone secretion, however, suppresses LH

allowing bacteria to gain entry to the vagina and the

pulse frequency and the first dominant follicle under-

Uterine involution

LH

Progesterone

***

FSH

0

5

10

15

20

days

Fig. 34.2

Cartoon of resumption of ovarian cyclical activity in a dairy cow during the first 20 days postpartum. As uterine involution (--) progresses, there is a transient increase in plasma FSH concentration (—), followed by the emergence of several follicles > 4mm diameter (•), with subsequent selection of a dominant follicle (粽) and atresia of the subordinate follicles (粍). The fate of the first dominant follicle is dependent on LH pulse frequency, which in the present case is sufficient to cause ovulation (*), and the subsequent formation of a corpus luteum secreting progesterone (...), heralding the return of ovarian cyclical activity.

goes atresia. Conversely, at the other end of the cycle,

quency; ovulation generally occurs once the LH pulse

after luteolysis the LH pulse frequency increases,

frequency is one per hour. Therefore, factors that sup-

stimulating growth of another dominant follicle that

press LH pulse frequency in the postpartum period can

increases plasma oestradiol concentrations, which

delay the return of ovarian cyclical activity. Those

subsequently stimulate an LH surge and ovulation.

factors causing anoestrus tend to be more common in

Throughout pregnancy, regular periodic emergence *the beef suckler cow, and include suckling or the mater-*

of anovulatory follicular waves occurs in response to

nal bond, low body condition score and inadequate

recurrent FSH surges, except for the last 21 days of

nutrition. The principal factor causing anoestrus in

pregnancy due to very high plasma progesterone and

dairy cattle is negative energy balance.

oestrogen concentrations. After parturition steroid

An interesting feature of ovarian follicular growth

hormone concentrations decrease to basal values, there

within 4 weeks of parturition is that there are fewer

is an increase in plasma FSH concentration within days

dominant follicles or corpora lutea in the ovary ipsilat-

of calving and that stimulates the emergence of the first

eral to the previously gravid uterine horn, compared

postpartum follicular wave. Subsequently, the first

with the contralateral ovary (Sheldon et al. , 2000).

dominant follicle is selected around day 10 to 12 post-

However, the presence of a dominant follicle in the

partum (Savio et al. , 1990; Beam & Butler, 1997). These ipsilateral ovary, although less frequent, is a positive *events occur in all postpartum cows irrespective of peri-*

marker of subsequent fertility.

parturient disease, environment or dietary deficiencies.

Early return of cyclical ovarian activity is generally

However, the first dominant follicle has three possible

accepted to be beneficial for subsequent fertility

fates: ovulation and formation of the first postpartum

(Darwash et al. , 1997); however, others have reported corpus luteum (return of ovarian cyclical activity),

the converse (Smith & Wallace, 1998). Furthermore, it

atresia with the emergence of one or more follicular

is suggested that an early postpartum first ovulation in

waves without ovulation (anoestrus) or formation of an

the presence of uterine infection can lead to pyometra

ovarian follicular cyst (Beam & Butler, 1997). In

with persistence of a CL in the presence of pus within

Europe, 70–80 per cent of first dominant follicles are

the uterine lumen (Olson et al. , 1984).

ovulated in dairy cattle fed an appropriate diet whereas

Farmers rarely observe oestrus at the time of the first

in the beef suckler cow ovulation of the early postpar-

postpartum ovulation in cattle, and in a significant

tum dominant follicles is less frequent (Roche &

number of animals the first luteal phase is relatively

Boland, 1991). The prolonged interval to return of

short. Using continuous observation, oestrus is detec-

ovarian cyclicity in beef suckler cows is an expression

table at the time of about 50 per cent of first and 95

of their failure to ovulate, rather than a failure to

per cent of second ovulations. It is suggested that a

develop, dominant follicles. The principal factor deter-

period of progesterone dominance prior to ovulation is

mining the fate of the dominant follicles is LH pulse fre-

important for oestrous expression.

Monitoring the postpartum period

animals an examination is made three to five weeks

postpartum to identify abnormalities of the puerperium

Herd records

that might lead to subsequent infertility. This may

include the following procedures.

Recording the basic fertility parameters including the *date of calving, dates of observed oestrus and service*

dates is invaluable for analysis to determine whether a

Physical examination

herd is achieving its fertility targets (see also Chapter

Body condition scoring of cows at drying-off, at calving,

41 (b)). The importance of efficient and accurate heat

at routine postpartum examinations and at the time

detection cannot be stressed too often to farmers. In

of insemination is an effective method to assess the

addition, the recording of calving ease, the occurrence

adequacy of nutrition in a herd and to monitor energy

of retained fetal membranes, abnormal vulval discharge

balance. Indeed, changes in body condition score reflect

and other peripartum problems identify those herds,

the effect of negative energy balance on fertility as well

and animals within a herd, that warrant particular atten-

as other markers of energy balance such as plasma con-

tion during the postpartum period.

centrations of insulin-like growth factor 1 (IGF-1) and

b-OH butyrate (BHB). In addition, the presence of

Individual clinical cases

ketosis can be established by analysis of urine, milk or
serum, and is associated with postpartum uterine infec-
In many cows presented immediately after calving,
tion (Markusfeld, 1984). The use of milk analysis as a
diagnosis of postpartum problems is quite simple, for
method of assessing the nutrition of dairy cattle and
example retained fetal membranes or prolapse of
their metabolic status is discussed further in Chapter 47
the uterus. However, a cow that is acutely ill could be
(see p. 807).
suffering from a variety of conditions and, therefore, a
Palpation per rectum of the genital tract is the pre-
systematic approach to diagnosis is necessary both
dominant method of assessing uterine involution and
for differential diagnosis and to ascertain the severity
the return of ovarian cyclicity. Uterine involution
of the condition. Investigation of the individual cow
may be considered to be complete when the genital
should include the history, a thorough physical exami-
tract has contracted such that the uterine horns are of
nation and further investigations as indicated.

equal diameter and length and the uterus has returned

to lie within the pelvic cavity. Return of ovarian cyclic-

History

ity is usually determined by the palpation of a corpus

luteum in the ovary; palpation of follicles in the ovary

Questions should be asked to ascertain whether the

does not indicate return of ovarian cyclicity. Anoestrus

cow was ill before calving and whether the illness

cows may have ovarian follicles up to 18 mm diameter,

was related to reproduction or was a condition that is

but there is no corpus luteum. Palpation of ovarian

obviously related, such as a pathological vaginal

structures more than 25 mm in diameter may indicate

discharge. Information about previous feeding and

the presence of a follicular or luteal cyst. However, a

management should be gathered, particularly relating

substantial proportion of cystic structures identified

to the transition period, with the object of determining

before day 30 postpartum will spontaneously regress

whether the diet could have predisposed to metabolic

(Chapter 35).

diseases. Details of other postpartum problems in the

Palpation per rectum alone is not sufficient to deter-herd in this and previous breeding seasons should also

mine the adequacy of uterine involution and elimina-

be obtained.

tion of bacterial contamination. A vaginal examination

The place where the cow calved should be inspected

is essential for the assessment of the presence or

to assess the level of environmental hygiene during

absence of postpartum uterine bacterial infection. Gen-

calving. The farmer should be asked if the calving was

erally, a manual examination of the vagina is performed

assisted and, if so, how much and what help was given,

by inserting a lubricated, clean, gloved hand between

by whom and what hygienic precautions were taken. It

clean vulval lips. During the examination, vaginal and

is also important to determine whether the client has

cervical os lacerations and abnormalities are noted and

given any treatment already.

a sample of vaginal mucus withdrawn and examined for

character, volume and smell. The combination of a vaginal examination and a rectal palpation can be used

Clinical examination

to score the severity of endometritis, which is a prog-

A thorough clinical examination must be undertaken,

nostic indicator of the success rate of treatment for

although the optimum time after calving for examina-

endometritis (Sheldon & Noakes, 1998). Observation of

tion is debatable. Most often in outwardly healthy

the vagina, vaginal mucus and the cervix with a specu-

lum may provide additional information; sterile, dis-

nately, the cost of collection and evaluation for the

posable specula are available.

individual animal precludes the widespread use of the

technique in cattle.

Ultrasonography

Bacterial culture

Real-time B-mode ultrasonography using a linear array

transrectal probe has revolutionized the veterinarian's

Guarded transcervical swabs can be used to collect

ability to monitor the return of ovarian cyclical activity *samples of intrauterine fluid for bacterial culture and*

and uterine involution. Visualization of the genital tract

identification. It is essential that both anaerobic and

before day 10 postpartum is difficult, particularly in

aerobic cultures are used, which requires the use of

older animals, and a 5 MHz probe is more appropriate

a transport medium and specialized microbiological

for examination of the enlarged uterus at this time.

techniques. The predominant pathogens associated with

However, a 7.5 MHz probe is superior for examination

endometritis are A. pyogenes, E. coli, F. necrophorum of the ovaries. Ultrasonography is particularly useful

and Prevotella melaninogenicus. Sensitivity tests for for identifying ovarian follicles; a dominant follicle is

selection of an appropriate antibiotic might be of value

usually defined as a follicle ≥9 mm diameter in the

for herds with a high incidence of endometritis.

absence of other large growing follicles. However,

caution has to be exerted when considering structure

and function; the detection of a large follicle or follicu-

Principal factors affecting the

lar cyst alone does not indicate that it is endocrinolog-

postpartum period

ically active (Beam & Butler, 1997).

Use of the ultrasound machine's internal callipers

There are a variety of factors than can influence the

allows measurement of the diameter of the uterus and

duration of the postpartum period. For convenience, we

ovarian structures and comparison with the expected

have already considered the various components of this

normal values determined by sequential measurement

period as separate entities; however, this does not

of uterine horn diameter during the process of involu-

reflect the normal situation. Uterine involution, bacte-

tion. In addition, abnormal contents of the uterine

rial infection and the return of ovarian cyclicity are all

lumen are readily detected. The entire length of both

closely linked.

uterine horns should be scanned, because often pus is

Abnormalities of the puerperium such as dystokia,

localized within a limited section of the genital tract.

retained fetal membranes, stillbirths, abortions and

However, the use of transrectal ultrasonography does *twins delay uterine involution and the return of ovarian*

not negate the value of performing a manual or specu-

cyclicity. In addition, these problems are associated with

lar examination of the vagina before examining the

an increased risk of metritis and/or endometritis. Con-

remainder of the genital tract.

versely, early postpartum ovulation prior to the elimi-

nation of bacterial contamination may predispose to

pyometra if uterine infection persists in the presence of

Progesterone analysis

a corpus luteum.

Estimation of plasma or milk progesterone by enzyme-

Suckling has been widely reported to delay the return

linked immunosorbent assay (ELISA) or radioim-

of ovarian cyclicity. It is interesting to compare studies

munoassay (RIA), collected two to three times per

using milk progesterone estimation to determine the

week after calving is adequate to determine the first

mean time to postpartum resumption of ovarian cycles

postpartum luteal activity and abnormal patterns of

in dairy (Bulman & Lamming, 1978) and beef cows *ovarian activity. Milk samples are more practicable in*

(Peters & Riley, 1982), which were 24.0 ± 0.6 and

the field because of the ease of collection. Samples of

59.9 ± 2.5 days, respectively. It would appear that this

10 ml of milk can be stored for at least a month in con-

inhibitory influence, mediated by reduced LH secre-

tainers with a potassium dichromate tablet as a preser-

tion, is a function of the maternal bond attributable to

vative (Lactab Mk III, Thompson & Capper, Runcorn)

the dam's own calf, rather than simply an effect of suck-

and refrigerated at 4°C.

ling or milk yield (Williams & Griffith, 1995). It has also been suggested that higher milk yields are associated

with longer acyclic periods, although it is difficult to sep-

Endometrial biopsy

arate the effects of milk yield and confounding factors

Histological examination of endometrial biopsies has

such as nutrition.

not been used as frequently in cattle as in mares.

Inadequate nutrition, and particularly a diet deficient

However, endometrial biopsies are valuable indicators

in energy, is the most important cause of postpartum
of subsequent reproductive performance. Unfortu-
anoestrus. Body condition score (BCS), particularly in

beef suckler cattle, is an important factor affecting the
The first action of the obstetrician after the delivery and
resumption of ovarian cyclicity and cows with a body
resuscitation of a calf should always be to check the
condition score less than 2.5 are likely to have a signif-
dam for trauma. If haemorrhage is apparent its sever-
icant delay (see p. 10). In dairy cows, changes in BCS
ity should be assessed and appropriate action taken;
after calving are more important than BCS at calving.
severe haemorrhage involving a large artery can be
rapidly fatal.

Traumatic and post-traumatic lesions are treated

Enhancement of the

according to general principles of wound management.

postpartum period

If the calf has been delivered without the use of
epidural analgesia, but surgical intervention is required

Shortening the postpartum period would increase the

to control haemorrhage, then the use of an epidural

opportunity for rebreeding cattle after calving. Unfor-

should be considered. In order to prolong the duration

tunately, most practical attempts to advance uterine

of analgesia obtained by this method it may be advan-

involution have been disappointing; a variety of thera-

tageous to include xylazine in the epidural (Ko et al. , peutic agents have been used in the early postpartum

1989; Holden, 1998). When a vaginal vessel is bleeding

period with no significant effect.

severely, an attempt must be made to clamp the trau-

A number of therapeutic agents have been used to

matized vessel with artery forceps which can them be

try to induce ovulation in the early postpartum period

left in place for 24 hours. Ligation and the suturing of

and, therefore, shorten the interval to return of ovarian

lacerations would also be indicated in some cases,

cyclicity; these agents include GnRH, progesterone and

although it is often impractical due to the inability to

eCG (see p. 678). However, results are inconsistent and *gain adequate access to the site. If bleeding vaginal*

often of little long-term benefit to the fertility of the

vessels cannot be clamped or ligated the only other

herd.

option is to apply pressure using materials such as clean

In the absence of consistently effective pharmaco-

towels or bedsheets or a pressure pad containing ice in

logical methods of shortening the postpartum period, it

an attempt to bring about constriction of the bleeding

is particularly important for the veterinary surgeon to

vessels and promote blood clotting.

be familiar with the management factors affecting this

Where haemorrhage is occurring from uterine

period and to give appropriate advice to clients to avoid

lacerations, oxytocin may also be used to promote con-

their negative effects. For example, veterinarians should

traction of the uterus. In cases of uterine rupture,

use condition score targets for key points in the man-

laparotomy and surgical repair may be the only alter-

agement cycle such as at calving and drying off, in dairy

native to emergency slaughter. Following severe haem-

cattle, or weaning, in beef suckler cows. In addition, it

orrhage a blood transfusion may be indicated as a life

is important to ensure the cows are fed an appropriate

saving procedure.

diet, paying particular attention to the energy density

In less severe cases the bleeding may stop sponta-

of the ration.

neously, although lacerations, severe bruising and tissue

trauma may result in the later development of necrotic

vaginitis. Where perivaginal fat prolapses through

Postpartum lesions of the

vaginal lacerations and becomes necrotic, this may have

genital tract

to be removed to allow closure of the vaginal tear.

Infection with F. necrophorum or Clostridium species Traumatic injuries to the genital tract, bony pelvis and

may result in a locally severe reaction and serious

nerves of the pelvis sometimes occur during normal

systemic illness or death.

parturition. However, they are more common following

In the case of necrotic vaginitis emollient fluids and *dystokia. Postpartum problems include traumatic*

antiseptics are applied locally along with an appropri-

injuries such as penetrating wounds and tears of the

ate systemic antibiotic such as a cephalosporin or

uterus or vagina, tearing of the cervix or vulva,

potentiated amoxycillin. Following any difficult partu-

rectovaginal fistula formation, haemorrhage and

rition with associated trauma to the reproductive tract

haematoma, as well as other conditions such as reten-

the cow is likely to benefit from the administration of

tion of the fetal membranes and prolapse of the uterus

systemic non-steroidal anti-inflammatory drugs

(Noakes, 2001a).

(NSAIDs) (Chapter 62).

The response to treatment of many vaginal lesions is

good and the clinical signs will disappear within about

Lacerations and haemorrhage

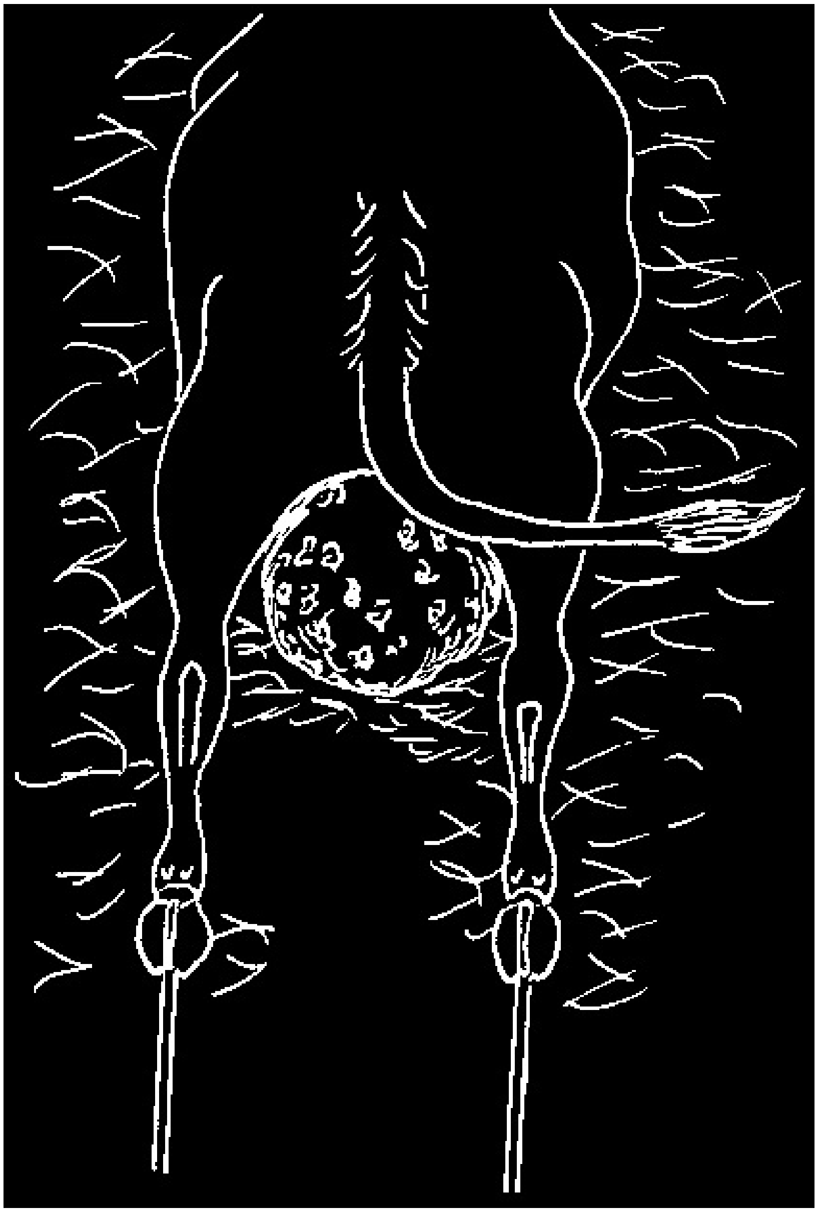
10 days. In these cases there is no interference with

There is usually, but not always, a history of a protracted

future reproduction. In a few cases infection spreads

or particularly difficult per vaginam delivery of the calf.

and affects the uterus, with resultant poor prognosis for



fertility. Scar tissue may cause narrowing of the birth

with reduced abdominal straining may actually aid

canal and interference with the next calving.

replacement of the prolapsed organ if the procedure

For further information on nerve damage, the reader

can be undertaken swiftly and treatment with calcium

should consult Chapter 32.

borogluconate is not delayed too long.

The replacement of the uterus is aided by the correct

positioning of the cow. If the cow is standing the uterus

Uterine prolapse

may be lifted on a sheet with the aid of two assistants

Uterine prolapse is a relatively common complication

and replaced from that position. However, if the cow is

of third stage labour in the bovine, with the uterus

recumbent she should be placed in sternal recumbence

prolapsing within hours of the calf being delivered and

in the frog-leg position as described by Plenderleith

prior to the cervix contracting (Noakes, 2001b). The

(1986) (Fig. 34.3) and if possible positioned facing down

usual presentation is of a complete inversion of the

hill. This positioning of the cow is achieved by rolling

gravid uterine horn. While prolapse of the uterus may

her onto one side and pulling the opposite leg straight

follow a dystokia with a high degree of traction, it is also *back, before rolling her to the other side and repeating*

commonly seen as a sequel to a normal or unassisted

the process. If necessary, ropes can be used to hold the

second stage labour. Plenderleith (1986) reports that

cow in this position until the uterus has been replaced.

the condition is recorded in 0.5 per cent of assisted calv-

Replacement of the uterus is greatly aided by the

ings and 0.3 per cent of all calvings, while Correa et al.

administration of an epidural anaesthetic, possibly

(1992) report the condition in 0.6 per cent of calvings.

including xylazine (Ko et al. , 1989; Holden, 1998); this The main predisposing factor in the aetiology of this

also reduces postoperative straining and improves pain

condition is considered to be uterine inertia immedi-

relief for the cow. Before replacing the uterus it must

ately postpartum. Hypocalcaemia (milk fever) (see p.

be carefully checked for trauma and cleaned as much

781), which results in a reduction of smooth muscle tone

as possible using a warm, non-irritant, antiseptic solu-

in the uterus, and elsewhere, has been shown to increase

tion or normal saline; lacerations of the uterus may *the risk of uterine prolapse threefold, while dystokia*

require suturing. There is no absolute need to remove

increased the risk fivefold (Correa et al. , 1992). The the placenta, but often the most effective way of clean-increased risk of hypocalcaemia in older cows may

ing the organ is to remove the heavily contaminated

explain why multigravida are more commonly affected

fetal membranes. However, if the placentomes are still

than primigravida. Factors that are considered to pre-

intact and the fetal membranes are not removed easily

dispose to prolapse of the uterus are summarized in

they should be left in place.

Box 34.2.

Box 34.2.

Possible predisposing factors for uterine

prolapse.

• *Fetal oversize and maternal/fetal disproportion*

• *Prolonged dystokia*

• *Fetal traction*

• *Hypocalcaemia*

• *Retained fetal membranes*

• *Chronic disease, particularly cattle in very poor body* *condition*

When notified of a case of uterine prolapse, the vet-

erinarian should inform the client to wrap the prolapse

in a clean sheet to prevent further trauma and contam-

ination and reduce heat loss.

When faced with a case of uterine prolapse in a cow

with overt clinical signs of hypocalcaemia, treatment of

the hypocalcaemia should probably be carried out prior

to replacing the uterus, in case regurgitation and aspi-

ration of rumen contents occurs or the cow succumbs

Fig. 34.3

Recumbent cow in the 'frog-leg' position for replac-

to the hypocalcaemia. However, a non-life-threatening

ment of a uterine prolapse. Reproduced from Plenderleith (1986) hypocalcaemia which maintains a cow in recumbency

with permission.

The weight of the uterus is best supported by an assis-

study before the end of the next breeding season. Of

tant on either side of the cow while the surgeon replaces

those cows that were subsequently mated, 78 per cent *the uterus little by little starting at the vulval lips. Gentle were found to be pregnant, although 9 per cent subse-but continuous pressure is applied with a clenched fist or*

quently aborted. This indicates that prompt attention

the open palm of the hand as portions of the uterus are

to uterine prolapse gives a reasonable survival rate and

pushed back into the vagina. Care must be taken to

acceptable subsequent conception rates. Possible com-

ensure that fingers are not pushed through the often

plications following uterine prolapse are listed in Box

friable uterine wall. Once the uterus begins to be

34.3.

replaced it is best to maintain momentum, as a single

abdominal contraction from the cow while the uterus is

Box 34.3.

Possible complications of uterine prolapse.

not held can result in the entire uterus once again

becoming prolapsed. As the uterus disappears within the

• Hypocalcaemia

vulval lips the veterinarian should continue to press it

• Haemorrhage

forward to the full length of his/her arm. It is important

• Metritis

• Endometritis

that the whole of the uterus passes through the cervix

• Peritonitis

and that the total length of the uterine horn is fully

• Toxaemia/septicaemia

replaced and any remaining inversion of the tip of the

• Necrosis of devitalized tissue in longstanding cases

uterine horn reduced. This can be achieved using some-

• Uterine rupture

thing to extend the veterinarian's reach such as a clean

smooth-ended bottle. Alternatively a volume (5–10

litres) of warm clean water, normal saline or dilute anti-

Retained fetal membranes

septic solution can be instilled into the uterus and then

Introduction

the majority can be siphoned back out. This has the

added advantage that it also has a cleansing action, and

Retained fetal membranes (RFM) is a common condi-

any fluid remaining in the tip of the uterine horn may act

tion that is defined as non-separation of the fetal mem-

to hold the uterus in place until the recurrence of normal

branes by 12 hours after calving (some authors extend

uterine contractions results in its expulsion.

this period to 24 hours before they consider the pla-

There is debate within the profession as to whether

cental retention to be pathological). The incidence

there is a need to suture the vulval lips closed after

varies from study to study but tends to be about 5–10

replacing a uterine prolapse. If suturing is considered

per cent (Kossaibati & Esslemont, 1995; Parkinson,

necessary it is best to use Buhner's technique with

2001); in a survey of >160 000 calvings in the Nether-

obstetrical tape, although many other techniques are

lands the average incidence was 6.6 per cent (Joosten et

available (Hooper et al. , 1999). Following replacement al., 1988). In problem herds the incidence may be much of the uterus every effort must be made to restore

higher. The year of calving, season of calving, parity of

uterine tone and promote involution and closure of the

dam, calf mortality, calving difficulty and fetal presen-

cervix. To this end hypocalcaemia must be treated and

tation have all been shown to affect the incidence of *oxytocin may be administered; parenteral antibiotics*

RFM (Mee, 1991).

and analgesics are also indicated. Some uterine prolapse

cases prove fatal due to trauma and haemorrhage includ-

Diagnosis and consequences of retained

ing rupture of the uterine and/or ovarian blood vessels,

fetal membranes

shock or the often concurrent hypocalcaemia. However,

the prognosis depends largely on the following:

The diagnosis of RFM is self-apparent, the major vari-

able being the effect of the condition on the cow's

• The time lapse between the development of the

health. In many cases health is unaffected. However,

prolapse occurring and professional treatments

the majority of cows have mild disturbances of appetite

being undertaken.

and body temperature. In a small number of cows, acute

• The degree of trauma that has taken place to the

metritis develops causing severe illness, with typical

uterus.

signs of toxaemia and septicaemia. Without effective

• Associated periparturient conditions such us

treatment this condition can be fatal. Some of the

hypocalcaemia and haemorrhage.

effects of RFM are summarized in Box 34.4. Economi-

There are few published reports looking at success

cally, RFM represents one of the most significant post-

rates for uterine prolapse cases. However, a study

partum abnormalities with each case reported to have

undertaken in New Zealand (Oakley, 1992) showed

a direct cost of approximately £85, mainly due to a

that 19 per cent of cows died within 24 hours of treat-

reduction in milk yield and/or milk sales. When the

ment and a further 16 per cent died or were lost to the

effects on subsequent poor fertility are also considered

Box 34.4.

Some of the effects of retained fetal

than in cows that released the membranes nor-

membranes.

mally. However, on some occasions retention is

associated with uterine atony: for instance, after

• Reduced dry matter intake

overextension of the myometrium as in cases of

• Withholding of milk from the food chain and possibly a

lowered milk production

hydrops allantois, or prolonged labour or in

hypocalcaemic cows. It is unlikely, however, that

• Increased incidence of postpartum metritis, endometritis

and pyometra

uterine atony in the absence of some disturbance

• Increased time to first service

of the process of caruncle/cotyledon separation

• Reduced conception rates/increased services per

would result in RFM.

conception

• Increased days open

In addition to the above mechanisms, nutritional

• Longer calving interval

problems such as vitamin E/selenium, iodine and

• Predisposition of cows to other conditions such as

vitamin A deficiency have been reported to be associ-

left-displaced abomasum and laminitis

ated with an increased incidence of RFM in some herds,

• Mortality

although individual cows are not normally considered

to develop RFM due to nutritional deficiencies.

Laven and Peters (1996) have reviewed the aetiology

and pathogenesis of fetal membrane retention in

the cost is estimated to be around £300 per case

detail.

(Kossaibati & Esslemont, 1997).

Treatment

Aetiology

Over time the natural sloughing of the maternal

The specific pathogenesis of RFM still remains uncer-

caruncles and uterine involution contributes to the

tain due in part to our poor understanding of normal

loss of the membranes. If left untreated, freeing of

placental separation in the bovine. However in simple

the fetal villi from the maternal caruncles eventually

terms there are considered to be two main ways in

occurs as a result of bacterial putrefaction and autoly-

which fetal membrane retention occurs:

sis over several days. The toxic products of this putre-

(1)

Interference with the separation of the fetal villi

faction accumulate within the uterus, causing a fetid

from the maternal caruncles. This may be associ-

odour that taints the milk making it unfit for human

ated with the following:

consumption.

(a)

Premature calving (induced or spontaneous)

Moller et al. (1967) describe a large clinical trial in without the normal maturation of the pla-which the results of a wide variety of treatments were

centome involving hormonal and structural

studied. They pointed out that cows that are ill and cows

changes in preparation for separation.

with metritis must be treated, but they concluded that

This maturation involves changes in the

the evidence did not indicate a need to treat cases of

molecular structure of collagen within the

uncomplicated placental retention. In fact it appeared

placentome and alteration in binucleate cell *that any type of drug therapy for this condition tended*

numbers in the trophectoderm. Spontaneous

to depress subsequent pregnancy rates, whereas cows

premature calvings will include many twin

that were not treated (that is, membranes not removed,

births as well as abortions.

no drug therapy administered) had pregnancy rates that

(b)

Prolonged gestation may result in excessive

were not significantly different from those achieved by

growth of the dam's caruncles.

cows that passed the membranes at the proper time. In

(c)

Trauma with oedema of the villi, which

cows that remain healthy, treatment may therefore not

occurs after Caesarean section, torsion of the

be indicated. However, in a small proportion severe

uterus and other dystokias.

metritis and toxaemia may develop, which may be fatal

(d)

Infectious conditions (with or without abor-

if left untreated.

tion) result in inflammatory changes that

bind together the maternal and fetal tissue in

Manual removal of fetal membranes: Veterinarians have

the placentome.

been arguing for decades over the need for manual

(e)

Hyperaemia of the placentomes.

removal of retained fetal membranes. It should be

(f)

Necrosis of the villi.

borne in mind that although the results of many field

(2)

Observations on uterine contractions after calving

trials tend to favour non-removal, the arguments

suggest that in many cases of retained fetal mem-

in favour of manual removal are said to include the

branes, their frequency and amplitude are greater

following:

(1)

It removes a major source of infection and putre-

Advocates of conservative treatment may intervene

fying protein.

only if the animal develops signs of systemic disease, in

(2)

It removes the unpleasant smell, which can taint

which cases the treatment is systemic administration of

the milk, and physical presence of the retained

a broad-spectrum antibiotic. Other veterinarians simply

membranes.

cut off the part of the membranes that is visible to

(3)

The cow may be less likely to develop systemic

reduce the smell and only apply other treatment in

illness.

those (few) cases that become systemically ill.

(4)

The cow may be less likely to have disturbed

It would seem that current practice in the field is

fertility later.

often at odds with research findings regarding treat-

(5)

The cow may be less likely to suffer from reduced

ment of RFM. Laven (1995) undertook a survey of the

milk yield.

methods used by British veterinarians for treating RFM

(6)

A small number of conservatively treated cows

and found that manual removal was used in some cases

become very ill and require life-saving treatment.

by at least 92.5 per cent of respondents. Ecbolic agents

including prostaglandin F

These points are not necessarily sufficient justifica-

2a (or analogues of PGF2a)

and oxytocin were sometimes used by 84.2 per cent,

tion for manual removal of RFM, as point 2 is a benefit

with 15.7 per cent using oestradiol (no longer permit-

to the farmer rather than the cow and points 3, 4 and 5

ted in many countries) in an attempt to potentiate the

have been contradicted by many published trials. Points

effects of oxytocin. Most veterinarians reserved the use

1 and 6 are true, although there is little evidence that *of antibiotics for cows that were systemically ill, but 18*

toxaemia occurs because the placenta has not been

per cent used them in animals with no overt illness.

removed. Toxaemia can occur after removal of the

Only 1.6 per cent of respondents routinely left cases of

placenta (Peters & Laven, 1996).

RFM untreated.

Those in favour of manual removal claim that the

At the present time it is difficult to say categorically

danger of reproductive or general disease is greatly

that cows should or should not be treated by manual

reduced with gentle handling, a willingness to stop

removal of the membranes, or which cows would

manual removal where the attachment is firm, and

benefit from manual removal rather than other medical

the concurrent use of local or systemic antibiotics. If

or conservative treatment. However, it is in conditions

manual removal is to be used this should not be

such as RFM, where we need evidence-based medicine

attempted until a minimum of 96 hours after calving

most, that treatment decisions of this type should be *and in many cases it is necessary to leave for a longer*

based on sound scientific and economic analysis to

time period than this. Manipulation should be confined

provide decision support rather than individual

to gentle traction on the membranes and not involve

arbitrary decisions.

the manual breaking down of each individual placen-

tome as this results in significant trauma to the

Ecbolic drugs: Prostaglandin F

endometrium.

2a or analogues have

been administered systemically to encourage the

The arguments used against manual removal of the

removal of fetal membranes. Stevens et al. (1995)

retained fetal membranes include the following:

evaluated the use of an intrauterine infusion of oxy-

(1)

Just after calving the cow is ready to deal with the

tocin, subcutaneous injections of fenprostalene or a

large amount of infected material and decompos-

combination of both. They concluded that the interval *ing necrotic caruncles that are sloughed off into*

from parturition to expulsion of the fetal membranes

the uterus in the normal course of events; the need

was unaffected by treatment, as was the frequency of

to get rid of fetal membranes as well presents no

subsequent displaced abomasum, ketosis and mastitis.

insurmountable problem to most cows.

However, Stocker and Waelchli (1993) found that the

(2)

Intrauterine manual intervention should be

administration of PGF2a after Caesarean section

avoided because it interferes with the natural

decreased the risk of retention of fetal membranes.

defence mechanism by reducing phagocytosis for

Similarly, oxytocin used up to 36 hours after calving

several days.

may increase myometrial contractions and hasten

(3)

Manual removal of the membranes is never com-

expulsion of the membranes. Trial results have been

plete and numerous villi and remnants of placenta *variable regarding the use of oxytocin (Stevens &*

are left attached.

Dinsmore, 1997), however its administration may be of

(4)

Manual removal causes trauma and adds to the

some benefit to counteract the effects of uterine relax-

likelihood of local infection persisting.

ants used during obstetrical procedures or Caesarean

(5)

If the cow is ill, systemic treatment is sufficient to

sections. Oestrogen alone has also been used (but is

deal with the problem and manual removal may

probably contraindicated and is no longer available for

worsen the cow's condition.

use in food producing species in some countries). In

short, ecbolic drugs are unlikely to be effective after a

RFM, with close monitoring of the cow so that sup-

diagnosis of RFM has been made, but they may reduce

portive therapy can be instigated rapidly in the small

the incidence of RFM in certain groups of cows if *number of cases that develop systemic illness. Veteri-*

administered very soon after the delivery of the calf.

nary efforts should be concentrated on preventing the

high incidence of RFM at the herd level and minimiz-

Collagenase: Eiler and Hopkins (1993) reported using

ing the reproductive and economic consequences of the

collagenase as an infusion into the umbilical artery; a

condition.

dose of 200 000 iu of collagenase was dissolved in 1

litre of saline and infused between 24 and 72 hours after

Prevention of retained fetal membranes

parturition. The technique was reported to give an 85

per cent success rate in cases of spontaneous RFM.

General preventive measures for postpartum disease

However, no further reports of this technique

problems including RFM are discussed at the end of

have appeared in the literature and it has not been

this chapter (p. 526). With specific reference to RFM,

accepted and taken up widely. This author has no per-

attempts at prevention by routine treatment of all cows

sonal experience of this technique and feels that there *at calving are generally ineffective and impractical*

is a need for further research before it could be

because of the relatively low incidence and morbidity

recommended.

of the condition. However, incidence of retention is

increased greatly when parturition is induced with cor-

Intrauterine medication: Various intrauterine medica-

ticosteroids and there is some evidence that PGF2a can

tions have been advocated over the years including

be an effective therapeutic agent in such cases. Gross et

intrauterine infusions of oxytetracycline (Stevens et al., al. (1986) used dexamethasone to induce parturition in 1995). Brooks (2001) compared two different intrau-66 cows; they injected PGF2a into 40 cows within one

terine pessaries administered after manual removal of

hour of delivery and treated 26 cows with saline (con-

RFM, one containing penicillin, streptomycin and for-

trols). The incidence of retention in the PGF2a-treated

mosulphathiazole and another made up of 8 per cent

cows was 8.8 per cent compared with 90.5 per cent in

iodoform in a vegetable gelatine base. He was unable

the controls. This approach to prevention is supported

to detect any difference in the efficacy of the two prod-

by findings that suggest that cows which subsequently

ucts as determined by subsequent fertility, but did not

develop RFM have lower levels of endogenous PGF2a

compare the treatment groups with negative controls.

at the time of calving than those without RFM

Intrauterine antimicrobial and antiseptic treatments

(Wischral et al., 2001).

are probably best reserved for the treatment of the

sequels of RFM, including endometritis (see p. 521),

Effects of retained fetal membranes

rather than being seen as a treatment for RFM itself.

There is even a school of thought that advocates not

The effect of retained fetal membranes on subsequent

suppressing bacterial putrefaction of the membranes by

fertility depends on whether acute metritis, endometri-

administering local intrauterine antimicrobials as this

tis or pyometra develops or not. While there is argu-

slows the release of the membranes. Some intrauterine

ment about the best treatment at the time of retention,

medications may also interfere with the local immune

there is general agreement that it is important to *response within the uterus.*

monitor cases closely until the membranes are lost.

They should also be examined again about 18–30 days

Other treatments: Other treatments such as intravenous after calving to identify and treat those cows that have

calcium borogluconate, corticosteriods, multivitamins

developed endometritis or pyometra (see pp. 521, 524).

(Laven, 1995) and oral calcium chloride gel (Hernandez

In an extensive field study with cows that retained

et al., 1999) are advocated by some. However, their use the placenta for at least 48 hours, Leslie et al. (1984) is controversial and like the more established treatment

reported that 14 per cent of the cows developed pyome-

options there is a lack of evidence to support their

tra and 15 per cent developed chronic endometritis. In

use. In some cases these treatments may actually be

four herds in which a conservative approach to treat-

detrimental and thus contraindicated.

ment was employed, metritis developed in 40 of 73

It should perhaps also be borne in mind that other

cases of retained fetal membranes (Sandals et al. , 1979).

treatments administered to the postpartum cow such as

From a study of days to service, days to conception and

NSAIDs (e.g. flunixin meglumine) may even induce

services per conception these authors concluded that

RFM (Waelchli et al., 1999).

the condition of retained fetal membranes alone has

In summary, there is little scientific evidence to

little effect on subsequent fertility. In a large field study

support anything other than conservative treatment of

(Halpern et al. , 1985) 45 per cent and 41 per cent of

primiparous and pluriparous cows with retained fetal

ventral shelf of tissue can be formed cranial to the

membranes developed metritis. In the heifers there was

urethral orifice.

no significant adverse effect of retained fetal mem-

branes on fertility. In adult cows with no subsequent

Vaginitis

metritis, retention for five or more days caused lower

pregnancy rates than controls. Retention for more than

Vaginitis is often associated with a more extensive

seven days caused a long calving-to-service interval and

infection of the genital tract. However, inflammation
low pregnancy rate. Borsberry and Dobson (1989),
may also be associated with pneumovagina, urovagina
working in the UK, reported that RFM alone extended
or following trauma during parturition. In addition,
the calving interval by 25 days, but when it was associ-
infectious causes of vaginitis are reported especially
ated with a subsequent endometritis this increased to
where natural service is practised. Infectious pustular
51 days. McDougall (2001) also reported that cows with
vulvovaginitis caused by bovine herpes virus-1
RFM have lower pregnancy rates and take longer to
(BHV-1) is probably the most common. However,
conceive than unaffected herd-mates under New
other potential pathogens such as Ureaplasma diver-
Zealand management systems. Rowlands and Lucey
sum,
Mycoplasma bovigenitalium,
Haemophilus
(1986) reported that the lactation yield following
somnus and BHV-4 have also been implicated as

retained fetal membranes was 7 per cent lower than

causes of a mild granular vulvovaginitis (Cook,

expected (Box 34.4).

1998).

The presenting sign of vaginitis is usually tenesmus;

there may also be an abnormal vaginal or vulval

Pneumovagina and urovagina

discharge and changes in the mucosa, varying from

Pneumovagina may be caused by damage to the vulva

hyperaemia through necrosis to gangrene in rare cases.

during parturition or inadequate closure of an epi-

Occasionally there is a more extensive retroperitonitis

siotomy incision. However, often there is no specific

and septicaemia. A mild vaginitis has little effect on

cause of pneumovagina or urovagina evident on

subsequent fertility unless accompanied by endometri-

presentation. Both conditions are often associated with

tis, pneumovagina or urovagina. However, severe cases

a history of dystokia or delivery of a large calf; the

of vaginitis may cause extensive scarring leading to

affected cow frequently has a BCS < 2. Pneumovagina *infertility or in some instances to dystokia at the sub-*

and urovagina may be unobserved until a genital tract

sequent parturition.

examination or artificial insemination (AI) is per-

Treatment should be based on the severity of the

formed. Occasionally, the herdsperson will observe a

lesions and correction of predisposing factors. The

persistent dribble of urine from the vulva or hear air

vagina should be gently douched with normal saline or

being sucked through the vulval lips.

a mild antiseptic solution, following administration of

The treatment of pneumovagina is to perform a

an epidural anaesthetic. The duration of activity of the

Caslick's operation. Briefly, under epidural anaesthesia,

epidural anaesthesia can be extended by the addition

the lips of the vulva are scarified along a 1 cm wide strip

of xylazine to the anaesthetic solution (Caron & Le

from the dorsal commissure to the level of the ischial

Blanc, 1989). Douching of the vagina may be repeated

arch, leaving 2.5–3.0 cm at the ventral commisure to

on several occasions. In addition, infection of deeper *permit urination. The lips of the vagina are sutured with*

tissues should be treated using systemic antibiotics.

a non-absorbable material. Concurrent vaginal and/or

Inflammation can be reduced and analgesia provided

uterine infection is treated appropriately. Sutures are

using NSAIDs.

removed in 10 to 14 days and the animal artificially

inseminated at the next oestrus.

Acute puerperal metritis

There are a number of treatments for urovagina.

Some cases will respond spontaneously, particularly

Microbial contamination of the uterine lumen at par-

those cases identified before 4 to 6 weeks postpartum

turition is a normal event (Elliot et al., 1968) (see p.

and in animals that increase BCS. The return of ovarian

509), and in most cows this contamination is eliminated

cyclical activity, or possibly administration of PGF2a to

and does not result in severe infection. For this reason

induce oestrus, may help resolution in some cases.

acute puerperal metritis is relatively uncommon.

The use of AI can be successful even in the presence

However, in those cases where it does occur acute

of urovagina, in other cases. In severe or long-

inflammatory changes are seen in the endometrial,

standing cases surgical intervention may be necessary.

myometrial and peritoneal layers of the uterus within

A caudal extension to the distal urethra can be con-

ten days of calving. Pathogenic bacteria produce toxins

structed using the ventral vaginal wall or a transverse

and result in the development of septicaemia, toxaemia

and possibly also pyaemia. Cows with acute puerperal

(2)

The natural defence mechanisms are less effective

metritis have a very serious life-threatening condition

than normal. Factors that may cause this include

that requires intensive treatment.

the following:

(a)

Dystokia;

(b)

Manipulation within the uterus after calving,

Diagnosis

such as inappropriate and rough attempts to

A foetid, reddish to brown discharge flows from the

remove RFMs;

vulva and abdominal straining is noted. Affected cows

(c)

Uterine inertia;

also commonly exhibit pyrexia, tachypnoea, tachycar-

(d)

Concomitant infection with immunosup-

dia, anorexia, rumen stasis and dehydration. Severe

pressant agents such as bovine virus diar-

cases may have a toxaemia-induced diarrhoea and

rhoea virus.

develop signs of shock including a subnormal rectal

temperature. The infection may extend through the

The effect of diet before calving is unresolved; it is

uterine wall causing a localized or generalized peri-

possible that dietary energy intakes that result in fatty

tonitis. Therefore internal examination of suspected

infiltration of the liver, insufficient protein and *cases of acute metritis must be undertaken with*

micromineral deficiency may also impair uterine

extreme care. The uterus is often friable and liable to

defence mechanisms.

trauma, and therefore uterine exploration should be

minimized in the acute stages of the condition. Vaginal

or rectal exploration of cases of metritis often results in

Treatment and prognosis

acute discomfort and may be followed by persistent

straining.

Good nursing is vitally important. The cow should be

It is probable that in the future the diagnosis and

placed in a well-bedded, comfortable warm box and

monitoring of response to treatment of acute infections

encouraged to eat and drink. Systemic broad-spectrum

such as metritis will be aided by the use of acute phase

antibiotic treatment applied in the correct dose, and

protein estimations going some way towards removing

maintained for a minimum of 5 days, is essential.

the need for internal examinations (Eckersall, 2000;

Suitable antimicrobials include cephalosporins, poten-

Sheldon et al. , 2001).

tiated amoxycillin or possibly tetracyclines. However,

for good genital tract penetration postpartum oxytetra-

cycline should be prescribed at a dose of 10 to 15 mg/kg

Aetiology

b.i.d. This 'off-label' use is above the normal recom-

The physiology of the response to normal postpartum

mended dose and would require additional precautions

infection suggests that there are two main factors that

to be taken to prevent problems with milk or meat

lead to a pathological result.

residues. See also the section on antimicrobial treat-

ment of endometritis (p. 522) for a fuller explanation of

(1)

The uterus is exposed to an unusually high

the efficacy of antimicrobials in the treatment of

polymicrobial challenge that includes some of the

intrauterine infections.

more pathogenic organisms such as A. pyogenes,

Severely affected cows should also be treated aggres-

coliforms and anaerobes such as F. necrophorum *sively with intravenous fluid therapy using either high*

and Prevotella melaninogenicus. In rare cases

volumes (20–30 litres or more) of isotonic fluid or low

Clostridium spp. may cause severe disease and

volumes of hypertonic fluid (3 litres of 7.2 per cent

rapid death. The risk of postpartum intrauterine

saline) to combat the effects of the toxaemia and to

infection may be increased by:

reduce the development of shock. Non-steroidal anti-

(a)

Dystokia with resultant trauma inside the

inflammatory drugs (NSAIDs) such as flunixin meglu-

uterus;

mine are also indicated both to provide analgesia and

(b)

The use of dirty equipment and dirty calving

to reduce the effects of endotoxins (see p. 1050). It

boxes;

might be expected that the administration of flunixin

(c)

The delivery of an emphysematous calf, *meglumine would inhibit normal uterine involution in*

resulting in the uterus being heavily infected

cows with metritis, due to reduced biosynthesis of

with anaerobic organisms;

PGF2a. However, at least one study suggests that the

(d)

Retained fetal membranes;

administration of flunixin meglumine to cows with

(e)

Synergistic action between infectious

metritis accelerates uterine involution and shortens the

agents, such as A. pyogenes and anaerobic

calving to first oestrus interval (Amiridis et al. , 2001).

organisms (F. necrophorum and Prevotella

If the cow is continually straining, caudal epidural

melaninogenicus).

anaesthesia can be used; it may be advantageous to

include xylazine in the epidural in order to prolong its

Endometritis

duration of action (Ko et al. , 1989; Holden, 1998).

Introduction

Any manipulation of the uterus should be avoided while the cow is systemically ill. However, after the Endometritis is defined histologically as an inflamma- acute phase of the disease a technique of gentle tion of the endometrium. However, it is normally char- flushing and fluid withdrawal reduces the quantity of acterized clinically by the presence of a mucopurulent infected material in the uterus and may facilitate vaginal discharge, 21 days or more after calving, and myometrial contractions and uterine involution. This associated with delayed uterine involution. The inci- can be done using a wide diameter smooth ended tube, dence of endometritis is about 10 per cent in dairy such as a stomach tube attached to a funnel. The oper- cattle, although the incidence in beef herds is less clear. ator (taking extreme care not to traumatize the uterus) However, there is wide variation in the incidence of passes the tube through the cervix and pours in several endometritis between herds, ranging from a few cases litres of a flushing solution made up of warm sterile

to more than 40 per cent of the herd affected.
normal saline. The funnel is then lowered below the
Endometritis causes considerable subfertility and infer-
level of the uterus and the fluid along with debris from
tility. The presence of uterine bacterial contamination
within the uterus is siphoned out. This procedure can
disrupts the delicate hormonal milieu of the hypothal-
be repeated several times to remove as much as pos-
amic–pituitary–ovarian axis (see p. 489; Chapter 67)
sible of the uterine contents (Parkinson, 2001). While
and disrupts follicular growth and development.
removal of the uterine contents in this way seems
Uterine infection has been reported to be associated
logical, and has been undertaken many times by these
with an increased incidence of cystic ovarian disease.
authors, it should be noted that controlled studies to
Furthermore, the presence and persistence of patho-
evaluate this form of therapy are lacking. Flushing the
genic organisms causing endometritis is assumed to
uterus in this way also has inherent risks: the uterus may
preclude the establishment of pregnancy. Thus,

be punctured or damaged and irrigation fluid may flow
endometritis has a detrimental effect on fertility,
in a retrograde direction up the oviducts, resulting in
extending the calving to conception interval, and
salpingitis and adhesions of the ovarian bursae.
increasing the number of services per conception and
Many clinicians introduce antibiotics into the uterus
the proportion of culls for failure to conceive.
once the cow has responded to parenteral treatment,
The economic cost of endometritis depends on the
but the points discussed regarding the use of intrauter-
detrimental effect on fertility, increased culling rate
ine antibiotics for the treatment of endometritis (see p.
and, to a lesser extent, the cost of treatment. The esti-
522) should be borne in mind.
mated direct cost of a case of vulval discharge was £71
With acute metritis the prognosis refers to the possi-
for treatment and a 300 litre reduction in milk yield
bility of death, adverse effect on health, milk yield and
(Kossaibati & Esslemont, 1997). However, the total cost
future reproductive function. Most cases make a fairly

was £160, including an increased calving interval of 18

slow recovery as regards body condition, milk yield and

days and an increase of 0.3 services per conception.

return to cyclicity and pregnancy. In the worst affected

cases, if the cow survives the acute metritis episode

Aetiology

treatment can be considered a reasonable success.

It is assumed that the uterus and its contents are sterile

during a normal pregnancy and prior to parturition.

Consequences of metritis

Then at the time of parturition or just afterwards the

A small proportion of metritis cases develop embolic

uterine lumen becomes contaminated by micro-organ-

pneumonia, polyarthritis or endocarditis (see p. 726) as

isms from the animal's environment, skin and faeces,

a consequence of a bacteraemia or laminitis following

through the relaxed perineum, vulva and dilated cervix.

the toxaemia. In those cases that do respond to treat-

There are a variety of predisposing factors for

ment, after recovery there may be adhesions affecting

endometritis (Box 34.5). Cows with a uterine infection *the uterus, the oviducts and ovarian bursae, resulting in*

associated with A. pyogenes more than 21 days post-

reduced fertility. The majority of cases of acute metri-

partum develop a severe endometritis and are almost

tis will also progress to endometritis.

invariably subfertile to the first service. In addition,

In a meta-analysis of papers published since 1960,

there is synergism between A. pyogenes, F. necropho-metritis was shown to be associated with a seven-day

rum and Prevotella melaninogenicus, causing more increase in time to first service and a 20 per cent

severe cases of endometritis. Interference with uterine

reduction in conception rate to first service, resulting in

defence mechanisms such as uterine involution or neu-

a delay to conception of 19 days (Fourichon et al. ,

trophil function will delay the elimination of bacterial

2000).

contamination. Dystokia, the delivery of twins or a

Box 34.5.

Predisposing factors for endometritis.

to assess the degree of uterine and cervical involution, *and the nature of the vaginal discharge. The majority of*

• Retained fetal membranes

systems use a combination of uterine horn and cervical

• Dystokia and/or assistance at calving

diameter and a score for the contents of the vagina (Fig.

• Caesarian section

34.4) (Sheldon & Noakes, 1998).

• Twins

• Stillbirths

• Induced parturition

Treatment

• Dirty calving environment

• Postpartum ovarian inactivity

The treatment of endometritis has caused considerable

• Diet–possibly vitamin E/selenium deficiency

debate and has been reviewed extensively in the liter-

ature (Bretzlaff, 1987; Sheldon, 1999). The value of

treatment of clinical cases has not been accepted by

all clinicians, despite evidence that cows administered a

dead calf and assistance at calving increase the oppor-

placebo, rather than an accepted therapy, had longer *tunity for faecal contamination of the genital tract.*

intervals from calving to conception and higher culling

Retained fetal membranes are a predisposing factor for

rates (Steffan et al. , 1984). Treatment success rates are endometritis and are associated with an increase in

higher for mild cases of endometritis compared with

severity of endometritis (Sheldon & Noakes, 1998).

severe cases and the success rate is reduced if the

Uterine infection has a seasonal incidence, being

vaginal discharge has a foetid odour.

highest during the housed period, presumably because

The three treatments most often used are parenteral

of environmental contamination. A dirty calving envi-

PGF2a or analogues (see p. 524), oestrogen (see p. 523)

ronment may increase the risk of endometritis. Noakes

and intrauterine antibiotic. There are a limited number

et al. (1991) described two hygienically contrasting

of products licensed for endometritis; in addition, a nil

farms: on one with a relatively clean environment the

milk withholding period is usually demanded in dairy

incidence of endometritis was 2–3 per cent, compared *cattle.*

with an incidence of 15 per cent for one with a dirty

environment. However, there was no difference in the

Antimicrobial treatment: A number of antimicrobial

quantitative or qualitative uterine bacterial flora in

selection criteria have been suggested for endometritis

cows calved on either farm.

including efficacy against the causal organism in the

A delay in the return of cyclical ovarian activity after

uterine environment, but without inhibiting natural

calving appears to predispose to endometritis. Con-

uterine defence mechanisms. Fluid and tissue debris

versely, if the interval from calving to first ovulation is

reduce the effect of sulphonamides, aminoglycosides

too short, it has been suggested that pyometra could

and nitrofurazones, and aminoglycosides are ineffective

occur because A. pyogenes and Gram-negative anaero-

in an anaerobic environment, such as the uterine lumen.

bic bacteria would remain within the uterus after ovu-

The chosen antibiotic must reach appropriate concen-

lation, allowing bacterial growth to continue following *trations at the site of infection and persist a sufficient*

corpus luteum formation (Olson et al. , 1984).

length of time to eliminate the infection. At less than

30 days postpartum, mixed bacterial infections may

render intrauterine infusion of penicillin ineffective,

Diagnosis and assessment

due to penicillinase produced by bacteria. In contrast,

Clinically, endometritis is characterized by the presence

oxytetracycline and cephalosporins are broad spec-

of a mucopurulent discharge in the vagina, associated

trum, and are effective in the uterine lumen in the pres-

with delayed uterine involution. The definitive diagno-

ence of pus and reduced oxygen tension. In addition,

sis of endometritis would be made based on histologi-

pharmaceutical preparations of oxytetracycline and

cal examination of endometrial biopsies. However,

cephalosporins produce effective antimicrobial concen-

under field conditions, examination of the vagina and

trations in the endometrium, but with minimal concen-

palpation of the genital tract per rectum are the most trations in milk. Any milk withdrawal period would *useful techniques for the diagnosis of endometritis.*

make a treatment for endometritis unattractive under

Visual or manual examination of the vagina for an

practice conditions; for example, parenteral tylosin gave

abnormal uterine discharge is essential for the diagno-

effective concentrations in genital tract tissues and the

sis of endometritis, although the contents of the vagina

uterine lumen, but has a significant milk withdrawal

do not always reflect the contents of the uterus. Flakes

period (Cester et al. , 1993). Metronidazole and chlo-

of pus in the vagina could come from the uterus, cervix

ramphenicol are prohibited in food producing animals

or vagina and slightly cloudy mucus is often regarded

in the UK. The use of the intrauterine route of admin-

as normal. A number of scoring systems have been used

istration has prevailed for many years and the pharma-

Clinical sign

Point score

Smell

Foul

3

No smell

0

Bloody

3

Vaginal discharge

>50 ml pus

3

Character

< 50ml pus

2

Flecks

1

Normal

0

External diameter

Pregnancy

Primiparous

Multiparous

of largest uterine

horn

Large

> 5.5 cm

> 6.0 cm

2

Medium

3.5 to 5.5 cm

4.0 to 6.0 cm

1

Normal

< 3.5 cm

< 4.0 cm

0

Pregnancy

Primiparous

Multiparous

External diameter

Large

> 7.0 cm

> 7.5 cm

2

of cervix

Medium

4.5 to 7.0 cm

5.0 to 7.5 cm

1

Normal

< 4.5 cm

< 5.0 cm

0

Clinical assessment from total score

Severe

8–10

Moderate

4–7

Mild

1–3

Normal

0

Fig. 34.4

Scoring system for the assessment of the severity of endometritis, suitable for use from 21 days postpartum.

ceutical industry continues to develop antibiotic prod-

A. pyogenes when either endogenous or exogenous

ucts administered by this route, despite the widespread

oestrogen was present compared to during dioestrus,

use of systemic antibiotics for treatment of other bac-

and suggested that exogenous oestrogen may be used

terial infections in cattle.

therapeutically. Despite the potential of oestrogens for

the treatment of endometritis, results have been equiv-

Hormones: The hormonal treatment of endometritis

ocal and vary with the pharmaceutical preparation and

is based upon observations that the genital tract is

dose administered. The treatment-to-conception inter-

more susceptible to infection when under progesterone

val was longer for cases of endometritis treated with a

dominance and more resistant under the influence of

single intramuscular injection of 3 mg oestradiol ben-

oestrogens (Rowson et al. , 1953).

zoate per 500 kg body weight, compared with those

***Oestrogens**: Rowson et al. (1953) demonstrated that treated using prostaglandin or intrauterine oxytetracy-the bovine uterus was more resistant to infection with*

cline (Sheldon & Noakes, 1998). Furthermore, regula-

tory authorities have prohibited the use of oestrogens

appear ill; however, they are anoestrus and may be pre-

in several countries.

sented to the veterinarian as 'not-seen-bulling' or for

***Prostaglandins**: The parenteral application of*

pregnancy diagnosis.

PGF2a, or its analogues, has been used widely for the

Pyometra may be a sequel to the conditions discussed

treatment of endometritis. The majority of authors

earlier in this chapter and therefore those factors that

report that the presence of an active corpus luteum is

predispose a cow to RFM, metritis and endometritis can

required for optimal results when using prostaglandin

also be considered to predispose to pyometra. In addi-

to treat endometritis, which supports the hypothesis

tion pyometra may also be seen in cows after service

that the subsequent induced oestrus increases the

(either natural or by AI).

uterine resistance to bacteria (Jackson, 1977; Sheldon &

In most cases pyometra is a sequel to chronic

Noakes, 1998). Conversely, Pepper and Dobson (1987) endometritis as the uterus ceases to release the endoge- reported that the efficacy of prostaglandin therapy for nous luteolysin PGF2a. Research has shown that the endometritis did not depend on the presence of an persistence of the CL in cows with pyometra is not due active CL, as determined by measuring milk pro- to an insufficiency in the synthesis of uterine PGF2a but gesterone concentrations. An alternative hypothesis is associated with inadequate secretion of luteal oxy- for the mechanism of action of prostaglandin as a treat- tocin (Vighio et al. , 1991). The result is that the ment for endometritis is a direct myometrial effect, with dioestrus CL persists and the genital tract remains physical expulsion of uterine detritus.

under the influence of progesterone. The infection is A number of clinical trials have studied the pos- thus not eliminated and the cervix remains closed, sibility of using the direct myometrial effect of resulting in the accumulation of large quantities of prostaglandin therapy, to reduce the incidence of *purulent exudate in the uterine lumen. Occasionally*

endometritis and improve subsequent fertility. A

there will be slight leakage through the cervix,

routine injection of prostaglandin shortened the

resulting in a small amount of pus accumulating in the

calving-to-conception interval in normal cows com-

anterior vagina and an intermittent purulent vaginal

pared with control animals (Etherington et al. , 1988).

discharge. In a small number of cases the persistent

However, a number of subsequent trials gave conflict-

luteal tissue is a progesterone secreting (luteal) cyst

ing results. Meta-analysis of 24 trials where PGF2a was

rather than a persistent CL. In some instances the intro-

administered to cattle within 40 days of calving

duction of infection during dioestrus, such as occurs

reported no beneficial effect on first-service pregnancy

when a cow is artificially inseminated at an incorrect

rate, although there was a small reduction in days open

time, results in pyometra. Pyometra may also occur

for treated cows (Burton & Lean, 1995).

secondary to the death of a fetus, either caused by, or *followed by, bacterial invasion by A. pyogenes and*

Other treatments: A variety of antiseptics have been

persistence of the CL of pregnancy. Infection with

administered by intrauterine infusion for the treat-

Tritrichomonas fetus also causes embryonic death and

ment of endometritis including solutions of Lugol's

pyometra formation (Bon-Durant, 1997).

iodine, polyvinyl pyrrolidine iodine, povidone-iodine,

When examined per rectum, cases of pyometra have

chlorhexidine and metakresol sulphonic acid. Many of

enlarged uterine horns and must be accurately differ-

these solutions cause a necrotic endometritis within 24

entiated from a normal pregnancy before treatment can

hours of infusion that may stimulate release of PGF2a

be administered. There are a number of distinguishing

in addition to possible direct effects on pathogenic

points:

organisms. However, despite clinical resolution of

• *The uterus feels 'doughy' and the uterine wall is*

the endometritis using antiseptic solutions, the effect on

thicker than during pregnancy.

fertility may not be beneficial. Nakao et al. (1988)

• It is not possible to palpate the amniotic vesicle or

administered a 2 per cent polyvinyl pyrrolidine iodine

'slip' the allantochorion membranes.

intrauterine infusion and reported that treated cows,

• Placentomes are not palpable or visible on ultra-

particularly those with a purulent discharge, had an

sound examination, although the caruncles of the

increased calving-to-conception interval compared with

previous pregnancy are occasionally detected.

controls. In addition, some of these antiseptic products

• Ultrasonography will demonstrate the absence of a

are not licensed for use in food producing animals.

fetus and the presence of pus rather than normal

fetal fluids.

Pyometra

The best and most appropriate treatment of pyometra

Pyometra is associated with the accumulation of pus in

is to bring about luteolysis with PGF2a or PGF2a

the uterus and by the persistence of functional luteal

analogues. However, this treatment should never be tissue on one or both ovaries. Affected cows do not

administered if there is any suspicion that the cow

may be pregnant, as it will cause abortion in early

>1.0 BCS points during the first 30 days after calving

pregnancy.

take longer to the first postpartum ovulation than those

The administration of PGF2a to cases of pyometra

losing less than one unit (Beam & Butler, 1999).

usually results in dilation of the cervix and expulsion of

However, monitoring BCS over periods greater than 6

the purulent uterine contents, with oestrus occurring

weeks postpartum often has a less clear association with

three to five days later. There is evidence to suggest that

the length of the anoestrus period. The pituitary secre-

treatment of pyometra is improved by the administra-

tion of FSH appears to be insensitive to NEB. Thus, suc-

tion of two doses of PGF2a 8 hours apart (Archbald

cessive waves of follicular growth start within 10 days

et al., 1993). This is probably due to the fact that a single of calving. However, in the anoestrus cows, dominant *dose of exogenous PGF2a has only a very short dura-*

follicles fail to ovulate because of inadequate LH

tion of action, as the inadequate release of ovarian oxy-

pulse frequency. Insulin-like growth factor-1 (IGF-1) is

tocin from the CL in these cases is insufficient to

a likely hormonal mediator between nutrition and fer-

maintain the normal positive feedback loop that brings

tility. However, the precise mechanisms and how they

about luteolysis by the release of further endogenous

may be modulated are not yet clear. Shortening the

PGF2a.

postpartum interval to the NEB nadir is a more tangi-

Many cases of pyometra go on to become pregnant,

ble management objective to reduce the incidence of

despite having a prolonged first luteal phase and a pro-

anoestrus in a herd.

longed calving to pregnancy interval of 125 days com-

The suckling calf inhibits the release of GnRH from

pared to 74.8 days (Etherington et al., 1991). However, the dam's hypothalamus, so suppressing LH pulse fre-longstanding cases are associated with endometrial

quency. However, this inhibitory influence occurs as a *degeneration, which may increase the rate of late*

consequence of the maternal bond between cow and

embryonic and early fetal losses. Comparison between

calf, and it is not dependent upon sensory innervation

pregnancy rates at first pregnancy diagnosis 33 to 70

of the udder (Williams & Griffith, 1995). The frequency

days postservice and a subsequent diagnosis 120 to 150

and duration of suckling by a single calf are unrelated

days postservice have shown that attrition rates are 2.6

to the period of anoestrus, although suckling following

times higher in cows with previous pyometra than in

adoption of an additional calf will delay the return of

cows without the condition (López-Gatius et al., 1996).

ovarian cyclicity. If the single calf is removed from its

dam there is a corresponding increase in the frequency

of LH pulses within two to six days. The inhibition of

Postpartum anoestrus

GnRH release is dependent on the cow being suckled

Introduction

by her 'own' calf, which she identifies by sight and smell.

The mechanisms underlying this effect are unclear; in

Postpartum anoestrus is a greater problem for beef

part, they may involve increased opioid tone within the

cattle than dairy cows, and it is often evident in specific

brain.

herds.

Diagnosis

Aetiology

At least two examinations, 10–14 days apart, are

The two main predisposing factors are inadequate

required to make a clinical diagnosis of anoestrus. Both

nutrition, specifically energy deficiency, and suckling or

ovaries are small and there is no CL detectable at either

the maternal bond. Other associated factors are that it

of the examinations; however, follicles up to 18 mm

is more common during late winter, in the absence of a

diameter may be identified. An alternative or addi-

bull and following dystokia. Rarely, anoestrus may be

tional method of diagnosis is to use milk progesterone

associated with pituitary or ovarian damage.

analysis; two low values, at 10–14-day intervals, is

Negative energy balance (NEB) is common to most *indicative of anoestrus.*

postpartum cows and is the difference between the

dietary intake of metabolizable energy and the expen-

Treatment

diture for maintenance and lactation (see p. 103). Con-

sequentially, the balance between milk yield and

The most important consideration when presented with

feeding (including diet composition, feed supply and

an anoestrus animal is to correct the underlying causes,

appetite) is an important determinant of the severity of

in particular dietary deficiencies. The quantity and

NEB. However, in first lactation an animal's metabo-

quality of feed supplied to the animal in relation to its

lizable energy may also have to contribute to continued

milk yield should be determined. In addition, dry-cow

growth. The effect of NEB is most easily identified by

management should be examined, paying particular

monitoring body condition score (BCS). Cows that lose

attention to the transitional period. Monitoring BCS

during the dry period and early lactation will help to

Control of these conditions is not simply a matter of

quantify the severity of dietary energy deficiency. Two

good management at the time of calving.

groups of pharmaceutical products may be used to treat

anoestrus: GnRH and analogues, and progestagens.

Breeding decisions and the

GnRH: The pituitary LH content and responsiveness

management of the pregnant

to GnRH are complete by day 10 postpartum and so

and periparturient cow

exogenous GnRH administered to the anoestrus cow

will induce a transient LH and FSH release. However,

The most important way of reducing puerperal prob-

the response to treatment depends on the stage of

lems is to avoid dystokia. Where dystokia does occur it

ovarian follicular wave. If there is a dominant follicle

is essential that it is dealt with correctly at an early stage present, ovulation will occur. So, when daily ultrasound

and that any developing problems observed after

monitoring was used to identify a suitable dominant

calving are also treated as soon as possible. Attention *follicle, administration of GnRH consistently induced*

to all aspects of hygiene is also a basic requirement.

ovulation (Roche et al., 1992). However, the majority of If it were purely a veterinary matter it would be rel-animals did not express oestrous and had short luteal

atively simple to reduce the incidence of dystokia in the

phases after ovulation.

Gonadotrophin releasing

majority of herds. However, the measures required may

hormone administered in the absence of a dominant

not be acceptable to the farmer. Simple modifications

follicle is ineffective, so overall blind-treatment success

such as improved supervision of calving and better

rates are variable.

housing may be judged to be too expensive. Selecting

an easy calving breed of bull or individual bull within a

Progesterone: Administration of progesterone, using

breed may not produce calves with the desired confor-

an intravaginal device or norgestamet by injection and

mation or genetic potential.

implantation, is an alternative treatment for the

The consequences of several synergistic adverse *anoestrus cow. In the absence of severe NEB, once the*

effects tend to be particularly serious. Therefore, if a

progesterone treatment is removed, there is an induced

client chooses to use a bull that is liable to produce a

ovulation and such treatment overcomes the absence of

high rate of dystokia it is particularly important to avoid

behavioural oestrous that often occurs at the first post-

any other factor that predisposes to dystokia.

partum ovulation. However, if the NEB is severe, prog-

Application of the following precautions will reduce

esterone treatment requires supplementation with

the incidence of dystokia in a herd.

400–700 iu equine chorionic gonadotrophin (eCG) by

intramuscular injection at the time of implant removal.

(1)

Selection of sires that produce calves of suitable

An alternative to eCG is the administration of 1 mg

size and conformation for the dams concerned.

oestradiol benzoate 24 hours after a seven-day proges-

This refers to the breed and to the individual bull

terone treatment which increased oestrus expression *within the breed. Special care is needed for heifers*

and ovulation (MacMillan et al. , 1995).

(see Chapter 5).

(2)

Induction of premature calving, if the fetus is

likely to be too large at full term for a normal

Cystic ovarian disease

calving (see p. 687).

Cystic ovarian disease can be a major problem in the

(3)

Control of energy intake and avoidance of

postpartum dairy cow resulting in an increase of 6 to 11

macromineral and trace element imbalances.

days to first service and an increase in the calving-to-

(a)

Do not let the dams get too fat, as the

conception interval of 20–30 days (Fourichon et al.,

perirectal and perivaginal fat will narrow the

2000). However, this subject is dealt with elsewhere in

birth canal, the dam may be less capable of

this book in Chapters 35 and 36.

forceful labour and the calf may also be

larger. This is also an important way of

avoiding necrotic vaginitis and other damage

Prevention of postpartum

to the vagina. At calving a condition score of

disease problems

2.5 (see p. 10) is advised.

(b)

Avoid undernutrition as cows in very poor

The key to controlling postpartum disease problems is

condition also have problems of dystokia.

to recognize that they are interlinked (Peeler et al. , (c)

Regular body condition scoring and careful

1994) and that their control is related to breeding man-

attention to the late lactation, dry period and

agement, nutrition, the management of the transition

particularly the transition period ration are

cow and management at and immediately after calving.

required. This may be aided by the use of

metabolic profiles (see Chapter 47). Specific *tum problems. The preparation of cattle for breeding*

dietary manipulations such as the use of

begins well before the expected service date. Preparing

salts to manipulate the dietary cation–anion

the cow for parturition and particularly dry cow and

balance (DCAB) of the transition cow ration

transition cow management in the previous gestation

may also be useful in reducing the incidence

period are crucial stages in this preparation. However,

of periparturient problems (see p. 787).

parturition is the key event, and it must be managed

(4)

Provision of a suitable environment, especially for

to minimize the development of abnormalities of the

cows that calve inside or in a restricted area. This

genital tract in the postpartum period, which may lead

should be clean, well bedded, with a good water

to problems of subsequent oestrous cyclicity, depression

supply, properly lit and with enough space to get

in conception rates, increased embryonic loss and

at the cow if need be and to allow observation *subfertility.*

without disturbance. There also need to be facili-

ties to safely restrain the cow.

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(5)

Avoid stress and disturbance of the calving cow

(Hindson, 1976).

Adams, G.P., Matteri, R.L., Kastelic, J.P., Ko, J.C.H. &

(6)

Suitable supervision and timely intervention at

Ginther, O.J. (1992) Association between surges of follicle-

calving will reduce the severity of those cases of

stimulating hormone and the emergence of follicular waves

dystokia that do occur (Hodge et al. , 1982).

*in heifers. Journal of Reproduction and Fertility, **94**, 177–88.*

(7)

Proper training of the farmer and stockworkers in

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Fthenakis, G.C. (2001) Flunixin meglumine accelerates

veterinarian.

uterine involution and shortens the calving-to-first-oestrus

(8)

When veterinary assistance is needed, the farmer

interval in cows with puerperal metritis. Journal of Veteri-and his staff must decide at an early stage to call

*nary Pharmacology and Therapeutics, **24**, 365–7.*

for help. It is important that the veterinarian and

Archbald, L.F., Risco, C., Chavatte, P., Constant, S., Tran, T., the farmer should agree before the start of the

Klapstein, E. & Elliot, J. (1993) Estrus and pregnancy rate calving season how these problems will be dealt

of dairy cows given one or two doses of prostaglandin F2

*alpha 8 or 24 hours apart. Theriogenology, **40**, 873–84.*

with and at what stage the farmer will call for

Beam, S.W. & Butler, W.R. (1997) Energy balance and ovarian professional help.

follicle development prior to the first ovulation postpartum

*in dairy cows receiving three levels of dietary fat. Biology of Reproduction, **56**, 133–42.*

Therapy immediately postpartum

Beam, S.W. & Butler, W.R. (1999) Effects of energy balance on follicular development and first ovulation in postpartum

In addition to specific therapies such as those described

dairy cows. Journal of Reproduction and Fertility Supple-

above for uterine prolapse, cows that have had obstet-

*ment, **54**, 411–24.*

rical interventions at calving may benefit from a course

Bon-Durant, R. (1997) Pathogenesis, diagnosis and manage-

of systemic antibiotic.

ment of trichomoniasis in cattle. Veterinary Clinics of North Metabolic diseases, such as milk fever, should be

*America: Food Animal Practice, **13**, 345–61.*

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their effect on reproductive performance in five dairy herds.

investigation into their causes is essential. This aspect

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of bovine medicine is dealt with elsewhere in this book

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(Chapter 46).

in the dairy cow. Veterinary Clinics of North America: Food The routine administration of agents such as PGF2a

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(see p. 524) and oxytocin (see p. 517) to postpartum

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cows is not justified by improvements in subsequent fer-

retained fetal membranes on clinical signs in cattle. Veteri-tility; reports of the benefits in the published literature

*nary Record, **148**, 243–4.*

are inconsistent. Their use postpartum should therefore

Bulman, D.C. & Lamming, G.E. (1978) Milk progesterone

be restricted to animals where a specific indication

levels in relation to conception, repeat breeding and factors

exists, as described earlier in this chapter.

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The key to good fertility in multiparous cattle is to

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in cattle using xylazine. Canadian Journal of Veterinary

to manage cattle in such a way as to minimize postpar-

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retention. Animal Reproduction Science, **67**, 181–8.

Chapter 35

Problems Associated with Oestrous Cyclicity

H. Boyd, D.C. Barrett and M. Mihm

Manifestation

530

nancy causing very prolonged calving seasons results in

Aetiology

532

a similar loss; this is partly due to management problems,

Diagnosis

535

such as loss of the seasonal calving pattern, but also

Treatment

541

because at weaning the calf is younger and therefore

Prognosis

542

weighs less. The marketing advantage of being able to

Long interservice interval

544

sell uniform batches of calves may also be lost if the

Prevention

544

calving season is extended much beyond nine weeks.

Clients may present individual cases of cows that have *not been seen in oestrus when due or overdue for*

Manifestation

service, but mostly the problem is seen on regular fertil-

ity visits when post service anoestrus is also detected in

Normal oestrous cycles, clear oestrous expression and

animals diagnosed not pregnant. It is important to dif-

efficient and accurate detection of oestrus with a

ferentiate as far as possible those cows that have not

predictable interval to ovulation are still essential for

been in oestrus from those that have simply not been

the successful management of reproduction in cattle.

seen in oestrus either because of poor expression of heat

Failure to observe oestrus or lack of oestrus adversely

or poor oestrous observation. This may require an ass-

affects the efficiency of production and profitability by

essment to be made of the efficiency of oestrous detec-

interfering with the reproductive markers shown in Box

tion in the herd and careful examination of 'anoestrus'

35.1 (see also Chapter 41 (b) page 678). Inaccurate

cows on more than one occasion. Regular milk proges-

oestrous detection, i.e. identification of a cow as being

terone assays may also be useful when attempting to
in oestrus when she is not, leads to cows being insemi-
determine whether an individual cow is undergoing
nated when fertilization is not possible because there is
oestrous cyclicity or is truly anoestrus. Suckler cows
no ovulation at the expected time after insemination,
running with the bull may be presented as failure to con-
and to pregnancies being lost when already pregnant
ceive towards the end of the breeding season. The
cows are inseminated using artificial insemination (AI).
problem of abnormal oestrous cyclicity, which is most
Missed heats that result in longer than planned inter-
serious when it occurs on a herd or group basis, is often
vals from calving to first service cause considerable eco-
picked up retrospectively on herd record analysis.
nomic loss. A missed oestrus will cause a delay of about
21 days until the next chance for service and this loss in
Heifers
milk production time and delay in producing a calf
Delayed puberty may affect targets for breeding age or
results in a loss of income. Assessment of the real loss

date. It occurs mainly as a group problem because

(litres of milk/year; calves/100 cows per year) and the

heifers are handled and fed in groups and the cause of

economic loss is complex. Where possible, herd-specific

anoestrus is nearly always related to the environment

economic estimates should be undertaken to determine

or to the management, particularly feeding (Webb et al.,

the cost–benefit of alterations in the various elements of

1997). Occasionally, anoestrus is manifested in a group

herd fertility (Dijkhuizen et al., 1997). However, in herds of heifers after natural service, which the farmer

with a conventional breeding strategy it may be useful to

erroneously thought was successful because of lack of

consider a rule-of-thumb value to estimate losses occa-

returns to service.

sioned with every day the calving interval is extended

beyond the target of 365 days. A figure that has remained

Cows after calving

remarkably constant over the last decade (to 2002) is

£2.50 to £3.00/day for every day over the planned calving

An extended interval between calving and first service, *interval. In beef suckler cows, delay in achieving preg-*

calculated on a herd basis, is the most important

530

Box 35.1

Aspects of reproduction affected by failure to

different countries and demonstrates the seriousness of

observe, or lack of, oestrus.

the problem. Within herds the incidence of the problem

is quite variable at different times and there may be

Heifers

periods of four to six weeks during the year when a high

Age at first calving

proportion of cows appear to stop cycling or exhibit

Season of first calving

poor oestrous signs. This may be a direct seasonal effect

Cows

in certain climates, but in temperate regions is proba-

Interval from calving to first service (and thus calving to

bly largely a nutritional effect (Butler, 1999).

conception)

The number of cows treated by veterinarians for

Timely observation of returns to service

anoestrus and suboestrus was reported to be low in the

1980s. Saloniemi et al. (1986) gave the incidence as 5.2

per cent of cows, falling from first calvers (6.3 per cent)

to older cows (3.7 per cent). Markusfeld (1987) diag-

Table 35.1

Percentage of cows with various calving-to-first-

nosed inactive ovaries after two rectal examinations in

service intervals in days, based on 1595 cows in 15 herds.

8.5 per cent of 7751 lactations. However, more recently

20 per cent of high-yielding cows have been shown to

Calving-to-first-service

interval (days)

exhibit a delayed interval to first ovulation postpartum

based on progesterone profiles (Opsomer et al. , 1996).

0–55

Target

78–99

> 100

Another manifestation of absence of oestrus is the

56–77

cow that starts cycling and then stops, a situation

recorded in 5.2 per cent of cases in a survey based on

Percentage of cows

15.9

32.2

24.7

27.1

progesterone assays by Bulman and Lamming (1978).

Cumulative percentage

15.9

48.1

72.8

99.9

In a similar study (Kassa et al., 1986), cyclicity started and then stopped in four (3.2 per cent) of 125 lactations.

Once again this situation seems to have worsened over

time; in a recent Dutch study, true return to anoestrus

manifestation of dysfunction of cyclicity and oestrus or

was seen in only 3 per cent of high-yielding cows,

oestrous detection. A farmer with a serious problem *however, 20 per cent of cows showed a prolonged first may not be aware of it because of poor records or good luteal phase of more than 20 days based on their pro- ones that are not used properly. In the example given gesterone profiles (Opsomer et al. , 1996). Royal et al. in Table 35.1, in 15 herds that were not in fertility (2000) have shown an increase in the proportion of control programmes, the target for calving interval was animals with one or more atypical ovarian hormone 12 months and to achieve this target, cows should have patterns from 32 per cent of cows in the period 1975–82 had their first services 56–76 days after calving. The dis- to 44 per cent in the period 1995–98. During the same tribution of days from calving to first service for the period pregnancy rate to first service declined from 55.6 1595 cows served in these herds shows that about half per cent to 39.7 per cent, again suggesting that fertility of the cows were first served after the target date (Boyd in dairy cattle has declined over time.*

& Munro, 1980). Recent data from the National Milk Records (NMR) representing approximately 1 million

Cows after service

dairy cows shows that between January 1997 and

September 2000 the mean calving to first service inter-

Analysis of data from approximately 35 000 cows in 255

val rose from 84 to 88 days (Barrett, 2001), therefore

British herds (Warren, 1984) showed that 26 per cent of

the majority of cows are probably now served after the

interservice intervals were greater than 48 days, i.e.

target 56–76-day window (assuming a target calving

more than two cycles (Table 35.2). These results are

index of 365 days). However, the voluntary waiting

similar to the results obtained in other surveys. For

period, i.e. the number of days postpartum waited until

example, in the 15 herds discussed above (Table 35.1),

first service, may be deliberately increased in high-

25 per cent of the returns to service were after a delay

yielding cows, where the decision is taken to extend

greater than 48 days and in Boyd and Reed's (1961)

their lactation for economic and welfare reasons

study in smaller herds at a time when management was

(Knight & Sorensen, 1998). On the best farm illustrated

less intensive, 23 per cent of returns were greater than

in Table 35.1, 67 per cent of the cows were served within

48 days.

77 days of calving and on the worst farm only 21 per

In Warren's (1984) report the average interservice

cent of cows reached that target.

interval was 39 days, possibly due to a delay in the

The situation in this group of herds is quite typical of

return to service of 39 - 21 days = 18 days. In some other

the results obtained in many surveys carried out in

surveys there were rather fewer very long intervals,

Table 35.2

Percentage of cows with various intervals between services in days (Warren, 1984)

Interservice interval (days)

1–17

18–24

25–35

36–48

49–90

91+

Percentage of cows

6

37

13

18

18

8

possibly due to different culling patterns or more effi-

Box 35.2

Aetiology of anoestrus.

cient heat detection. In New Zealand, Moller et al.

• Physiological anoestrus: prepuberty, pregnancy,

(1986) reported that only 8.6 per cent of return-to-

puerperium

service intervals were greater than 36 days. Nowadays

• True anoestrus: no oestrous cycle and no ovulation or

in New Zealand and other locations where dairy

blocked cycle (prolonged luteal phase, such as with

farming is highly seasonal, repeats are often resynchro-

pyometra)

nized which increases the submission rates for the first

• Silent oestrus : better termed silent ovulation, i.e. ovarian and second repeat cycles of the breeding season.

cycles occur but no oestrous behaviour is detected

While survey data do not explain why a cow has not

• Weak oestrus: poor oestrous expression (reduced length

been served, discussion with farmers makes it clear that

or intensity)

in the majority of cases the reason is that the cow has

• Unobserved oestrus: oestrus normal, human error

not been seen in heat. In conclusion, failure to have

cows served because they have not been seen in season

is a widespread and important problem.

first ovulation may be prolonged to 60 days in high-

yielding cows (Opsomer et al., 1996). In cows that are ***Aetiology***

suckling, usually beef cows, the duration of non-

cyclicity may be extended from 25 to beyond 100 days,

The aetiology of anoestrus in the cow and heifer is

depending on body condition score at calving and post-

complex because as presented to the veterinarian it

partum nutrition (Stagg et al., 1995). The effect of *includes several different conditions, as shown in Box*

suckling of one or more calves is to inhibit the return

35.2. Because there is a wide range of types of anoestrus

to cyclicity via neurohormonal routes, which can be

there is also a wide range of causes, some unknown.

modified by nutritional factors. This is demonstrated by

Moreover, a variety of management and environmental

the observation that some well-fed, well-managed beef

factors contribute to poor oestrous detection rates.

suckler herds achieve a tight calving pattern at the same

time each year, which requires an early return to cyclic-

ity while the cows are still suckling their calves. For a

Physiological anoestrus

list of factors that affect the onset of puberty, see

It is important to bear in mind that during certain

Chapter 5.

phases of the reproductive cycle, the absence of oestrus

is physiological. These phases are prior to puberty,

True anoestrus

during pregnancy and for at least two weeks after

calving. It is not uncommon for a cow that is pregnant

The major causes of true anoestrus characterized by

to be presented to the veterinarian as a case of

lack of ovulation are summarized in Box 35.3.

anoestrus. This occurs if there is unknown access to a

bull, or unrecorded insemination or misidentification of

(1)

In heifers, bilateral gonadal aplasia, which causes

the cow inseminated.

permanent anoestrus and sterility, occurs in the

In dairy cows, from which the calves are removed a

common condition of freemartinism, found in the

day or so after birth, ovulation rarely occurs earlier than

majority of female calves that are cotwins with males.

15 days after calving; in general first postpartum ovula-

It is also observed in bilateral ovarian hypoplasia, a rare

tion occurs 17–21 days after calving in medium-yielding

inherited condition, in which the genes are passed on

dairy cows calving in appropriate body condition and

through fertile individuals with unilateral gonadal

experiencing no major loss in body condition subse-

hypoplasia. Poor nutrition is important and discussed *quently (Savio et al., 1990). This postpartum interval to below.*

Box 35.3

Major causes of true anoestrus.

easy to understand why the cow with the luteal cyst,

which is predominantly progesterone producing, does

Heifers

not exhibit oestrus, though it is less clear why she fails

Freemartinism

to cycle. However, follicular cysts with oestrogen pro-

Ovarian hypoplasia

Inactive ovaries (poor nutrition)

duction are also found in cases of anoestrus. This may

be due to the low level of the steroid produced in some

Cows

cases, while in other cases it may result from the nega-

Dystokia and postpartum problems

tive effect on the behavioural centre of high levels of

Delayed involution (inactive ovaries)

oestrogen circulating more or less continuously.

Pyometra (persistent corpus luteum)

Another explanation for the lack of oestrus in cows

Cystic ovarian disease

Poor nutrition prepartum, severe energy deficit postpartum,

with follicular cysts is that the behavioural centres in

especially first calvers

the brain, which control the expression of oestrus,

Age-related factors

respond better to oestrogens if they have been primed

by progesterone.

Garverick (1997) in the USA and Dobson et al.

(2001a) in the UK have both reviewed cystic ovarian

(2)

In cows a variety of abnormalities at or around

disease. Factors associated with the occurrence of cystic

calving, such as dystokia, retained fetal membranes,

ovarian disease are discussed further in Chapter 36.

hypocalcaemia, metritis, endometritis and other post-

partum abnormalities may result in delayed return to

(4)

The role of nutritional deficiencies in anoestrus is

cyclicity (for a full discussion of this see also Chapter *relatively straightforward in heifers but is complex in*

34).

adult dairy cows.

(3)

Ovarian cysts, traditionally defined as fluid-filled

(a)

In heifers it has been shown in many field trials

structures >25 mm in diameter and present for more

that low energy intake that causes slow growth rate is

than 10 days in the absence of a corpus luteum (CL),

associated with delayed puberty. Onset of puberty

are quite commonly recorded in cases of anoestrus and

tends to be related to body weight rather than age. The

in fact the majority of cows with cystic ovarian disease

mechanism is discussed in Chapter 5.

exhibit anoestrus. This traditional definition implied

that cysts were static structures; however, this is now

(b)

In adult lactating dairy cows it is not clear how

known not to be the case, and cysts should be con-

feeding affects return to cyclicity after calving, even *sidered dynamic both in structure and function (Cook*

when only energy is considered; however, evidence is

et al., 1990). The likely hormonal mechanism of cystic growing to suggest that the effect may, at least in part,

ovarian disease is failure of the preovulatory luteiniz-

be mediated by insulin-like growth factor-1 (IGF-1)

ing hormone (LH) surge. In some cases there may be

levels (Taylor et al., 2001). It is clear that dairy cows failure of the ovary to respond to LH at the start of

experience a metabolic crisis early postpartum, as

oestrus (Brown et al. , 1986). Cystic ovarian disease is a energy loss cannot be compensated for by energy

very complex condition and in many cases the cyst pro-

intake and stored energy is utilized. Factors that exac-

duces a mixture of steroids, which are variably absorbed

erbate the negative energy balance including the

into the general circulation.

feeding levels before and after calving, particularly the

In the postpartum period, particularly during the first

energy density of the ration, excessive energy loss due

six weeks, some cows (approximately 20–25 per cent)

to high milk yield and increased body condition loss

experience ovulation failure followed by the develop-
after calving (body condition score loss of more than
ment of palpable but functionally transient cystic struc-
0.5) will prolong the interval to first ovulation, as will
tures that may not interfere with subsequent cyclicity.
associated metabolic or other diseases postpartum. A
Towards the end of this period many farmers become
clear relationship has been shown between the timing
concerned about lack of oestrus and so the cow is pre-
of the negative energy balance nadir (the lowest point
sented for veterinary examination. Cystic ovaries were
of the negative energy balance postpartum) and the
associated with 6 to 11 more days to first service and
interval to first ovulation, the LH pulse frequency and
with 20 to 30 more days to conception in a meta-
the LH-dependent fate of the first dominant follicle
analysis of papers published between January 1987 and
selected postpartum (Canfield & Butler, 1990; Beam &
January 1999 (Fourichon et al., 2000). By about six
Butler, 1997). First ovulation occurs 7–14 days after the
weeks after calving an ovarian cystic structure should

energy balance nadir; thus, if the lowest point of the

be regarded as pathological. Cysts are often classified

negative energy balance is reached between the first to

as either follicular (about 70 per cent; single large cyst

second week postpartum, cows can be expected to

or multiple smaller cystic structures) or luteal and it is

ovulate by 21–30 days postpartum. However, in cows in

which body condition score loss exceeds 1, the interval

for food. It is also presumably a stressful experience

to first ovulation may be prolonged to 60 days and

being low within the herd hierarchy.

beyond. One method to try to take into account these

(d)

In many cases first calvers may exhibit a high

many interacting factors is regularly to measure the

incidence of lameness. Lameness (see Chapters 31 and

body condition score of cows (Anon, 1984); particularly

32) is a cause of weight loss that can result in true

important times include drying off, calving and service

anoestrus and also, because of the associated pain, can *times.*

cause poor oestrous expression in animals that are

cycling. Various other forms of stress such as surgery,

(c)

In the beef suckler cow, prepartum nutritional

changes in social grouping, transport and heat stress

deficits leading to reduced body condition at calving

may all affect fertility, thus stress on breeding cattle

delay the interval to first ovulation by more than 40

should be minimized whenever possible (Dobson et al.,

days to 90 days and beyond (Stagg et al., 1995, 1998).

2001b).

The delay in resumption of ovulatory activity is associ-

ated with continued atresia of recurrently selected

(5)

Among miscellaneous causes of persistent corpus

dominant follicles; instead of ovulation of the 2nd to

luteum is the rare condition of uterus unicornis, in

4th dominant follicle postpartum, it is on average the

which one horn of the uterus is absent. Ovulation on

9th dominant follicle which eventually secretes suffi-

the side without a uterine horn results in a corpus

cient oestradiol to induce the gonadotrophin surge and

luteum that is not exposed to locally produced

ovulation. As circulatory concentrations of FSH are not

prostaglandin and therefore does not regress after 16 or

affected by pre- or postpartum diet, the detrimental

17 days.

effects of low body condition score at calving on the

fate of dominant follicles selected early postpartum are

Silent ovulation and unobserved oestrus

attributed to reduced LH secretion, which reduces

dominant follicle oestradiol production.

First ovulation postpartum is generally silent (80 per

The relationship between nutrition and fertility is a

cent), but once cycles have been established, silent

complex one which is still not fully understood. There

oestrus is not a common phenomenon, as was clearly

is a vast body of literature on this subject which is too

demonstrated by Williamson et al. (1972), who carried

extensive to review here. However, the reader may find

out continuous observation of 107 cows for 21 days and *the following reviews of interest: Britt (1995); Webb et*

concluded that four demonstrated silent oestrus. This

al. (1997, 1999); Wathes et al. (1998); O'Callaghan and has been confirmed by others in field trials in herds in

Boland (1999); Garnsworthy and Webb (2000) and

which silent oestrus was thought to be a problem. Gen-

O'Callaghan et al. (2000).

erally, when oestrous detection methods are improved,

Several studies have shown that cows in their first

there is a corresponding reduction in the number of

lactation exhibit a disproportionately high incidence of

cases regarded as silent oestrus. Many cases previously

true anoestrus, with lack of ovulation. A variety of expla-

diagnosed as silent oestrus are in fact unobserved

nations for this have been put forward, in particular the

oestrus.

inhibitory effects of lactation and growth on the recov-

Incidence figures for silent ovulation are most reli-

ery of the LH pulse frequency early postpartum, pre-

able when based on serial progesterone assays, as in the

venting dominant follicle maturation and ovulation.

study of 1400 cows by Ball and Jackson (1984) in which Another suggestion is that this is mainly the result of the

21 per cent of the cows had ovulated but had not been

high incidence of dystokia that occurs in first calvers.

seen in oestrus. This level of non-detected oestrus is in

However, the high incidence of anoestrus in first

agreement with other studies. McLeod et al. (1991)

calvers is often attributed to nutritional and environ-

reported 78 per cent of ovulations in their study were

mental factors. Excessive weight loss and very poor

correctly identified by conventional oestrous detection,

body condition result in cessation of ovulation and

confirming that approximately 20 per cent of those

cyclicity, presumably through hypothalamic–pituitary

cows ovulating are not seen in oestrus.

dysfunction (see Chapter 67). Cows continue to grow

To what extent delayed return to service is due to

until their second or third lactation and therefore young

unobserved oestrus is not clear, but Humbolt (1982),

animals have to carry out the tasks of milk production,

using milk progesterone assays, calculated that only *growth and reproduction simultaneously, at a time*

29 per cent of delayed returns were due to embryonic

when adult dentition has not been fully developed. In

death and that 73 per cent were due to anoestrus

dairy cows it is also the time when the young, smaller

(including true, silent and unobserved oestrus).

cow is introduced to the highly competitive environ-

However, ovulation without the accompanying signs

ment of a herd, which, particularly during the housing

of oestrus (that is, silent oestrus) does occur. The best

period, makes it difficult for small animals to compete

documented situation relates to the first ovulation after

sexual monitoring of the herd. However, a bull may not

Box 35.4

Causes of silent and weakly expressed oestrus.

choose to serve all cows in oestrus if several are in

season at the same time.

• Social

• Pain and fear

(2)

Pain and fear. As oestrus is a behavioural phe-

• Weight loss

nomenon that is subject to psychological influences, it

• Genetic factors

can be inhibited by discomfort, pain or fear. Severe

• Presence of calf and suckling

adverse weather conditions such as driving rain and

cold reduce cows' interest in sexual behaviour. Slippery

flooring produces fear of falling and may inhibit

calving, particularly if it occurs within the first 20 days.

oestrous behaviour. The pain caused by lameness

Otherwise it is almost impossible to distinguish between

inhibits oestrous expression.

silent and unobserved oestrus. Some instances of oestrus

are so weak or last for such a short time that detection by

(3)

Weight loss. It has been suggested that weight loss

conventional observation is a matter of chance.

is associated with an increase in silent heats.

Standing oestrus lasts for about 8–12 hours in cows

(4)

Genetic factors are almost certainly involved. The

and 6–8 hours in maiden heifers. However, 20 per cent

subjective nature of the measurement of oestrous

of heats last less than 6 hours (Esslemont et al. , 1985).

expression makes it difficult to gather enough reliable

Increasing herd sizes and decreasing availability of

data to evaluate the hereditary influence. Reports

skilled manpower on many farms is probably exacer-

from progeny testing stations, where large groups of

bating the problem of poor oestrous detection. It may

daughters from bulls under test were kept, showed

also be the case that high-genetic-merit, high-yielding

that different daughter groups exhibited oestrus in

modern dairy cattle exhibit oestrous behaviour either

characteristic ways. There may also be differences

less intensely or for a shorter duration, making oestrous

between breeds in expression of oestrus. Currently,

detection more difficult.

there is much anecdotal evidence to suggest that the

The causes of silent oestrus, weak oestrus and short

modern high-genetic-merit Holstein exhibits oestrus

oestrus are not well understood, but those considered

less well than the traditional British Friesian, or some

to be the main factors are presented in Box 35.4.

other dairy breeds.

(1)

Social factors within the group of cows, the size of

(5)

Presence of calf and suckling. The presence of a

the group and the reproductive status of the rest of the

suckling calf may reduce expression of oestrous behav-

group all play a role in oestrous behaviour and in the

iour in some cows as well as affect oestrous cyclicity.

frequency of mounting (Britt, 1987). Mounting requires

that there is both a cow in oestrus and a cow that is

willing to mount.

Epidemiological data

Cows that are usually bullied or are low in the

In a study of 70 775 lactations in Finnish Ayrshire cows

pecking order are less likely to stand to be ridden when

in which only cases treated by veterinarians were

they are in oestrus than more dominant cows. A small *analysed (Saloniemi et al. , 1986) it was noted that the group of cows, say fewer than four or five, may be less*

chance of a cow being presented to the veterinarian as

effective at stimulating mounting behaviour than a

anoestrus was affected by parity (highest risk in first

larger group of sexually active cows. Cows at different

calvers), calving season (highest risk in cows that calved

stages of the reproductive cycle vary in their likelihood

from September to February), herd milk yield (highest

of trying to mount a cow in oestrus. The most likely

incidence in high-yielding herds) and the occurrence of

to jump are those in or near oestrus, followed by non-

metritis (Chapter 34), mastitis (Chapter 23) and ketosis

pregnant cows in the early luteal phase followed by

(Chapter 46).

pregnant cows. At the end of an intensive breeding

season when most cows are pregnant the remaining

cows to be served may be more difficult to detect

because of the absence of cows willing to mount. In the

Diagnosis

main, oestrous detection is therefore easier in tight sea-

sonally calving herds, where a large number of cows are

A systematic approach to diagnosis is essential and the

eligible for service within a given time period, than in a

clinician should follow the steps outlined in Box 35.5.

herd with a wide calving spread and fewer non-preg-

If the anoestrous cow is in a herd in which the

nant cows in the herd at any one time.

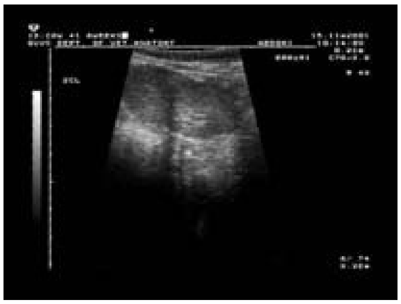
veterinarian is running a fertility control programme

The presence of a bull inhibits cow-to-cow inter-

involving regular visits, diagnosis will be both easier and

action, but this may be made up for by the bull's own

more reliable because there will be historical informa-



Box 35.5

The diagnosis of anoestrus.

- *History (including records)*
- *General clinical examination (including condition score)*
- *Special examination of the reproductive system*
- *Rectal palpation and transrectal ultrasound examination*
- *Vaginal specular examination*
- *Laboratory tests, e.g. progesterone assays*

Fig. 35.2

Cyclic solid CL.

Fig. 35.1

Cyclic CL with lacunae on right ovary.

tion available and it will be simpler to introduce routine sampling where this is indicated.

Fig. 35.3

Dominant follicle on right ovary bordering the CL.

There are two separate but overlapping aspects of diagnosis:

- *Stage 1: assessment of ovarian status to determine whether the case is true anoestrus, in which there is no ovulatory activity, or in which cyclicity is prevented by a persistent corpus luteum or other progesterone producing structure; or silent or unobserved oestrus, in which ovarian cycles are taking place.*
- *Stage 2: assessment of the causes of the condition.*

Stage 1: assessment of ovarian status

Since the word 'cycle' implies repetition, theory would

Fig. 35.4

Two corpora lutea in a 6-week pregnancy.

dictate that assessment of whether or not a cow is cycling necessitates repeated examinations over an interval that should allow the observation of two *oestrous periods. Under practical conditions it is*

may be functional before that time. However, positive

usually assumed that the animal is cycling if it is possi-

detection of a functional corpus luteum via ultrasound

ble to prove that ovulation has recently taken place.

examination (size and echogenicity, Figs 35.1–35.4) is

Another common assumption concerns a group of

usually closely related to its progesterone secretion.

animals. It is usually considered that the group as a

Progesterone assay of milk or plasma will only produce

whole is cycling if two-thirds of the cows are in the

a definite, recognizable rise after a similar delay; to

luteal phase, i.e. the same fraction of the oestrous

confirm cyclicity a sequence of progesterone assays two

cycle that the luteal phase occupies. Furthermore, the

or three days apart showing a pattern consistent with a

description of the 'luteal phase' given in Chapter 33

luteal phase followed by a period of low progesterone

presents some difficulties in connection with diagnosis.

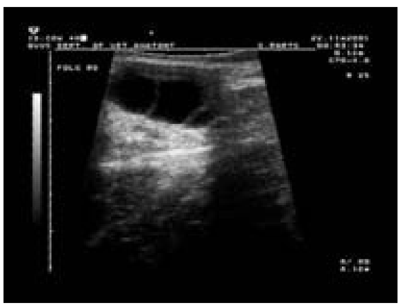
level and another luteal phase should be seen.

This is because a corpus luteum is unlikely to be pal-

Accordingly, for clinical purposes 'luteal phase' is

pable until approximately seven days after oestrus, but

defined as from day 5 to day 17 and the normal 'period



Box 35.6

History taking for anoestrus cows.

Table 35.3

The accuracy of corpora lutea detection by rectal

palpation based on comparison with milk progesterone assay.

• *Date of calving*

• *Any abnormality at and after calving*

Corpus luteum

• *Has the cow been seen in oestrus since calving?*

• *Could the cow be pregnant?*

Present

Absent

• *Oestrous detection methods in the herd*

• *Are there other cows in the herd with similar problems?*

Number of cases

244

158

Accuracy (%)

82

70

of low progesterone' is expected to be from day 18 through oestrus (day 0) to day 4. This definition applies to the majority of cows in a normal population and is needed to form a basis for rational diagnosis, but its use should be tempered by the realization that no definition will fit all cases (Bloomfield et al. , 1986).

The first step is to take a history of the case. Relevant information, required for both stages of diagnosis, is shown in Box 35.6.

The next step is to find out if there is functional luteal tissue present in the ovaries. The traditional way to do this is to palpate the ovaries per rectum, but there are now several choices. One is to carry out a single or a series of milk progesterone assays, which gives a quick,

Fig. 35.5

Long-standing follicular cyst.

reliable result. Another is ultrasound scanning, which allows the user to observe functional luteal tissue in the ovary (Figs 35.1–35.4) (Omran et al. , 1988; Boyd & Omran 1991). The choice of method will depend on circumstances as each method has advantages and disadvantages.

Rectal palpation is immediate, simple, requires little restraint of the cow and, if part of a regular visit, is relatively cheap. It also allows other observations to be made on other parts of the reproductive tract and on the animal's general condition. There is minimal risk of misidentification of the animal, a danger always present *when samples are taken for analysis. On the other hand, it is a less accurate indicator of luteal function than a progesterone assay. Real-time ultrasound scanning is a*

Fig. 35.6

Follicles on right ovary.

valuable tool that, in experienced hands, is capable of giving a very accurate picture of ovaries and uterus (Figs 35.1–35.13).

Rectal palpation alone, when undertaken by an experienced clinician, can be relatively accurate. For example, Dawson (1975) compared the findings made by rectal palpation shortly before slaughter with post-mortem observations. He identified accurately 125 (89 per cent) of 141 ovaries with corpora lutea. The errors were mainly in cows with small corpora lutea and also some with cysts or follicles. However, others have suggested that rectal examinations alone are less accurate. On the basis of milk progesterone assays (which were assumed to be correct) Ott et al. (1986) summarized their own and other workers' results, as shown in Table

Fig. 35.7

Non-pregnant right uterine horn during the luteal

35.3.

phase.

Fig. 35.8

Non-pregnant left uterine horn during the luteal phase

Fig. 35.11

Early PD 5.5 weeks.

with bladder ventrally.

Fig. 35.12

Early PD 6 weeks.

Fig. 35.9

Pyometra.

Fig. 35.13

Male fetus (3 months).

Fig. 35.10

Early PD 4.5 weeks.

The use of progesterone assays has the advantage

The accuracy of ultrasound scanning was investigated

that they can be incorporated into a fertility control

by Pieterse et al. (1990), who examined the ovaries of programme and used prior to a visit, so that the clini-59 cows by rectal palpation, ultrasound scanning

cian has information available before the examination

(5 MHz linear array transducer) and dissection on the

of the animal. They can also be used after the visit to

day of slaughter, and concluded that for the detection

give extra information about the case. There may be

of a mid-cycle corpus luteum the sensitivity of rectal

slight problems in deciding the level of circulating pro-

palpation was 83 per cent and for ultrasonography the

gesterone that can be taken as indicative of luteal func-

sensitivity was 80 per cent. For the detection of follicles,

tion and caution needs to be exercised in interpretation

ultrasonography was considered to be significantly

of absolute values, as these may change depending on

better than rectal palpation, with ultrasonography

time from milking (Waldmann et al., 1999).

detecting 95 per cent of follicles over 10 mm in

diameter whereas rectal palpation only detected 71 per

Box 35.8

Likely reasons for no luteal tissue being present.

cent. These results obviously reflect in part the quality

• True anoestrus

of the ultrasound equipment used and the skill of the

• Cycling (day 18 through oestrus to day 4)

clinician palpating the ovaries and interpreting the

• Ovarian pathology

ultrasound images. In another study comparing the use

Freemartin: heifer

of ultrasound and rectal palpation (Fishwick, 1993), the

Cystic ovarian disease

accuracy of palpation and ultrasonography in detection

of luteal tissue was compared to contemporaneous

plasma progesterone concentrations. In this study the

overall accuracy of manual palpation was 62 per cent

compared with 83 per cent for ultrasound examination.

Booth (1988) has investigated the accuracy of diag-

In cows with high progesterone status, manual palpa-

nosis of luteal cysts using rectal palpation, and the

tion (60 per cent) was significantly less accurate than

clinical finding of luteal cysts was confirmed by

ultrasound imaging (94 per cent), whilst in cows with a

progesterone assay in only 54 per cent of cases. This

low progesterone status manual palpation (65 per cent)

accuracy can be improved by transrectal ultrasound

and ultrasound imaging (70 per cent) were both equally

scanning. For example, Douthwaite and Dobson (2000)

accurate.

reported that diagnostic criteria for follicular cysts

In general it would be expected that imaging of

using ultrasound examination and plasma progesterone

the ovaries using modern ultrasound equipment, for

assays agreed in 92 per cent of cases; a similar compar-

example using a 7.5 MHz transducer, would be more

ison for luteal cyst diagnosis gave a 74 per cent agree-

accurate than manual palpation. However, individuals

ment. The rapid on-farm diagnostic method of choice

highly skilled in rectal palpation may be able to detect *should thus be transrectal ultrasonography, supported*

luteal tissue with an accuracy comparable to ultra-

by milk progesterone assay where required.

sound, but will not be able to palpate small follicles that

If initial examination shows there is no functional

are readily detected by ultrasound scanning. Reduced

luteal tissue, there are also the various possibilities

cost of equipment and improved image quality

shown in Box 35.8.

combined with practice and much increased use within

When the initial examination reveals no luteal func-

veterinary medicine have made transrectal real-time

tion and apparently normal ovaries and tract, and no

ultrasound examination of the bovine reproductive

evidence of mucus or mucohaemorrhagic discharge on

organs the examination of choice in regular fertility

the tail to indicate recent oestrus or ovulation, the cow's

visits.

ovarian status is unresolved. If she is cycling normally

If there is evidence of functional luteal tissue, the

and in the low progesterone phase of the cycle, a corpus *possibilities shown in Box 35.7 exist.*

luteum will become palpable and visible by ultrasound

The simplest way to decide whether the animal is

examination in the ovary within approximately 7 days

pregnant or has a pathological condition is to carry

from the first examination. A second examination at

out rectal palpation or ultrasound examination of the

7–10 days after the first will detect this corpus luteum.

ovaries and genital tract, plus in some cases a vaginal

This second examination must not be delayed too long,

examination. This will, however, fail to reveal very early

as some cows (those at day 5) will go into the low pro-

pregnancy before 25–28 days after service using ultra-

gesterone phase again in about 12 days after the first

sound and below 35–40 days using manual palpation.

examination. These calculations can be upset by the

Figures 35.10 to 35.12 show examples of ultrasound

considerable variations in cycle lengths and proges-

images of early pregnancy. Figure 35.13 shows an image

terone patterns that occur in a normal population of

of fetal sexing in a three-month-old fetus. The most *cows, as detailed by Bloomfield et al. (1986). It is also common finding is that ovaries and uterus appear to be*

very useful to carry out a vaginal examination at the

normal and these cases are usually regarded as normal

time of the first examination, as the presence of copious,

cycling cows that have simply not been seen in oestrus.

clear mucus is strongly indicative of the peri-oestral

stage of the cycle. In this way vaginal examination may

allow a diagnosis to be made without the need for a

Box 35.7.

Likely reasons for the presence of functional

second progesterone assay or a second rectal palpation.

luteal tissue.

If a second examination or sampling is required it is

• Cycling (days 5–17 inclusive)

best done 7–10 days after the first. It is even better if

• Pregnancy

serial sampling for progesterone assays can be

• Ovarian pathology (luteal cyst)

arranged. It is necessary to work out a satisfactory

• Uterine pathology (pyometra with persisting corpus

regimen of sampling. This involves making a compro-

luteum)

mise between the biological ideal, which might be daily

samples, and what is acceptable to the farmer because

Box 35.9

Causes of dysfunction of the ovarian cycle.

of the cost, labour and interference with the milking

• Freemartinism (congenital)

routine. For example, a sampling regimen of two to

• Ovarian hypoplasia (inherited)

three samples per week, which will give a useful picture

• Uterus unicornis (congenital)

of the oestrous cycle but is not frequent enough to time

• Pyometra (periparturient problems)

oestrus exactly, may be unacceptably frequent for a

• Some cases of inactive ovaries

farmer. This situation may change in future if accurate

• Nutritional and metabolic stress

and reliable automated systems to assess the cows'

• Systemic disease

physiological state using biosensors can be developed

• Delayed involution

(Koelsch et al., 1994; Mottram, 1997; Scully et al., 2000).

New developments in this area of technology may allow

automatic milk progesterone assays, and other assays,

involution and concomitant disease, present some prob-

to be performed while cows are being milked, allowing

lems in diagnosis.

the timing of ovulation to be accurately predicted and

In cases of delayed involution, the enlarged uterus

removing the need for oestrous detection.

and particularly the enlarged cervix, which involutes

Detection of antral follicles in the ovary, the obser-

more slowly, usually make the diagnosis of the imme-

vation of uterine tone and assays for oestrogens are all

diate cause easy. However, on some occasions, by the

of limited value because they do not give clear indica-

time the cow is examined the uterus may well have

tion of exact timing of oestrus to predict ovulation.

returned to normal size and the veterinarian will have

There are a number of aids to detection of oestrus that *to depend on a history of periparturient problems and*

can aid diagnosis (Boyd, 1984).

possibly of abnormal vaginal discharges noted by the

The veterinarian now knows whether the cow or

farmer (see Chapter 34 page 523 for details of an invo-

group of cows is exhibiting true anoestrus or is under-

lution scoring system).

going ovarian cycles. If a conclusion of anoestrus has

The clinician should look for any other disease con-

been reached an important question is whether (i) the

dition in the cow examined for anoestrus. Especially

cow is in 'deep' anoestrus, which means that she is not

important is any disease that causes loss of body con-

likely to start cycling soon and may revert to an anoe-

dition or pain.

strous state following treatment, or (ii) whether she is

There is a complicated series of factors, such as actual

in 'shallow' anoestrus and liable to begin cycling

and potential milk yield, feeding before and after

soon and be responsive to therapy. Unfortunately, it is

calving and weight change after calving, which are very *almost impossible to predict accurately the 'depth' of difficult to assess. Body condition of the cow should be anoestrus. However, if the cow is in extremely poor con- noted at the time of examination for anoestrus, but this dition and if she has small hard ovaries she is probably deals with only part of the problem (Anon., 1984). If in deep anoestrus and may require a combination of body condition is poor or loss of body condition score treatments to induce first ovulation, with the possibility has been extreme, or if there are many cases of inactive of subsequently reverting to an anoestrous state. ovaries, feeding should be investigated. Feeding analy- Detection of the LH pulses that occur in the cow sis and metabolic profiles are discussed elsewhere in about to start cycling and are absent in those in deep this book (see Chapters 9 and 47).*

anoestrus requires a series of samples taken at short On occasion there is no clear reason for the occur- intervals. At present (2003) LH assays cannot be done rence of inactive ovaries, either in the individual cow or in a practice laboratory but are routinely carried out in *when the condition affects a group of animals.*

affiliated research laboratories.

When investigating silent oestrus and unobserved

oestrus, the veterinarian should find out about the

Stage 2: assessment of the cause of anoestrus or

following:

silent ovulation

• Organization of oestrous detection.

This section deals with the difficult question of how to

• Ease of cow identification.

find out what has caused the abnormal ovarian status

• Method of recording.

or the problem of oestrous expression or detection.

• Layout of the buildings.

To some extent procedures followed for diagnosis of

• State of the floors and levels of lighting.

ovarian status also give the clinician an understanding

• The way the cows are handled, moved around and

of the causes of the ovarian dysfunction. Examples of

assigned to groups.

these are listed in Box 35.9. Three of the causes of inac-

• Amount of knowledge of oestrus and the oestrous

tive ovaries: nutritional deficiency causing metabolic

cycle among the people who are detecting oestrus.

stress and severe negative energy balance, delayed

• Motivation for oestrous detection.

• Time made available for oestrous detection.

Administration of an adequate dose of GnRH

• Personalities of the people involved.

results, in the majority of cases, in luteinization or ovu-

lation of healthy dominant follicles present at the time

followed by a transient period of progesterone produc-

tion that can first be identified about five days after

Treatment *(see also Chapter 42)*

treatment. The duration of this progesterone phase is

very variable, ranging from one or two days to the life-

When using proprietary products, the clinician should

span of a normal cyclic corpus luteum, and therefore

consult the data sheets, produced by the manufacturers,

the interval from treatment to oestrus is very variable,

for details of use, contraindications and other guidance.

about 8–22 days. It is desirable to follow up these cases

Successful treatment, leading to oestrus, service and

to ensure that luteinization or ovulation has taken

pregnancy, depends not only on veterinary therapy but

place; this is best done by ultrasound scanning or by

on husbandry and breeding management, some aspects

progesterone assay.

of which are described in the data sheets and also on

If there is luteal tissue present at the follow-up exam-

page 525. Different manufacturers of apparently similar

ination 7 days later, it is useful to treat the animal with

products often give slightly different advice about their

PGF2a or an analogue, as this will make the resulting

use and users should be aware of the major differences

oestrus more predictable. Regular fertility control visits

between some of these products. Some of the thera-

at weekly intervals are ideal for this regimen; however,

peutics, for example Prostaglandin F2a (PGF2a) are dan-

visits are often at fortnightly intervals and this may be

gerous for humans and could cause return to service

a less suitable period between the initial and follow-up *and abortion in cows, and therefore the veterinarian*

treatment when using the GnRH–PGF2a regimen.

must handle them responsibly and with care.

If, on the follow-up examination, there is no luteal

Where drugs that result in oestrus are used, efficiency

tissue the cow should be dealt with as a new case.

of oestrous detection will be enhanced as the clients are

The use of a progesterone or synthetic progestagen

told to concentrate on a specific time for oestrous detec-

slow release device also mimics the progesterone rise

tion; their attention is focused on the cows treated and

before first ovulation. This device is left in the vagina

aids to oestrous detection such as tail paint are often

or implanted subcutaneously at the base of the ear for

used.

8–12 days and the animal should be served at the

oestrus that occurs in many cases about two or three

days after withdrawal. Fixed-time insemination 48 and

True anoestrus: no functional luteal tissue

72 hours (or a single insemination at 56 hours) after

Two points should be remembered when dealing with *withdrawal may be carried out (follow data sheet*

these cases:

recommendations for whichever product is selected).

If oestrus is observed later another insemination

• All healthy, suitably fed cows will start cycling in the

should be carried out. Avoid stress and drastic change

first two months after calving.

of diet during and after treatment (see p. 683).

• There must be an underlying reason for the occur-

In those animals in which increased negative energy

rence of this type of true anoestrus and an attempt

balance, poor body condition or very strong behav-

should always be made to find the cause and deal

ioural effects inhibit LH pulse frequency and thus

with it. Where the cause appears to be nutritional,

dominant follicle maturation, final differentiation of

improved feeding should be part of the treatment

the preovulatory dominant follicle or the preovulatory

of the affected individual and should also be

oestradiol rise may have to be enhanced. The addition

considered for other recently calved cows. Consi-

of equine chorionic gonadotrophin (eCG) given at the

deration should also be given to the body condition

end of the progesterone or synthetic progestagen

changes and feeding regimen of the dry cows as well

treatment will induce oestrus 48 hours later. Similarly,

as the management and nutrition of the transition

treatment with a very low dose of oestradiol benzoate

cow. Particular care should be taken to ensure that

24 hours after device withdrawal will induce oestrus

high-genetic-merit dairy cows do not become

12–20 hours later, but consideration will have to be

too fat during the dry period (Rukkwamsuk et al.,

given to the national legislation relating to the use of

1999).

these drugs in dairy or beef cattle.

At present there are two main hormonal treat-

The treatment of follicular cysts involves either using

ments for inactive ovaries: (i) administration of

intravaginal progesterone releasing devices (PRID or

gonadotrophin-releasing hormone (GnRH) or ana-

CIDR) or establishment of endogenous luteal tissue logues with GnRH activity and (ii) insertion of a

with chorionic gonadotrophin or GnRH (Dobson et al.,

progesterone-releasing device (see p. 681).

2001a). There is evidence to suggest that the success of

treatment of follicular cysts depends on whether the

with a view to treating with PGF2a or an analogue, if

cyst is producing oestradiol or not, as reflected by the

appropriate.

presence or absence of other follicles >5 mm in diame-

Conservative treatment is preferred in the first

ter. Treated with either an intravaginal progesterone

instance by some clients who would rather leave the

releasing device or GnRH, cystic follicles in the

animal untreated, are content to know that she is

presence of other follicles had a pregnancy rate to all

cycling and hope to observe the next oestrus. In these

inseminations of 91 per cent compared with 69 per cent

cases aids to heat detection should be used and the

if no other follicles were present at the time of

animal re-examined if she is not seen in season within *treatment (Tebble et al., 2001).*

the next two weeks.

True anoestrus: functional luteal tissue

Silent oestrus/unobserved oestrus: no corpus

luteum present

The therapeutic approach is to cause luteolysis by

parenteral administration of PGF2a, or an analogue,

These cases do not benefit from immediate drug

followed by intensive oestrous detection up to one

therapy as animals are showing ovarian cycles but have

week after injection and insemination at observed

either just regressed their CL or are in the early luteal

oestrus. In the case of pyometra (Fig. 35.9), the client

stage following ovulation. Improvements in husbandry,

should be advised to delay service until it appears that

i.e. oestrous detection, and, possibly, feeding may be

the infection has cleared up, as indicated by an oestrus

required to enhance detection and oestrous expression,

at which the mucus from the vulva is free of pus. It is

and it may be useful to enhance oestrous expression

advisable that the veterinary surgeon should examine *hormonally by using eCG or oestradiol benzoate fol-*

these cases at a follow-up visit to ensure the uterus has

lowing treatment with a progestagen device (see

returned to normal (Figs 35.7 and 35.8).

above).

The treatment of cystic ovarian disease depends

Because diagnosis is uncertain until the second

largely on whether the structure is progesterone pro-

examination (7 or 14 days later), it is questionable

ducing or not. If considered a luteal cyst with functional

whether these cows should be treated at the first visit.

luteal tissue, as judged by ultrasound examination or

If there is no corpus luteum on the second examina-

milk progesterone assay, the logical treatment is to

tion, the condition is to be regarded as true anoestrus

administer PGF2a, although alternative therapies such

and dealt with accordingly.

as the use of intravaginal progesterone releasing

devices may also be successful (Douthwaite & Dobson, 2000).

Prognosis

In considering prognosis, primary attention has to be

Silent oestrus/unobserved oestrus: corpus

paid to the return to cyclicity, which can be measured

luteum present

either by observation of oestrus or, more reliably, by

There are two standard approaches in these cases, the

one or more progesterone assays at planned times after

choice being between (i) the induction of luteolysis

treatment. The outcome of treatment is influenced by

using PGF2a or an analogue and (ii) leaving the animal

both the veterinarian and the client (and perhaps also

untreated to be observed when she comes in heat. The

by the cow), as presented in Box 35.10.

method chosen will depend on many variable factors,

Factors influenced by the veterinarian, which affect

such as the season, the time since calving, the herd

the outcome of treatment for anoestrus, are as follows:

calving pattern and the inclination of the client, and

therefore the decision has to be made individually for

Box 35.10

Contribution of farmer and veterinary surgeon to *each case.*

influencing prognosis.

Treatment with PGF2a or an analogue should, in the

majority of adult cows, result in oestrus in 2 to 7

Prognosis influenced by veterinarian

Accuracy of diagnosis

days, with the peak period being days 3 and 4 after

Selection of cases

treatment. Service should be at observed oestrus and

Choice of therapeutic intervention

aids to oestrous detection should be used. Enhanced

Follow-up examination

oestrous expression may be observed when combining

a progesterone or synthetic progestagen device with

Prognosis influenced by farmer

PGF

Oestrous detection

2a.

Herd pregnancy rate

Cows that are not seen in oestrus after treatment

Culling rate

should be re-examined after 14 days (Young, 1989)

• The accuracy of diagnosis is the basis for correct

Heifers

treatment. There is good evidence that identification

Freemartins and cases of bilateral ovarian hypoplasia

of a corpus luteum by palpation by experienced

are sterile and will never cycle or become pregnant.

veterinarians is over 80 per cent accurate (see p. 537)

Groups of heifers with delayed puberty due to low

and that differentiation between follicular and luteal

energy intake will return to cyclicity after restoration of

cysts is much less accurate (see p. 539); however,

a suitable energy intake level and other correction of

such a diagnosis can now be more specific due to

the feeding. How long this will take depends on many

the routine use of ultrasound scanning, and can be

things. Under the best possible circumstances, i.e. where

enhanced via using milk progesterone assays.

the animals are in not excessively poor condition and

• Selection of cases for treatment has an important *where there is no complicating disease factor, it will*

influence on the outcome. For example, the corpus

take approximately two months of good feeding before

luteum early in the cycle is less responsive to PGF2a

most of the group start cycling (Imakawa et al. , 1986).

or an analogue than is the mid-cycle corpus luteum.

Hormonal treatments to induce and thus advance

Accurate assessment of the stage of the cycle will aid

first ovulation can be used if the management system

in the correct selection of animals for treatment.

is seasonally restricted; introduction of a bull may

Similarly, if treatment is confined to cases in which

also aid in the induction and synchronization of first

corpora lutea are positively diagnosed, better results

ovulation.

may be obtained than if less critical selection of cases

is undertaken. However, when PGF2a treatments

based on the presence of a corpus luteum were

True anoestrus after calving in cows

compared with 14-day fixed treatments, the fixed

treatments were still superior resulting in better

In cases of pyometra with a corpus luteum, the failure
reproductive performance (Heuwieser et al., 1997).
to cycle is very effectively dealt with by using PGF2a.
Ott and Gustafsson (1981) reported that more than 80
Other factors that influence the success of luteolysis
per cent of treated cows emptied the uterus and came
and whether the cow comes in season after successful
in season a few days after treatment. If one treatment
luteolysis are not well documented. However, it is
fails to produce luteolysis, then a second injection
possible that nutritional factors are involved in the
almost certainly will be successful. There is evidence to
subsequent expression of oestrus.
suggest that treatment of pyometra is improved by the
administration of two doses of PGF2a, 8 hours apart
• None of the luteolytic products commercially
(Archbald et al. , 1993) (see p. 524).
available achieve 100 per cent luteolysis (Ball &
Inactive ovaries are treated with either GnRH to
Jackson, 1984; Martinez & Thibier, 1984).
cause ovulation and thus a progesterone rise, which

• Re-examination and retreatment in good time of all

then primes the animal to express heat at the next

cases that do not respond to the initial treatment

ovulation, or a progesterone or progestagen releasing

will affect the time from initial treatment to oestrus,

device. Some indications of the results that can be

service and conception.

obtained were shown in a field study involving 62

The farmer also affects the outcome of the treatment

acyclic cows (Ball & Lamming, 1983). There were two

in important ways.

main differences between the two methods. Firstly,

ovarian response to the progesterone intravaginal

• The efficiency of detection of oestrus in the herd

releasing device (PRID) was better, as 89.7 per cent of

is crucial to the effectiveness of treatment when

cows ovulated compared to 73.9 per cent of those

measured by the number of cases that come into

treated with GnRH. Secondly, after the PRID, fixed-

season within a certain number of days.

time insemination resulted in 59 per cent conceptions

• The first-service pregnancy rate in the herd which

(measured by milk progesterone) whereas after GnRH,

is to some extent under the control of the farmer,

a number of cows that responded successfully were not

not least because correctly timed insemination is

seen in heat so that only 26 per cent of the cows treated

essential for conception, will have a great effect on

became pregnant at the ovulation after treatment. One

the success rate as measured in time to conception.

problem with GnRH treatment is that the luteal tissue

• High culling rate and willingness to cull may result

produced has a very variable lifespan with the result

in apparently good results because the failures are

that the timing of heat and the next ovulation cannot

culled, but depending on the economic factors per-

be predicted and may occur from 8 to about 20 days

taining at the time this may be a false economy

after treatment. In order to cause more predictable

(Esslemont & Kossaibati, 1997; Whitaker et al. ,

onset of oestrus and next ovulation following GnRH

2000).

treatment, a luteolytic dose of PGF2a can be given 6–7

days after GnRH. Such a protocol can be further com-

Silent and unobserved oestrus after calving in cows

bined with a second injection of GnRH or an injection

Prognosis for unobserved oestrus is good and preg-

of human chorionic gonadotrophin (hCG) 48 hours

nancy rate is not greatly different from that for cycling

after PGF2a to time the next ovulation in all animals

cows in the same herd that have been observed in

and use fixed-time insemination (De Rensis & Peters,

oestrus. Seguin (1981) compiled results from six trials

1999). Occasionally, cows will come into oestrus quickly

in which 886 cows were treated; 67 per cent were in

after GnRH treatment and this may be due to treat-

oestrus after treatment and pregnancy rate to service at

ing an animal that was just about to start cycling

that oestrus was 54 per cent. Seguin (1981) also cited

spontaneously.

trials in which controls and treated cows had the same

In all reports on treatment of inactive ovaries there *pregnancy rate, whereas O'Farrell and Hartigan (1984)*

are some animals that do not respond to conventional

obtained a statistically significantly poorer pregnancy

treatment. It is obvious that cows that are still under the

rate in the suboestrus cows treated with an analogue of

influence of the original aetiological factors (such as

PGF

poor condition) are unlikely to respond well. Similarly,

2a than in controls. This latter finding is supported

by an analysis of more than 10 000 cases of unobserved

cows in deep anoestrus may not respond satisfactorily

oestrus in Israel and 30 000 normal controls (Mayer et

to hormonal treatment. It appears that those cows

al. , 1987). First-service pregnancy rate for unobserved with inactive ovaries, lacking any detectable structures,

oestrus cows was 35.2 per cent compared with 60.3 per

respond poorly to treatment and may revert to an

cent for the controls.

anoestrous state.

In an interesting study (Ball & Jackson, 1984) in

In considering the outcome of treatment of cows with *which non-detected oestrus cows were treated with an*

cystic ovarian disease associated with anoestrus there

analogue of PGF

are a number of relevant points to note:

2a, and monitored by observation and

progesterone assays, 84 per cent of the cows had com-

plete luteolysis after a correctly timed injection. Of all

• With the important exception of cases seen within

the cows treated 42 per cent were seen in oestrus within

six weeks of calving, spontaneous resolution of

4 days of treatment and 60 per cent within 14 days.

these cases is not to be relied upon (Garcia &

One factor that makes prognosis difficult is the effect

Larsson, 1982).

of the age of the corpus luteum on the response to

• The condition tends to recur unless treatment

PGF

results in ovulation of a healthy new dominant

2a or an analogue. Luteolysis is unlikely to occur in

cows treated before day 5 of the cycle and it may be day

follicle and conception occurs.

7 before maximum effect results. Even when luteolysis

• To the extent that there is a familial predisposition

occurs, the time from treatment to ovulation varies

to cystic ovarian disease, the use of offspring from

greatly depending, in a complex manner, on the stage

affected dams for breeding purposes is not

of dominant follicle development when the cow is

advisable.

treated (MacMillan, 1983; Kastelic et al. , 1990). If there

• Results have to be looked at in two stages. The first

is a healthy dominant follicle present, oestrus will

stage is the resolution of the cystic condition and

usually occur on the third day after treatment; should

the induction of normal oestrus and ovulation. The

there be no dominant follicle present at the time of

second is getting the affected cow pregnant.

PGF2a injection, 5–7 days will pass until induction of

oestrus occurs.

Where diagnosis is correct and appropriate treatment

Prognosis is improved if the veterinarian actively

is given the return to ovarian normality is good. The *follows up all cases, both those treated and those left*

majority of luteal cysts respond to PGF2a or an ana-

untreated, within two weeks.

logue; in one study (Booth, 1988) 79 per cent of cows

had low levels of circulating progesterone within 7 days.

In the same field trial, 73 per cent of cases with

Long interservice interval

follicular cysts that were treated with GnRH or hCG

plus progesterone had functional luteal tissue by 14

Prognosis in these cases is similar to preservice cases,

days after treatment.

but because of the longer time since calving the urgency

The pregnancy rate achieved again depends very

to get the cow reserved is greater.

much on the ability of the farm staff to detect oestrus

and have the cow served at the correct time. This, plus

the difficulty in accurate diagnosis of the type of cyst

Prevention

present, means that on many farms an unacceptably

high percentage of cows with cystic ovarian disease are

The economic importance of prevention of anoestrus in eventually culled.

all its forms can hardly be overstated. The cost-effective

application of preventive measures, however, calls for

and onset of puberty. The farmer should consult the

careful consideration, and a balance has to be achieved

veterinarian at an early stage if it looks as though not

between undue intervention in cows that would resume

enough animals are starting to cycle at the expected

normal cycles spontaneously and unnecessary loss of

time, and hormonal treatments to induce first ovulation

time due to leaving intervention too late. For example,

and synchronize oestrus and ovulation in a group of

the majority of cows that are not cycling by six weeks

heifers may be considered.

after calving will be coming in season by eight weeks,

Avoidance of disease conditions that will interfere

i.e. in time for service within the target period. On the

with growth is also the veterinarian's responsibility and

other hand, cows that are left without examination and

is described elsewhere in this book. This should not only *treatment until the end of the target period for first*

assist the attainment of the target for age at puberty but

service, say 11 weeks after calving, will lose a great deal

should also help to reduce the high mortality rate that

of production time. However, with the increase in milk

occurs between birth and puberty.

yield and genetic merit of dairy cows, more prolonged

Most farmers are aware that female calves born twin

voluntary waiting periods may be economically viable

to a bull calf are very likely to be sterile freemartins.

and of benefit to the individual animal.

Few realize that measurement of the vagina in the very

young calf and comparison with a normal calf can be

used to decide if a suspect calf is a freemartin.

Heifers

Alternatively, in valuable animals blood sampling both

Prevention of delay in the onset of puberty depends

twins for karyotyping will usually clarify the issue and

on good nutrition and the avoidance of diseases that

allow early culling if desired. However, this procedure

interfere with growth rate (see also Chapter 5).

is too expensive for use in most commercial cattle.

The first step is establishment of clear targets. The

farmer should decide at what age, or at what time of the

Prevention of anoestrus in adult cows after calving

year, the heifers should have their first calves. It is a

simple calculation from that target to decide when the

The foundations for early return to normal cyclicity and

service period should start, so that the majority of the

getting cows served are listed in Box 35.11. All these

heifers calve within the planned period. The exact

factors are very much under the farmer's control,

timing for the start of the service period will depend on

although the veterinarian has an important part to play

how critical both the beginning and the end of the

in ensuring that the husbandry is up to standard, that

calving period are held to be. If conditions are good,

intervention, if required, at and after calving is timely

such as a healthy, fertile young bull running with

and appropriate and that cyclicity is monitored and

well-grown, healthy, cycling heifers, more than 80 per

aberrations are treated.

cent of heifers should be in calf after six weeks of the

• Prevention of dystokia and postpartum abnormali-

service period and practically all by nine weeks.

ties is a basic requirement for optimal cyclicity and To ensure that the majority of the heifers are cycling

fertility and has been discussed on p. 526.

at the beginning of the service period it is necessary to

• Routine veterinary postpartum examination and

aim for a growth rate that achieves the appropriate

treatment can effectively limit the adverse effect of body weight, taking account of the breed involved.

abnormalities around calving and delayed involu-

Puberty occurs around 280 kg in large Holsteins and

tion. It is essential to examine all cows that experi-

Holstein/Friesians, around 260 kg for Friesians and

enced dystokia or postpartum problems by not later

around 230 kg for Jersey heifers; these weights equate

than 28 days after calving. Many veterinary practi-

to approximately 40–45 per cent of the expected adult

tioners incorporate routine examination of all cows

weight. A rough rule-of-thumb for the rearing of heifers

two to four weeks after calving, as this allows them *to calve at 2 years of age is to aim for prepubertal*

to deal with problems early (see also Chapter 34).

growth rates in g/day that equal the adult body weight

in kg. For example, if the expected adult weight is

650 kg, rear at a rate of 650 g/day. Target growth rates

Box 35.11

Factors likely to prevent postpartum anoestrus.

and the key target weights for dairy heifers in the UK

are given in Chapter 5.

• Appropriate body condition and nutrition in the dry period

The veterinarian has a number of roles to play.

• Normal calving

Initially, it is necessary to make the farmer aware of

• Disease-free puerperium, or adequate rapid treatment of

the need to plan for a specific calving season or age

diseases in the puerperium

and what this implies in terms of growth rates. There-

• Suitable transition period feeding and regular checking of

body condition score postpartum

after, the job is mainly to give advice and to make sure

• Efficient oestrous detection

that the client monitors the growth rate of the heifers

Table 35.4

Effect of various treatments on interval from calving to first service.

Calving – service interval (days)

Reference

PGF2*a*

GnRH

Both

None

–

81

–

77

Langley & O'Farrell (1979)

–

88/89

–

83

Nash et al. (1980)

–

72/74

–

73

Nash et al. (1980)

–

–

61

63

Richardson et al. (1983)

92

108

85

84

Etherington et al. (1984)

61

67

64

58

Benmrad & Stevenson (1986)

73

–

–

69

Young & Anderson (1986)

81/51

–

–

91/58

Schofield et al. (1999)

There is an attractive concept that by routinely

terms of reproductive efficiency, there is the danger

administering PGF2a or an analogue, GnRH or both in

that induction of a corpus luteum with GnRH in a cow

the early postpartum period it is possible to improve

that still has an infected uterus after calving can lead

return to cyclicity and pregnancy rate. It is clear that

to pyometra. Selected treatment of cows with uterine

GnRH given before day 20 after calving will initiate

or ovarian pathology is on the other hand entirely

early cycles and PGF2a or an analogue given a little later

justified.

increases the number of cycles in the first six weeks

• Nutrition. For normal reproductive function it is

after calving (Benmrad & Stevenson, 1986). The effect

vitally important that nutritional levels before and

of these treatments on overall fertility is less well

after calving are correct. It has been suggested that

defined; Table 35.4 shows results obtained in several

condition score at calving should not exceed 3.0 and

field trials.

2.5–3.0 should be the target at service.

Meta-analysis of data from 4052 cows in 24 trials pub-

lished in 10 papers looking at the effect of injecting

PGF2a in dairy cattle within 40 days of calving on the

Oestrous detection

rate of pregnancy at first service and the number of days

open came to the following conclusions. Treatment with

Once the foundation for good fertility has been estab-

PGF2a during this early postpartum period had no

lished it is essential to ensure that oestrous detection is

effect on the first service pregnancy rate of cows with a

as good as humanly possible.

normal or abnormal puerperium. An analysis of those

Before discussing how oestrous detection can be
data for the number of days open showed that a signi-
improved it is worth asking the question: why is
ficant percentage (54 per cent) of the treated cows had
oestrous detection inefficient? After all, many stock-
fewer days open than the untreated cows, and that this
workers who carry out this task have worked with cows
difference tended to be greater for cows with an abnor-
for years and know the signs of oestrus well. However,
mal puerperium. The weighted average reduction in
in a recent study of stockworker's attitudes, oestrous
days open between treated and control cows was 2.6
detection was recognized as being an important task,
days for trials with abnormal cows and 3.3 days for trials
but was generally a task that was disliked (Seabrook &
including normal and abnormal cows (Burton & Lean,
Wilkinson, 2000). This may be because it is time con-
1995). This effect is probably largely due to improve-
suming and often requires the stockman to spend time
ments in the submission rate; it is questionable whether
watching cows at antisocial hours. The decreasing

any improvement in calving-to-first-service and calving-
availability of labour on farms is resulting in reduced
to-conception interval justifies the treatment costs and
labour hours per cow per year and overworked staff
the cost of the extra semen that would be used if PGF2a
often do not have the necessary time to dedicate to
were administered routinely to postpartum cows. Thus
oestrous detection.
the routine administration of PGF2a (or other hormone
Good oestrous detection requires regrouping and
preparations) to cattle without a specific therapeutic
possibly moving animals as well as accurate observation
indication probably cannot be justified.
and recording of behavioural events several times a day
In addition to the routine application of these treat-
over months on end and is therefore a very demanding
ments to normal cows not conferring any benefit in
task. It is made more difficult because of the short dura-

tion of oestrus exhibited by many cows, the time of the
A rational system of oestrous detection should be based

night or day when oestrus occurs, the weak and indefi-

on these facts and the following points are required for

nite nature of signs shown by some cows when in season

a good heat detection system:

and the fact that some animals not in season exhibit

(1)

The cows should be observed three times per day

some of the signs of oestrus. Veterinarians who wish

for 30 minutes each time. The periods of observa-

to educate dairy workers on heat detection would be

tion should be when the herd is peaceful after

well advised to attempt to carry out heat detection

milking and feeding. Often these times are:

themselves, so that they may understand the practical

(a)

briefly before collecting the cows for

difficulties.

morning milking;

If oestrous detection is not a priority for staff and

(b)

in mid-morning;

is impossible to organize even with the assistance of

(c)

before the evening milking; and

oestrous detection aids, then the use of hormonal treat-

(d)

late in the evening, a very good time for

ments to synchronize oestrus and ovulation should be

detection of oestrus.

contemplated and discussed (see p. 678). This will

(2)

The housing conditions must be suitable for cows

reduce oestrous detection periods to very specific times,

and observer. Good non-slippery floors on which

or allow the use of fixed-time artificial insemination

the cows feel secure are essential. The observer

with no heat detection. However, pregnancy rates to

must be able to see all the cows clearly, should be

single fixed-time insemination may be low, and this will

comfortable and should have a paper and pen to

also have to be discussed with the client. The details

write down details of the cows' behaviour. Good *of the various oestrous synchronization regimens for*

lighting is required.

cattle are discussed elsewhere in this book (see p. 684).

(3)

The cows must be clearly identifiable from a

The stockworker's dilemma occurs when a cow

distance.

exhibits signs of oestrus just short of actually standing

to be ridden and the decision is taken to have the

There are many aids to oestrous detection; however,

cow inseminated. If the cow is not in season this

there is at present no one substitute for close observa-

decision is criticised. However, if the cow is not

tion of the cows' behaviour (review by Boyd, 1984;

inseminated, a cow in season may have been missed. In

Stevenson, 2001). Aids to heat detection either detect

a large herd these critical decisions have to be made

unobserved standing to be ridden or depend on the fact

many times a year.

that cows in oestrus are likely to behave in ways that,

Good heat detection is based on the following facts.

although not unique to oestrus, occur with greater fre-

quency during oestrus. Increased frequency of bellow-

• *The definitive sign of oestrus is standing freely*

ing, increased restlessness, reduced milk yield, change

to be ridden. It has been proposed that a cow

in routine behaviour such as order of coming into the

that mounts onto another cow's head is in

milking parlour for milking, and increased body tem-

pro-oestrus. Cows in oestrus, of course, also mount

perature are non-specific, oestrus-related events. There

other cows.

are also a number of physical changes in the genitalia

• *There may be an interval of as much as 30 minutes*

related to oestrus that can be measured, such as change

between bouts of riding.

in electrical resistance and viscosity of the vaginal

• *Oestrus rarely lasts for more than 18 hours and in*

mucus.

many cases lasts for less than 6 hours.

Marking systems fixed on the cow's pelvic region to

• *Oestrus often starts during the night.*

detect standing to be ridden when the cows are not

• Oestrous expression is greatest during quiet times

being observed can be valuable in suitable circum-

of the cow's day and night. This means oestrus is

stances. Examples are tail paint, tail flags and detectors

seen less often around milking times and when cows

that contain dye that is squeezed out under sustained

are fed.

pressure from another cow. All of these suffer from the

• As well as a willingness to stand on the part of the

defect that rubbing or pressure that is not caused by the

cow in oestrus, it is necessary to have a cow that

cow standing freely to be ridden may trigger them.

wants to and can mount as discussed above (see

Television cameras with video recording have also

aetiology, p. 532). This can cause particular prob-

been used to observe cows continuously and can be

lems when most cows in the herd are pregnant.

viewed later, at increased speed. There are problems of

• When cows are loose housed there is often a par-

identity (very big numbers on shoulders and rumps are

ticular area that cows prefer to use for oestrous
needed) and replaying the recordings is a tedious chore.
expression.
Milk progesterone assays, which can be used either
• Stalled cows may have reduced physical expression
as an aid to or as a replacement for oestrous detection,
of oestrus (Claus et al. , 1983).
are discussed later (see p. 548).

Pedometers that automatically monitor and record
ferred sampling regimen was every second day from
the cow’s level of activity can also be used to detect
days 18 to 24 after service. The financial benefit to cost
behavioural changes that are consistent with oestrus in
ratio was 7.5:1. Some veterinarians report improve-
some management systems.
ments based on a single progesterone assay on day 19
It is probable that in future sophisticated decision
after service. For good results it is necessary for the
support software integrated into computerized milking
stock personnel to understand the test and to be willing

parlour systems will be developed to detect cows likely

to carry out the extra work carefully and conscien-

to be in oestrus and automatically shed them from the

tiously. Very poor pregnancy rates have been reported

main herd for the attention of the stockman. These

to result if progesterone assays are used as the only

decision support tools will use various data automati-

basis for insemination without the active incorporation

cally generated from a number of sources such as

of oestrus detection (Foulkes & Goodey, 1988).

pedometers, milk yield, milk temperature, order of

However, the use of milk progesterone assays to

milking and milking frequency (fully automated

confirm that cows are in oestrus before inseminating

milking systems only), and data detected by integrated

them can improve pregnancy rates and reduce the

biosensors such as in-line milk progesterone assays and

number of mis-timed inseminations (McLeod et al. ,

assays of other milk constituents. Cows will be identi-

1991; Watson, 1996). Strategic milk progesterone

fied by implanted microchips. These may also advance *monitoring as a diagnostic and management tool in*

beyond the current static data-specific microchip that

dairy cattle is discussed by Darwash and Lamming

simply holds the data it was implanted containing, to a

(1997). Under experimental conditions milk proges-

new generation of smart chips that record the animal's

terone monitoring has also been used in suckler cow

health and disease history along with other information

fertility investigation and management (Mann et al. ,

such as its movement history. It may even be possible

1998); however, logistical problems will almost certainly

in future to develop integrated implanted biosensors

prevent widespread use of this technology in the field.

that analyse and record the animal's physiological state,

Resynchronization of repeats following an initial

including data related to reproduction.

synchronizing treatment using a progesterone device is

used successfully in New Zealand and other locations

where the breeding period needs to be kept short; used

Anoestrus after service

progesterone devices are re-inserted on day 16 to days

In the majority of cases, delayed return to service is due

21 or 22 following first service, and return oestrus

to unobserved oestrus, as has been shown in the reduc-

detected on days 23 or 24 (Van Cleeff et al. , 1996;

tion in the number of long return-to-service intervals

McDougall, 2001). This increases submission rates in

when oestrous detection is improved. One problem, in

the first three weeks of the breeding season and focuses

a case where the return-to-service heat signs are not

heat detection periods to a specific time following first

clear, is that the result of inseminating by AI a cow that

service. A similar regimen has been successfully used in

has been served, and could be pregnant, may be loss of

the UK in beef suckler herds (Penny et al. , 2000).

the conceptus.

Improved efficiency by the use of aids for heat detec-

tion is particularly useful in these cases because the

Acknowledgement

service date can be taken as the start of the oestrous

cycle. Clearly, in those cases where insemination takes

The ultrasound images were produced at the University

place in the luteal phase this starting point is erroneous,

of Glasgow Veterinary School using digital acquisitions

a fact that will become clear to the stockworker as heat

from Toshiba Medical Systems.

detection aids and substitutes are used.

Use of a three-week calendar and the application of

a marker such as tail paint shortly before expected

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return to service can help efficiency of observation.

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84.

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Chapter 36

Failure to Conceive and

Embryonic Loss

D.C. Barrett, H. Boyd and M. Mihm

Manifestation

552

of the pelvic ligaments and voice change. In general,

Aetiology

554

however, the cow that returns to service presents an

Stage 1 Failure of ovulation after oestrus

554

apparently normal oestrus as regards both behaviour

Stage 2 Fertilization failure

557

and visible signs.

Stage 3 Embryonic death

559

The way in which the client presents return to service

Stage of failure not known

562

cases affects the clinician's response to the problem. It

Diagnosis

563

is presented either as an individual cow problem or as

Treatment

566

Prognosis

569

a herd (or group) problem, and it is presented with or

Prevention

572

without evidence of past or present pathology.

Individual cows

Manifestation

Individual cases are presented in two quite different

Return to service or detection of non-pregnancy up to *ways, which influence how they are dealt with.*

six weeks after insemination/natural service are the

In the first way, some cows are presented to the vet-

ways in which poor pregnancy rate due to failure to

erinarian that have been served two or three times and

conceive and embryonic losses are presented. This can

are still not pregnant. To understand these cases prop-

have a major economic impact in any herd, but is

erly they have to be considered within the context of

particularly noticeable where a tight seasonal calving

the entire population of cows and heifers in the herd.

pattern is sought.

In any group of apparently normal cows served cor-

rectly by a fertile bull or inseminated properly with

good semen, either for the first time after calving or at

Interservice intervals

a repeat service, a considerable number will return to

The interval in days that has elapsed between the

service depending on first-, second- and third-service

unsuccessful service and the next oestrus is part of

pregnancy rates in each particular herd. Most of these

the manifestation of the condition of return to service.
animals are only temporarily infertile and the majority
The concept of normal and abnormal interservice inter-
will become pregnant within an acceptable time.
vals has been discussed in connection with postservice
Although there is some understanding of the stage at
anoestrus (see p. 531). While the distribution of inter-
which these losses occur, i.e. whether there is fertiliza-
service intervals varies greatly between herds, reflecting
tion failure or early embryonic death, the aetiology is
in part the management efficiency in the herd, in many
known to only a limited extent. For this reason these
cattle populations fewer than 50 per cent have a normal
returns appear to happen at random.
interservice interval of 18–24 days.
Field studies show that about 12 per cent of cows are
still not pregnant after three services as is demonstrated
in Table 36.1, which is taken from a population of 5744
Observable abnormality
cows with a first insemination pregnancy rate of 60.6
Another manifestation of return to service is the nor-

per cent (Boyd & Reed, 1961a). 'Actual results' are

mality or otherwise of the cow at the return oestrus. The

compared with the 'expected results' that would have

farmer can observe certain deviations from normality

occurred if all subsequent inseminations had had a

in these cows, in particular the presence of a purulent

pregnancy rate of 60.6 per cent. However, in recent

discharge from the vulva. The farmer may also report

years a drop in pregnancy rates of approximately one

aberrant sexual behaviour. In relevant cases, the obser-

per cent per annum has occurred in high-genetic-merit

vant client may notice some of the changes associated

dairy cattle populations (Royal et al., 2000; Barrett, with chronic cystic ovarian disease, such as slackening

2001). This has resulted in expected pregnancy rates of

Table 36.1

The percentage of cows that required various numbers of inseminations for pregnancy with a first insemination pregnancy rate of 60.6 per cent.

Number of

Actual results

Expected results

inseminations

required for

Percentage

Cumulative

Percentage

Cumulative

pregnancy

percentage

percentage

1

60.6

60.6

60.6

60.6

2

20.4

81.0

23.9

84.5

3

7.2

88.2

9.4

93.9

>3 or culled

11.8

100.0

6.1

100.0

50 per cent or less to a single service, thus increasing the

There is no realistic incidence figure for chronic

proportion of animals within a herd not pregnant after

repeat breeders because their retention in the breeding

three services.

herd is dependent on extraneous factors but clearly is

Farmers often wait until a cow has had three

unlikely to be more than 6 per cent of the breeding

unsuccessful services before presenting her to the

population, although it may be higher in individual

veterinarian and Table 36.1 shows that (with

herds. The number in any given herd will be determined *certain reservations) about half of these cows, 6.1%*

by various economic factors which dictate at what point

versus 11.8%, are not pregnant because of the same

it becomes more economic to cull a cow and replace her

(unknown) factors that establish the level of the first

rather than persist in attempting to get her in calf.

insemination pregnancy rate. It is therefore to be

Overall culling rates in UK dairy herds are about 20–25

expected that half of these cows will not exhibit any

per cent per annum (Esslemont & Kossaibati, 1997;

diagnosable cause of return to service and that their

Whitaker et al., 2000). Poor fertility is the single most expectation of pregnancy at the next service is about

important reason for involuntary culling. With 30–40

the same as that for first insemination. However,

per cent of cull cows being culled for infertility, this

pregnancy rates to three or more services are usually

represents almost 10 per cent of dairy cows calving each

reduced due to an accumulation of animals with repro-

year (Kossaibati & Esslemont, 1995). The exact cost to

ductive problems. Warren (1984) cited published data *the farmer of an involuntary cull will vary from farm to*

from four different cattle populations in which preg-

farm and from time to time, depending on the cost of a

nancy rates to first service ranged from 47–57%. Within

replacement, the value of a cull cow, the milk price and

these populations, however, the herd pregnancy rates

availability (and cost) of milk quota, loss of genetic

would vary widely.

merit and many other factors. For this reason it is

In the second instance, other cases, for which the term

impossible to give an exact cost here, but on a typical

'chronic repeat breeder' might be used, are presented

commercial dairy farm it is probably between £600 and

because they have returned to service repeatedly over

£800 per cull cow at the present time (2003).

a long period of time. These cases have been differen-

tiated into apparently normal repeat breeders and

Herd or group problems

those with abnormalities on the basis of cycle length,

sexual behaviour and detectable abnormality, a differ-

Return to service may affect many animals in the herd *entiation of limited clinical value. These chronic repeat in which case the client is very worried about the extent breeders require a different approach from the cases of the problem and the serious effect it will have on pro- discussed above because they are generally cows that duction and profits. For an assessment of the condition the owners regard as particularly valuable and there- it is necessary to analyse the breeding records to fore the clinician can devote more time and money to determine pregnancy rates to first, second and further their diagnosis and treatment. The prognosis in chronic inseminations (or other measure of the success rate of repeat breeders is inevitably poor because they have services) and interservice intervals (see also Chapter been given so many opportunities to become pregnant 41(b)).*

without success. It is animals of this type that may be The range of incidence of return to service is very hospitalized in teaching and research institutions where wide. In a population of herds with any given mean they are given expensive diagnostic and therapeutic herd pregnancy rate there is a tendency for the herd

treatment, although this is becoming more and more

averages to be distributed at random round this mean,

uneconomic within the UK.

as demonstrated in Table 36.2. Just over 40 years ago,

Table 36.2

Distribution (%) of herd average first insemination pregnancy rates in 191

dairy herds (Boyd & Reed, 1961a).

Herd first insemination pregnancy rate (herd average)

Total

<31

31–40

41–50

51–60

61–70

71–80

>80

3.1%

3.7%

16.2%

25.1%

27.2%

19.4%

5.2%

99.9%

the overall herd first insemination pregnancy rate in

Box 36.1

Reasons for unsuccessful services.

191 herds was 59.9 per cent (Boyd & Reed, 1961a).

Stage 1

Ovulation failure

Although not demonstrated here, it is usual for the dis-

Stage 2

Fertilization failure

tribution to be skewed towards the lower end of the

Stage 3

Loss of the conceptus, due to early (3 week return

scale. The skewed distribution of these data tends to be

intervals) or late embryonic death (3–6 week return

seen in all studies, however in more recent surveys the

intervals) or fetal death (>6 week return intervals)

Stage of failure unknown

first insemination pregnancy rates are lower than those

reported by Boyd and Reed (1961a). For example, the

mean first service pregnancy rate in 90 herds in the UK

was reported as 47.3 per cent in the 1992/1993 calving

season (Kossaibati & Esslemont, 1995). National Milk

such as bovine virus diarrhoea virus infection (see

Records (NMR) data from approximately one million

p. 578) or leptospirosis (see pp. 580, 735).

dairy cattle in 9000 herds showed that the pregnancy

• The incidence of chronic repeat breeders, which to

rate to first service (based on available pregnancy diag-

some extent relates to the background effect.

nosis data and non-return rates at 48 days) was 52.5 per

cent in September 2000 (Barrett, 2001). This will be an

overestimate of the true pregnancy rate as a proportion

Aetiology

of the data are based on non-return rates which will

include some cows culled that were not rebred after

There are three main stages at which failure to achieve

failing to conceive. Royal et al. (2000) reported that 265 *or maintain a pregnancy can occur. Although it is often*

first services out of 667 resulted in pregnancy in their

not possible to assign an individual case to one of these

study of Holstein Friesian dairy cows between October

stages this knowledge is useful in understanding the

1995 and June 1998. This equates to a first service preg-

aetiology of return to service. The stages are shown in

nancy rate of 39.7 per cent. Given these recent data it

Box 36.1.

seems reasonable to accept a target first service preg-

nancy rate of 50 per cent in modern dairy herds, while

accepting that in some high yielding herds this may be

Stage 1 Failure of ovulation after oestrus

difficult to achieve.

The most important condition in which there is oestrus

It is helpful to think of the pregnancy rate for any

without ovulation is cystic ovarian disease. It is im-

individual herd as dependent on the combined effects

portant to define 'cystic ovarian disease' because not all

of the following factors:

cases of ovarian cysts are pathological (see Box 36.2).

• The random variation around the mean of the

This traditional definition implied that cysts were

population of herds.

static structures; however, cysts should be considered

• The background effect, which is dependent on man-

dynamic both in structure and function (Cook et al.,

agement and environmental factors that are liable

1990). When studying the aetiology of ovulation failure

to be constant over a long period. Examples, any of

the conclusions reached are affected by which animals

which individually would tend to result in low herd

are included as clinical cases. For example, cows

pregnancy rates, are inaccurate oestrous detec-

identified as having cystic ovarian disease at routine

tion, unsatisfactory feeding, a high incidence of

preservice veterinary examination will form a different

endometritis (see p. 521) or poor semen handling

population from cystic ovarian disease cases detected in

and insemination techniques (see Chapter 39).

repeat breeder cows.

• Specific pathogenic causes, such as a subfertile bull

Histological and biochemical examination of ovarian

or venereal diseases such as campylobacteriosis, or

cysts demonstrates that cysts are complex structures.

other infectious conditions known to affect fertility

On clinical examination and gross anatomical inspec-

Box 36.2

Definition of cystic ovarian disease (see also

Box 36.4

Factors that predispose to or cause cystic ovarian

Chapter 35).

disease.

• Persisting, steroid-secreting follicles >2.5cm in diameter

• Heredity

• No functional corpus luteum present for more than 10

• High yield

days

• Age

• Abnormal sexual cycle (anoestrus, nymphomania, viril-

• Exogenous oestrogens

ism)

• Nutrition and season of the year

• More than six weeks after calving

• Dystokia and periparturient disease

Heredity: A familial predisposition to cystic ovarian

Box 36.3

The possible pathogenesis of cystic ovarian

disease through sire or dam has been recognized for

disease.

many years (Bane, 1964). Other studies have produced

• Insufficient luteinizing hormone (LH) release:

less clearcut results or even failed to detect a hereditary

hypothalamic–pituitary dysfunction causing lack of GnRH

effect at all (Dohoo & Martin, 1984a). It is possible that release (commonest cause)

this difference is partly due to the stage at which

• Insufficient production of LH by the pituitary (rare)

diagnosis is carried out. If the incidence is assessed at

• Failure of the dominant follicle to respond to LH

routine preservice checks most of the detected cysts are

likely to be attributed to environmental factors rather

than heredity; on the other hand, one might expect con-

tion, however, there appear to be two main types of
siderably more evidence of hereditary predisposition if
cysts: follicular cysts, which are like large follicles, and
the assessment is made on a sample of repeat breeders.
luteal cysts, in which obvious luteal tissue produces a
While most veterinarians are generally aware that
thicker cyst wall. These may be difficult to differentiate
there is a hereditary component in cystic ovarian
from a corpus luteum with a central lacuna, which
disease, their clients want to know to what extent breed-
frequently occurs during the normal oestrous cycle
ing a replacement heifer from a cow with cystic ovarian
(Okuda et al., 1988).
disease will increase the risk of that daughter having the
It is well known that follicular cysts can occur and
disease. It is not easy to answer this because cystic
spontaneously resolve during the first few weeks after
ovarian disease may not occur in a daughter until she
calving in some cows that then return to normal cyclic
has had several calves and so field studies take many
ovarian function, albeit later than normal counterparts

years and involve complex statistical analysis.

(Savio et al., 1990). It is often suggested that cows with Early studies carried out by Henricson (1957) helped

cystic follicles up to six weeks after calving should be

to answer the question. He analysed data from two

regarded as normal and not be interfered with unless

artificial insemination (AI) centres of cases presented

they are nymphomaniac or show other signs of

at the time of insemination and classified cows as:

abnormality.

• Having cystic ovarian disease on more than one

Box 36.3 is to some extent hypothetical but should

occasion in a service period;

act as a reminder that there are several possible routes

• Having only one observation of cystic ovarian

that can result in cystic ovarian disease, among them

disease; and

long-term exposure to oestradiol or subnormal concen-

• Without cystic ovarian disease.

trations of progesterone (Dobson et al., 2001a) and

cortisol release following stress (Dobson et al., 2001b).

The effect of age was taken into account and the results

There have also been suggestions that energy im-

expressed as an average frequency of the condition,

balance due to high milk yields may be contributory,

where 1.00 is equivalent to an incidence of 100 per cent

although this has not been substantiated by correlation

(Table 36.3).

with either b-hydroxybutyrate concentrations or body

Henricson (1957) also studied the effect of the sire

condition score (Dobson & Nanda, 1992; Tebble et al., and noted that the average frequency of cystic ovarian

2001).

disease in individual bulls' daughters ranged from 0.00

There have been many studies of the causes of cystic

to 0.258. Whether the low incidence of cystic ovarian

ovarian disease and factors that predispose to the con-

disease in beef breeds is directly due to hereditary

dition are listed in Box 36.4. There is lack of unanimity

factors, to the lower milk production or to some other

about causes, which may reflect differences between

factor is not known.

the populations of cattle selected for investigation as

well as variations in the definition of cystic ovarian

High milk yield: Cystic ovarian disease may be related disease.

to high milk yield. It occurs most frequently at the peak

Table 36.3

Dam effect on incidence of cystic ovarian disease

arise when oestrogenic substances, such as those found

(COD) in daughters (Henricson, 1957).

in mouldy brewers' grains, are eaten.

Number of times COD

Average frequency of

Seasonal effect: A very definite seasonal effect has

diagnosed in dam in

COD in daughters

been reported by many authors, with most reports indi-

one service period

cating that the incidence is highest in winter (Dohoo et

Centre 1

Centre 2

al., 1984a,b; Saloniemi et al., 1986). The effect can be so great that Bane (1964) *stated that it is meaningless to*

>1

0.255

0.228

1

0.170

0.158

talk of an incidence figure for cystic ovarian disease if

0

0.143

0.116

details of season (and age) are excluded. The range in

his data was from 2.23 per cent for cows that calved in

May to 9.68 per cent for October calvers. The relative

frequency of severe cases was higher in autumn calvers.

of lactation approximately six weeks postpartum and at

Some authors (Bartlett et al., 1986b) reported high

the age when the cow has reached her full milking

levels in summer and autumn. The causes of the sea-

potential, which is why it is more common in pluri-

sonal effect are not clear but may be linked to nutri-

parous cows than in first calvers. There is a secondary

tional effects, and could also include the hours of

peak of cases late in lactation; presumably these are

daylight, temperature extremes and stressors such as

cases that have been picked up on the examination

housing.

of repeat breeders. Bartlett et al. (1986b) discussed, without coming to a conclusion, whether high milk yield

Dystokia and periparturient disease: Some information

causes cystic ovarian disease, cystic ovarian disease

suggests that dystokia and periparturient diseases may

causes high yield or there is a common cause of both!

predispose to cystic ovarian disease. It is possible that

Saloniemi et al. (1986) thought that the relationship

preparturient factors that cause the postpartum condi-

between cystic ovarian disease and ketosis was due

tions also affect the incidence of cystic ovarian disease,

primarily to high milk yield, leading to greater energy

for example overfeeding leading to fatty liver (Reid et

demands that in turn resulted in both ketosis and inter-

al., 1979). It has been demonstrated experimentally that ference with LH production or release.

damage to the endometrium can prolong the existence

Some workers have been unable to find an adverse

of cystic follicles and so inhibit spontaneous recovery

effect of high milk yield on the occurrence of cystic

(Fathalla et al., 1978) (see also Chapter 34).

ovarian disease (Dohoo & Martin, 1984a).

Other causes: It is possible that gross adhesions can

bind the ovary so tightly that ovulation does not take

Age: It is widely accepted that cystic ovarian disease is place, but this must be a rare phenomenon. Of much

rare in heifers before their first calving, not common in

greater importance is the concept that in cows which

first-lactation cows and then increasingly observed in

had other reproductive disorders there were possibly

mature cows, with possibly some slight fall off in old

more than the expected cases of cystic ovarian disease

animals.

(Jasko et al., 1984).

Reviews of the literature show that incidence ranges

Exogenous oestrogens: Administration of oestrogens

from about 6 to nearly 20 per cent (Bartlett et al., 1986b; in the follicular phase will cause a premature LH peak.

Garverick, 1997). However, diagnostic methods affect

This will not cause ovulation if no dominant follicle

the reported incidence figure, for example Coleman et

is present at the time. If oestrogens are administered

al. (1985) found that the single most important factor shortly before dominant follicle selection, the cow may

that influenced the incidence was the veterinarian who

not be able to produce a second LH peak due to down

made the diagnosis! Selection of cases is also important,

regulation of the hypothalamic response to oestradiol

as has been discussed already.

and consequently the dominant follicle will continue to

It is generally agreed that follicular cysts make up

grow and not ovulate. This may be one explanation why

about two-thirds of recognized cases of cystic ovarian

a single large dose of an oestrogen for therapeutic pur-

disease (Booth, 1988; Garverick, 1997) although again

poses may be followed later by cystic ovaries. Recent

this figure depends a little on the diagnostic method and

transitions to organic farming may involve grazing

criterion used.

periods on pastures with a high component of oestro-

While the most important reason for failure to

genic plant material; however, a much increased inci-

ovulate is considered to be cystic ovarian disease, there

dence of cystic ovarian disease in such herds has not

are also a proportion of cows who have a delayed ovu-

been reported to date. An analogous situation may

lation after oestrus, resulting in an extended period

Box 36.5

Causes of fertilization failure.

Box 36.6

Causes of ovarian and bursal adhesions.

• Rectal palpation just before ovulation (bursting pre-

• Trauma

ovulatory follicles, interference with egg flow into the

• Rectal palpation

uterine tubes)

• (Enucleation of corpus luteum – no longer indicated as a

• Interference with egg transport

therapeutic practice in cattle)

• Interference with sperm transport

• Caesarean section – inducing (localized) peritonitis

• Delayed ovulation

• Ascending infection

• Insemination at wrong time in relation to ovulation

Postpartum metritis

• Service too soon after calving

Therapeutic infusion of uterus

• Poor quality spermatozoa

• Descending infection

• Poor quality oocyte (e.g. from persistent follicles)

from peritoneum

• Failure to serve the cow

• Specific infections, e.g.

• Metritis and salpingitis

Ureaplasma sp.

• Vaginitis and cervicitis

Mycoplasma sp.

from insemination to ovulation. The incidence of

As transport of the egg depends on secretory and

delayed ovulation can be as high as 11 to 13 per cent, *ciliary activity in the uterine tube, salpingitis will inter-*

as shown in one study by Lamming and Darwash

fere with transport of both eggs and spermatozoa, even

(1998).

when the lumen remains patent.

Interference with transport of spermatozoa: Adhesions

Stage 2 Fertilization failure

in the female tract that block egg transport, and have

To achieve fertilization a number of events in the cow

been discussed above, will generally interfere with

(oestrus, ovulation, gamete transport) and in the bull

transport of spermatozoa. There are rare anatomical

(spermatozoa production, insemination) have to take

abnormalities such as white heifer disease (segmental

place and must synchronize with each other. Failure of

aplasia of the paramesonephric ducts), which results in

any one of these events to occur correctly or at the right

blockage of the tubular genitalia at various levels.

time will almost certainly result in fertilization failure.

Poor AI technique, such as insemination in the ante-

The causes of fertilization failure will be discussed, *rior vagina or caudal half of the cervix, will result in the*

mainly based on the headings shown in Box 36.5. The

majority of cases in the loss of much of the inseminate

first two causes, interference with gamete transport, are

by reflux through the vulva. In contrast, in natural

relatively rare occurrences.

service the ejaculate is deposited in the anterior vagina

and on the external os of the cervix, but the volume of

Interference with egg transport: After ovulation the egg the ejaculate and the enormous number of spermato-has to be transported to the site of fertilization in the

zoa allow loss by reflux while sufficient spermatozoa are

uterine tube. Adhesions affecting the ovary and bursa

transported to the uterine tube. Returning to AI, a

and blockage of the uterine tube will prevent this hap-

rough operator could damage the uterus with the

pening. Factors that cause adhesions, which are fairly

insemination pipette. While it is unlikely that bad

rare, are listed in Box 36.6. The ease with which fluids

insemination technique is much of a problem with a

and small objects can be transported spontaneously up

technician inseminator service, it is very likely that the *or down the uterine tube is demonstrated in two tech-*

range of expertise among stockworkers who inseminate

niques used to investigate uterine tube patency. In one

their own cows is so great that some gross technical

of these tests, phenolsulphonphthalein (PSP) dye is

errors may be made.

introduced into the uterus and ascends spontaneously

Hunter (1999) discusses possible modifications of

through the uterine tube into the peritoneal cavity and

the technique used for AI involving deep intrauterine

becomes absorbed and secreted in urine. In the other

insemination and the effects this may have on the trans-

test, starch granules deposited in the bursa descend

port and storage of spermatozoa within the female

through the uterine tube into the uterus and vagina

reproductive tract.

(Kessy & Noakes, 1979).

Transport in the uterine tube is under hormonal

Delayed ovulation: Delayed ovulation is a condition in control and can be affected by abnormal variations in

which the interval from the onset of oestrus to ovula-

steroid hormone production and by oxytocin, but the
tion is so much longer than normal that service at the
role of these factors in field conditions is not known.
recommended time does not result in fertilization

because of the ageing of the spermatozoa. While many
of milk or blood taken on the day of insemination will
authors are of the opinion that the condition is rare,
detect insemination during the luteal phase of the cycle
there are a number of papers that suggest that it occurs
but will fail to pick up inseminations that are one or two
quite commonly (Hancock, 1948; Nakao et al., 1984;
days too early or too late. The reported incidence of
Lamming & Darwash, 1998). Watson and MacDonald
luteal phase progesterone levels on the day of insemi-
(1984) studied events around insemination using rectal
nation is variable. The incidence of 5.2 per cent in well-
palpation and assays for progesterone and oestradiol-
run herds reported by Claus et al. (1983), with over 20
17b. They concluded that in cows with a follicle in the
per cent in problem herds, is typical of several other

ovaries on the day after insemination (which may indi-

trials. Laitinen et al. (1985), in a large field study, cate delayed ovulation if onset of heat occurred more

reported that the lowest incidence of luteal phase

than 30 hours before) this was often due to erroneous

inseminations occurred in the summer. Oltner and

timing of insemination in relation to the onset of

Edqvist (1981) observed that in herds with a high inci-

oestrus and not to delayed ovulation.

dence of wrongly timed inseminations, even insemina-

As the condition is so difficult to study, ideas about

tions apparently at the correct time resulted in low

its aetiology must be theoretical. It is possible that there

pregnancy rates, presumably because of other aspects

is an abnormality of the LH surge or response of the

of poor management.

preovulatory dominant follicle to the LH surge. It has

The reasons are misidentification of a cow that actu-

been hypothesized that deficiency of energy intake may

ally is in season or misinterpretation of sexual behav-

be involved in the aetiology.

iour, such as jumping another cow, which is thought

The role of stress is also speculative, but it is

incorrectly to indicate oestrus. The stockworkers are

interesting that corticosteroids can block LH release

often under considerable pressure to get all cows served

(Wagner & Li, 1982); also the fact that the adrenal

by a target date and are criticised by veterinarians and

cortex under the influence of adrenocorticotrophic

others, that cows in oestrus are missed too frequently.

hormone (ACTH) can produce some progesterone may

This can result in error through an overenthusiastic

be significant in suppressing the LH surge (Watson &

determination to increase the oestrous detection rate.

Munro, 1984). The importance of stress in bovine

The importance of inseminating only cows in oestrus

reproduction is reviewed by Dobson et al. (2001b).

was demonstrated by Sturman et al. (2000), who

A little understood condition called prolonged low or

reported that in a herd they studied 19 per cent of

suprabasal progesterone was described by Jackson et al.

inseminations were performed when progesterone

(1979) as affecting 18 per cent of cows treated with an

levels were high in the oestrous cycle or while cows

analogue of prostaglandin F2a (PGF2a) and also about

were pregnant. Insemination of pregnant cows led to an

18 per cent of control cows. After oestrus there was an

estimated 17 per cent induced embryonic death or

excessively long period of low progesterone, followed

abortion!

by a rise which seemed to indicate that ovulation took

Incorrect timing of insemination in relation to onset

place eventually. The herd incidence ranged from 7 to

of oestrus also occurs. Watson et al. (1987) confirmed 33 per cent and appeared to be low in herds with ade-that insemination 24 hours or more after the cow is first

quate nutrition. Other surveys have not revealed such

seen in oestrus results in a marked reduction in preg-

a high incidence. Some workers think prolonged low

nancy rate, possibly due to ageing of the oocyte before

progesterone is most commonly associated with treat-

fertilization. It is likely that insemination very early in

ment with PGF2a or an analogue causing incomplete

oestrus also causes reduced fertility, possibly due to *luteolysis and subsequent recovery of some luteal func-*

reduced sperm survival rates before fertilization. There

tion. Independent of its cause, it will lead to persistence

is a long-established, successful rule of thumb about the

of a dominant follicle resulting in lowered fertility fol-

ideal time for insemination (Trimberger, 1948). Cows

lowing its ovulation. This does not appear to be due to

first seen in the morning should be inseminated late that

poor fertilization rates, but to more losses during early

afternoon. Cows first seen in the afternoon or evening

embryonic development (Mihm et al., 1994).

should be inseminated next morning. Cows still in

oestrus 24 hours after first being seen should receive a

Insemination at the wrong time in relation to ovulation: second insemination. This pragmatic recommendation

Service during the luteal phase is only a minor problem

takes account of the relatively short lifespan of both

with natural service but a major one with AI (Sturman

spermatozoa and ova within the female tubular tract

et al., 2000). However, on farms using hand mated

(about 24 hours), the need for capacitation of bull

natural service, a cow restrained in a service crate may

spermatozoa (about 6 hours) and the interval from the

be mated when she is not in oestrus.

onset of oestrus to ovulation (about 24–30 hours).

Artificial insemination at the wrong time is an impor-

Incorrect timing within oestrus is of little significance

tant cause of fertilization failure. Progesterone assays

with natural service in which the service is usually early

in oestrus. The large quantity of the ejaculate and the

served. Bulls can develop abnormalities of the penis

great numbers of spermatozoa deposited in the anterior

that prevent normal service, and lack of libido is not

vagina ensure that there is a long-lasting supply of

uncommon (see p. 610). When animals are running

fertile spermatozoa in the uterine tube at the site of

freely, such as heifers or beef cattle, it is essential to

fertilization.

include an adequate number of bulls in the group. If

there are too few bulls for the number of cows, some

Service too soon after calving: It has been known for *cows in oestrus may not be served. The required cow to*

many decades that service within six weeks of calving

bull ratio depends on the type of terrain, the age and

results in reduced pregnancy rates. The expected con-

libido of individual bulls (see p. 610).

ception rate increases from approximately 20 per cent,

at 20 days post partum, to reach normal rates (at the

Metritis, salpingitis, vaginitis and cervicitis: Infection of time the studies were carried out these were 50 per cent

the tubular genitalia may interfere with the survival of

calving rates) from 50 days post partum. The reasons

the spermatozoa in transit and so reduce the chance

are likely to be both ovarian and uterine in origin so

of fertilization. Endometritis and metritis are fairly

in some cases the cause is most probably fertilization

common (see p. 524) but in addition a number of

failure and in others embryonic death. Elimination of

species of organisms have been recovered from the

infection and restoration of endometrial structure and

uterine tubes and may cause salpingitis or directly

function after a normal calving requires 5–6 weeks in *affect fertilization, as for example reported by Grahn et*

most animals.

al. (1984), in connection with fertilization failure with BVDV infection (see pp. 578, 853). Infectious agents in

Poor-quality semen or poor insemination technique:

the uterine tube include Leptospira hardjo (see p. 735), Poor semen quality may result in either low pregnancy

Ureaplasma spp. and Mycoplasma bovigenitalium.

rate or no pregnancies at all, mainly through fertiliza-

tion failure but also to some extent through embryonic

Stage 3 Embryonic death

death. Again there are marked differences between

natural service and AI. Because of laboratory control

The stage of the embryo lasts from fertilization of the

of the semen and follow-up of the results of insemina-

egg until about day 42 after conception, by which time

tion it is very unlikely that semen supplied by a repu-

the organ systems have been laid down and placenta-

table AI organization will give poor pregnancy rates.

tion has been established. Failure of maternal recogni-

The exception to this is semen that has been poorly

tion of pregnancy will cause early embryonic loss, and

stored or incorrectly handled on farm for use in DIY
the animal returns to oestrus at normal intervals (<25
AI systems. Schermerhorn et al. (1986) found that a
days). Late embryonic loss occurs after maternal recog-
technician inseminator service gave rather better
nition of pregnancy, and animals may show their next
results than farmer DIY insemination, although this
heat 25 to 40 days after the previous heat.
may depend on the level of training received by DIY
In any group of breeding cattle, however normal they
inseminators before they begin inseminating their own
appear, there will occur a considerable amount of
cows. Howells et al. (1999) showed that the amount of
embryonic death, most of it within the first three weeks
training received with live cows significantly affected
after fertilization (Sreenan & Diskin, 1986). Ayalon
future pregnancy rates; for those who spent up to three
(1978) produced data to show that in repeat breeders
days training in an abattoir using live cows there was an
the majority of the losses occurred approximately 5–7
increase of 5.9 per cent in the calving rate they achieved

days after insemination, around the time the early

in their first year for every day they spent training. If

embryo enters the uterus and begins to synthesize its

AI technique is satisfactory, poor results with DIY

own proteins (Table 36.4). However, the exact timing of

inseminations could possibly be related to mishandling

early pregnancy losses in the modern high-yielding

of the semen. By contrast a bull used for natural service

dairy cow is largely unknown. Knowledge of the aeti-

may be of reduced or low fertility or even sterile and

ology of this important condition is still very limited but

serve a number of cows before the owner realizes that

it is possible to produce a list of factors that have been

something is wrong. Farmers are often not aware that

shown to cause embryonic death or are at least very

a bull that has been fertile may become infertile or lose

likely to be involved (Box 36.7). In the vast majority of

libido (see Chapter 38).

cases the actual cause is never established.

Where fresh diluted semen is used, semen that is

stored too long will give poor results.

Factors that may contribute to embryonic death

Failure to serve the cow: In certain circumstances when Extreme environmental temperatures: Controlled expera bull is used to serve the cows, a cow in oestrus is not

iments have demonstrated that cattle that are mated

Table 36.4

Timing of embryonic death, determined by slaughter and dissection of the cow (number and percentage containing viable embryos) (from Ayalon, 1978).

Time of slaughter (days)

Normal cows

Repeat breeders

Number

Percentage

Number

Percentage

2–3

10/12

83

12/17

71

4–5

22/25

88

20/25

80

6–7

10/12

83

5/12

42

8–10

13/18

72

9/18

50

11–13

16/18

89

9/18

50

14–16

16/20

80

10/20

50

17–19

12/21

57

9/21

43

35–42

9/13

69

8/24

35

Box 36.7

Factors that may contribute to embryonic death.

Crosses between indigenous heat tolerant breeds and

European breeds are more heat tolerant than the

• Extreme environmental temperatures, particularly heat

imported animals and they are more fertile (see

stress

Chapter 6). The improved fertility appears to be the

• Specific and non-specific endometritis or metritis

result of the dam's enhanced ability to control body

• Specific infections of follicles, gametes and/or embryo

temperature rather than an inherited ability of the

• Maternal pre- and postovulatory endocrine environment

embryo itself to tolerate high intrauterine tempera-

• Aged gametes

• Local trauma

tures. The position is less clear with extreme cold, but

• Genetic factors, resulting in non-viable genetic defects

there are indications that a corresponding adverse

• Nutrition

effect occurs. The problem could arise during unusually

• Possible fetal/maternal incompatibility

cold periods in temperate climates where housing tends

to provide cover rather than warmth.

Metritis/endometritis: Metritis or endometritis in

in a high environmental temperature and kept there

varying degrees of intensity is a common condition

after service exhibit a high rate of embryonic death.

causing infertility in cattle (see Chapter 34). Where

The dominance of the large preovulatory follicle is
caused by infection it can be divided into non-specific,
suppressed by heat stress, and the steroidogenic capac-
exemplified by Arcanobacterium pyogenes infection,
ity of theca and granulosa cells is compromised. Proges-
and specific, typified by Tritrichomonas fetus (see p.
terone secretion by luteal cells is lowered during the
584) and Campylobacter fetus (see p. 582) infection.
summer in hot climates, and in cows subjected to
There are also a number of infections that are difficult
chronic heat stress this is also reflected in a lower
to classify such as bovine herpes virus-1 (BHV-1), Ure-
plasma progesterone concentration. Heat stress has
aplasma spp. and Haemophilus somnus.
also been shown to impair oocyte quality and embryo
Non-specific metritis is the result of either massive
development, and increase embryo mortality. In addi-
infection or of the infective organisms taking advantage
tion to the immediate effects of heat stress, delayed
of a deficient uterine defence mechanism, usually
effects have also been detected. These include altered

caused by damage at and after calving. Non-specific

follicular dynamics, suppressed production of follicular

infection can be facilitated by the synergistic action of

steroids and lower quality of oocytes and developing

different organisms, for example A. pyogenes and

embryos. This may explain why poor fertility may

Fusobacterium necrophorum.

persist for some time after periods of heat stress

Specific infections colonize the undamaged uterus.

(Wolfenson et al., 2000).

Two important specific infective agents are C. fetus and Poor pregnancy rate is a problem when European

T. fetus. Campylobacteriosis is spread venereally and

cattle are introduced into hot countries where they are

causes a mild endometritis in infected females that have

exposed to ambient temperatures above 30°C; it is quite

not had previous experience of the condition. It has

likely that increased embryonic death is part of the

been shown in slaughter experiments that in infected

reason. There is little doubt that genetic factors are

animals fertilization rate is normal and that the infer-

involved in this as in other aspects of heat tolerance.

tility is due in the main to embryonic death within three

weeks of conception. Loss of the embryo is likely to be

Maternal endocrine environment: Mann and Lamming

due to interference with the uterine environment.

(1995) showed that low plasma concentrations of prog-

Venereal campylobacter infection and its control in the

esterone resulted in the development of a stronger

UK has been reviewed by Taylor (2002). Trichomonia-

luteolytic signal. This was taken as an explanation for

sis, a parasitic venereal disease that still occurs in some

the fact that cows with lower plasma concentrations

countries (Clark et al., 1986), is clinically similar to of progesterone postinsemination are more prone to

campylobacteriosis with one major difference, the

embryo loss than those with higher progesterone levels.

occurrence of pyometra in a number of cases (Bon-

Interferon tau (IFN-t) is a protein produced by the

Durant, 1997).

embryo that acts locally within the uterus to block lute-

Another infectious agent that is introduced from

olysis and maintain the corpus luteum; it prevents

the vagina into the uterus at insemination, but not

PGF2a secretion by inhibiting the development of oxy-

at natural service, is Ureaplasma (Doig et al., 1979), tocin receptors in the endometrium (Robinson et al.,

which causes a purulent metritis and infertility.

1999). More recently, further work has shown that

Haemophilus/ Histophilus also causes vaginitis and successful maternal recognition of pregnancy in cows

reduced fertility. For detailed discussion of a wide range

depends on the presence of a sufficiently well devel-

of infectious agents see Morrow (1986). For more

oped embryo producing sufficient quantities of IFN-t,

details on both endometritis and metritis see also

which is, in turn, dependent on an appropriate pattern

Chapter 34.

of maternal progesterone secretion (Mann, 1997; Mann

Infectious conditions can cause infertility in at least

& Lamming, 2001). Thus the maternal endocrine envi-

four ways:

ronment, and particularly maternal progesterone levels *within the first one to two weeks after insemination,*

• The febrile reaction raises the temperature of the

is likely to be extremely important in determining

uterus. Bluetongue (Chapter 43a) is an example of

whether an embryo signals its presence to the dam and

a disease that causes a high temperature resulting

survives or is lost as the cow returns to oestrus.

in loss of the embryo at about the time of hatching

from the zona pellucida, about day 10–12 after

Aged gametes: Fresh chilled semen ages after several

service.

days and the inseminated cows have a lower pregnancy

• The organism infects the uterus and causes metri-

rate almost certainly due to both reduced fertilization

tis, which presumably interferes with embryo nutri-

rate and increased loss of embryos. There is no evidence

tion and may also infect the embryo. Examples are

of adverse effects from ageing of frozen semen stored

BHV-1 virus (see p. 289) and Chlamydiales infec-

in liquid nitrogen. Fertilization of ageing eggs following

tions. It is likely that, in general, mild endometritis *ovulation of persistent dominant follicles (Mihm et al., causes embryonic death whereas in cases of puru-1994; Austin et al., 1999) is also likely to result in an lent metritis there may be interference with sper-increased amount of early embryonic death.*

matozoa survival and thus fertilization failure.

• Infection of the conceptus can cause its death. The

Local trauma: This cause of loss affects the late embryo thought that embryo transfer could transmit infec-and early fetus. One source of local trauma to the

tious diseases from the sire or the dam is worrying.

pregnant uterus is the hand of a person carrying out

In theory, bacterial and fungal infections are less

manual pregnancy diagnosis, or some other palpation

likely than viral infections to be carried by embryos.

of the uterus. In one study the average loss was 2.82 per

From experimental studies with many different

cent of cows diagnosed pregnant (Beghelli et al., 1986).

viruses it appears that if the zona pellucida is intact

Franco et al. (1987) reported a fetal loss rate of 9.5 per and the embryo is washed properly, there is little

cent in cows diagnosed pregnant on days 42–46. The

danger of the transmission of viral infections by

technique, which was carried out on two days, involved

embryo transfer (Singh, 1987; Wrathall, 1995).

palpation of fetal fluid, identification of the amniotic

However, the advent of in vitro technology may

vesicle and slipping of the chorioallantoic membranes.

increase the risk of disease transmission due to dif-

However, with good transrectal ultrasound examina-

ferences in the zona pellucida of in vitro derived

tion technique such losses should now be largely

embryos, enabling easier adsorption of pathogens,

preventable.

and due to the use of biological products for cul-

In a very large field study in which they used milk

ture which may be contaminated with pathogens

progesterone assays, Laitinen et al. (1985) estimated

(Stringfellow & Wrathall, 1995; Guerin, et al., 1997).

that 1.8 per cent of cows that returned to service were

• Endotoxins produced by Gram-negative infections

pregnant at the time of re-insemination. When a preg-

can increase PGF2a production and cause prema-

nant cow is inseminated, the conceptus must be at risk

ture luteolysis (Fredriksson, 1984).

either through direct trauma or by the introduction of infection into a progesterone-dominated uterus. An

To complicate matters further, additive effects of two

experienced inseminator may be able to feel the differ-

or more types will produce low pregnancy rates. Two or

ence in the cervix and uterine horns and avoid insemi-

more independent minor adverse factors that occur at

nation into the body of the uterus, electing instead to

the same time will produce a poor result. For example,

deposit the semen in the anterior cervix or not to insem-

Boyd and Reed (1961b) observed that variations in

inate the cow at all.

three factors (calving-to-first-service interval, age of

cow and age of fresh semen) caused a range of preg-

Genetic factors: Mention has been made of the variable nancy rates from 22 to 70 per cent. As mentioned

breed susceptibility to high environmental temperature

above, synergistic action of two or more adverse aetio-

that causes embryo death.

logical factors, for example A. pyogenes and F.

In some cattle, in the process of cell division, trans-

necrophorum, can result in a more severe pathological

location of parts of certain chromosomes without loss

condition than either alone.

of genetic material has taken place, a condition that is

Many of the putative causes of return to service are

passed on to future generations. These individuals can

far from being proven but they cannot be simply dis-

be identified by cytogenetic examination of leukocytes.

missed for that reason. Amongst these possibly adverse

When semen from bulls with a translocation is used for

factors are the following:

insemination there is a slight increase in the incidence

• *Short-term change in feeding and environment,*

of return to service, which is believed to be the result

particularly at turnout in the spring and at housing

of embryonic death, presumably because of lack or

in the autumn. This has been postulated to be due

excess of some genetic material due to abnormal divi-

to an energy–protein imbalance changing the

sion at meiosis.

uterine tube and uterine environment (pH and urea

It is also probable that many genetically abnormal

concentrations) and thus affecting normal early

embryos are lost early in development, with the advan-

embryonic development.

tage that the dam can return to normal breeding at the

• High milk yield leading to excessive metabolic

earliest opportunity. Early embryo development and

stress.

non-infectious causes of embryo loss are reviewed by

• Stressful effect of disputes about dominance among

Kastelic (1994) and Sreenan et al. (1999).

cows that are subject to frequent changes of groups

in dairy herds.

Stage of failure not known

• Non-reproductive systemic illness.

It should be clear from the limited number of factors

• Deficiencies and imbalances in minerals and vita-

listed as known to cause embryonic death, that in the

mins (almost impossible to generalize because of

majority of cases the cause is unknown. Some factors

very local effect of feeding practices, local soil *that result in return to service can affect different*

deficiencies and many other variables).

stages, for example late insemination can result in fer-

• Other conditions that stress the animal or affect its

tilization failure in some cases and embryonic death in

dry matter intake such as lameness.

others. There is a very large grey area concerning the

There are various reasons why there is so much

aetiology of return to service, particularly where groups

uncertainty in a field where numerous workers have

of affected animals are concerned. The difficulty con-

gathered observations and data for several decades.

cerning the relationship between (possible) aetiological

Because expected pregnancy rate is about 50 per cent,

factors and return to service is twofold.

the random variation in fertility in groups is great and

Some factors almost certainly cause an increased

this necessitates large, properly controlled groups in

return to service via an unknown mechanism. An

trials in order to give reliable results. The possibility of

example is the aetiological relationship between loss

erroneous conclusions from any single trial is so great
in body condition from calving to service and associated
that only results that are consistently repeated in dif-
poor pregnancy rate. The possible sites where inade-
ferent populations can be regarded as reliable.
quate nutrition may have detrimental effects on repro-
In recent years there have been a number of epi-
ductive function include:
demiological studies of a highly statistical nature on the
• The hypothalamus/pituitary gland to impair
relationships between various aspects of management
gonadotrophin release.
and production, disease and reproduction. Because of
• The ovaries, possibly resulting in altered follicular
the complexity of interrelationships very large numbers
growth patterns and reduced quality of oocytes and
of observations are needed and these reports are based
subsequent reduced embryo survival.
on data from populations that range from about 2000
• Inadequate uterine environment resulting in
to >70 000 lactation records. For the practitioner this

impaired embryo survival (Webb et al., 1997).

means that evaluation of fertility in small herds is

difficult due to the large impact of small numbers of

tion, weight loss and fertility; Loeffler et al. (1999): time observations on overall herd results.

of disease, milk yield and body condition; Dohoo et al.

While there are considerable differences between the

(1984): disease, production and culling; Rowlands et al.

findings certain concepts have emerged:

(1986) and Peeler et al. (1994): interrelationship of

diseases; Saloniemi et al. (1986) and Fourichon et al.

• Reproductive diseases at and after calving tend to

(2000): reproductive diseases.

occur as an interrelated complex (see Chapter 34).

• Some diseases that are not specific infections of

the reproductive tract have an adverse effect on

Diagnosis

reproduction, e.g. Leptospira hardjo, BVD virus

(McGowan & Kirkland, 1995) and BHV-1.

Although a herd consists of many individuals, diagno-

• There is disagreement on the effect of high yield on

sis of a return-to-service problem that affects a large

fertility.

part of a herd requires a different approach from that

• There is disagreement on the effect of hereditary

taken to investigate the cause in an individual animal.

factors on fertility.

For this reason the individual will be dealt with first, fol-

Although the relative importance of the factors listed

lowed by the herd fertility problem.

above, along with other management factors, is still

poorly understood, what does seem to be beyond doubt

Diagnosis of the individual repeat breeder cow

now is that fertility, at least in high producing dairy cows

in the UK, is declining over time (Barrett, 2001).

One problem with diagnosis is that by the time the cow

The relationship between nutrition and fertility is a

is recognized as being a repeat breeder the situation

complex one that is still not fully understood. The

that prevailed at the time of reproductive failure may

reader may find the following reviews of interest: Britt *well have changed.*

(1995); Webb et al. (1997); Wathes et al. (1998); Webb et The clinician should take a history and carry out a

al. (1999); O'Callaghan and Boland (1999); Garnswor-

systematic clinical examination to find out whether any

thy and Webb (2000) and O'Callaghan et al. (2000).

of the factors that are likely to cause return to service

As an example of the complex interactions affecting

are present. The fullness and, therefore, costs of the

fertility, data from the very large study by Saloniemi et

investigation will need to be discussed with the farmer

al. (1986) showed the consequential effects of specific in advance and a diagnosis may only be pursued in valu-causes described in Table 36.5.

able animals.

For details of other complex interactions, the reader

A systematic approach to diagnosis is essential and

is referred to some original texts: Andersson et al.

the following procedure is suggested (Box 36.8).

(1991) and Gustafsson and Emanuelson (1996): hyper-

ketonaemia and fertility; Bartlett et al. (1986b) and

History: The history should cover various points as

Garverick (1997): cystic ovarian disease; Bartlett et al.

shown in Box 36.9.

(1986a) and Sheldon (1999): metritis/endometritis;

Curtis et al. (1985): metabolic disease, mastitis; Dohoo General examination: The clinician should carry out

and Martin (1984a): age, season and sire; Dohoo &

a brief general examination looking at the following

Martin (1984b): mastitis and ketosis; Britt (1995): nutri-

points:

Table 36.5

The consequential effects of management and disease on problems of fertility (reproduced from Saloniemi et al. , 1986

with permission of the publisher).

Cause

Consequential effect

Retained fetal membranes

Metritis

Anoestrus/suboestrus

Ovarian dysfunction

Winter calving

No

Yes

Yes

Yes

Highest herd milk yield

Yes

Yes

Yes

Yes

Parturient paresis

Yes

Yes

Mastitis

Yes

Yes

Ketosis

Yes

Yes

Yes

Retained fetal membranes

Yes

Metritis

Yes

Yes

Box 36.8

The systematic diagnosis of return to service.

are discussed more fully in Chapter 35 (see p. 536). The

use of milk progesterone assays may also improve diag-

- *History*

nostic accuracy (see p. 548).

- *Analysis of records*

Accuracy of diagnosis of cystic ovarian disease by

- *General clinical examination and body condition*

rectal examination*: When undertaking rectal palpation*

- *Examination of the reproductive tract (rectal, vaginal and*

suitable aids including ultrasound examination)

there are obvious difficulties in trying to assess the

nature of a cyst without rupturing it. A large, soft corpus

- *Appropriate laboratory tests*

luteum with no palpable ovulation papillum can be mis-

taken for a cyst. Some authors are very sceptical about

the accuracy of diagnosis of cystic structures by rectal

Box 36.9

The main factors to be covered in history taking.

palpation alone, for example Stolla et al. (1980) and

Guenzler and Schallenberger (1981). However, accu-

• Date of calving.

racy is immensely improved with transrectal ultrasound

• Dystokia and puerperal diseases

examination (Douthwaite & Dobson, 2000), and once

• Postpartum reproductive disease

again milk progesterone assays have their place in con-

• Other diseases (e.g. lameness, metabolic diseases)

firming whether functional luteal tissue is or is not

• Service details

Dates

present (Chapter 35).

Bull used

***Accuracy of diagnosis of endometritis**: Clinical diag-*

Natural or AI

nosis of endometritis is discussed in some detail in

• Inseminator service or DIY AI

Chapter 34 (see p. 521).

• Major management or environmental changes

• Is this considered to be a herd or individual cow problem?

Vaginal examination: There is a choice of two methods

of vaginal examination on the farm: manual or visual

using a vaginal speculum. In both cases the perineal

region and vulva are thoroughly cleaned and the vet-

• Body condition and conformation;

erinarian uses fresh plastic gloves. With manual exami-

• Signs of non-reproductive disease;

nation mucus in the anterior vagina is gathered and on

• Signs of vaginal discharge or dried pus or mucus on

withdrawal of the hand examined visually and olfacto-

the tail or hindquarters; and

rily. Minimum lubrication is used to avoid confusion

• Other signs, for example a raised tailhead.

between clear mucus and the lubricant. The cervix and

vaginal wall are palpated for lesions and abnormalities.

Rectal examination: The technique of rectal palpation

The vaginal speculum should be introduced with care

of the genital tract is fully described in various text-

and, when fully inserted, will give a clear view of the

books, as are the characteristics of the various normal

cervix. With both techniques the clinician may have *and abnormal structures in the ovaries and tract. The*

difficulty in passing the vulvo–vaginal junction, which is

purpose of carrying out a rectal examination is to

the narrowest part of the tract at this level. When using

assess:

a speculum great care should be taken to ensure that

the speculum does not transfer infection between cows.

• *The state of the ovaries;*

This is best achieved by using disposable, single-use

• *The condition of the bursae and uterine tubes;*

specula or autoclaving equipment between cows. If a

• *Uterine abnormality or status (e.g. metritis, adhe-*

single speculum is to be used on a number of cows at a

sions, pregnancy);

single visit, it must be thoroughly disinfected between

• *Internal slackness of the pelvic ligaments;*

cows. Box 36.10 shows the factors that should be

• *Absence of fat inside the pelvis (body condition);*

checked in a vaginal examination.

• *Vulval discharge (stimulated by palpation);*

• *Evidence of other conditions detectable on rectal*

Selection of samples for laboratory examination: Selec-examination (e.g.

cystitis,

pyelonephritis,

fat

tion of the appropriate laboratory examinations and the

necrosis).

frequency of sampling depend very much on circum-

Nowadays it is general practice to supplement, or

stances, including the value of the cow. The items listed

even replace, the manual rectal examination with a

in Box 36.11 may be considered.

transrectal ultrasound examination. This has the same

To extend the physical examination beyond what is

aims as listed above, but will on the whole give more

possible by palpation and transrectal ultrasound, the

accurate results. The use of transrectal ultrasound

patency of the uterine tubes can be investigated using

examination as a diagnostic tool and the comparative

the phenosulphonphthalein (PSP) dye test and/or starch

levels of accuracy of rectal examination and ultrasound

grain test as described by Kessy and Noakes (1979).

Box 36.10

Factors to be checked by vaginal examination.

Box 36.12.

Steps required to diagnose a herd fertility

problem.

• *Anatomical abnormalities.*

Heifers

• *History*

• *Damage*

• *Analysis of records*

Caused by dystokia:

Breeding

Rectovaginal fistula

Health

Pneumovagina/urovagina (see p. 519)

Production

Damage to the cervix

• *Selected clinical examinations and sampling*

Serving injuries caused by the bull

• *Conclusion*

Sadistic human interference

Other acquired conditions

Vaginitis (see p. 519)

Type and quantity of mucus

• *Quick, cheap and, in some cases, automated*

Purulent

hormone analysis;

Bloody

• *Non-invasive (or acceptably invasive) examination*

Smelly

of internal organs: hysteroscopy, endoscopy (trans-

Clear oestrous mucus

rectal ultrasound is already routinely used during

on farm fertility examinations);

• *Automatic or semiautomatic recording of physical,*

behavioural and biochemical changes that are

Box 36.11

Types of samples required for various laboratory

related to the animal's reproductive status, such as

tests.

body temperature, restlessness, changes in milk

• Single milk progesterone assay: an adjunct to rectal pal-

composition and hormone content;

pation and ultrasound examination

• Computer analysis of data: compilation over time

• Serial milk progesterone assays: monitor events around

of various measurements in the individual and

service, confirm diagnosis, monitor treatment

analysis of herd records (see Chapter 41b).

• Oestrone sulphate from milk, blood (specifically from the

placenta: indicates live calf)

• Heparinized blood for cytogenetic analysis

Diagnosis of a herd problem

• Clotted blood for serology (e.g. BHV-1, BVDV, Leptospira It is necessary to approach the diagnosis of a herd fer-hardjo, Neospora caninum)

tility problem systematically. It is not practical to lay out

• Purulent material from the uterus: aerobic and anaerobic

culture, antibiotic sensitivity

in any detail a series of steps to be followed because

as the investigation develops the information obtained

• Uterine biopsy for histology

• Samples from the cervix and uterus for serology and

guides the continued course of the investigation.

cytology

The four main causes of herd problems are poor fer-

• Vaginal mucus for campylobacter diagnosis using the

tility management, an infertile 'male', nutritional errors

vaginal mucus agglutination test (VMAT)

and deficiencies and infectious conditions. In general

terms the steps required are shown in Box 36.12.

History: The object of history taking is to acquire infor-New technological aids to diagnosis: In recent years

mation on the factors shown in Box 36.13.

advances in biochemistry, electronics and fibre optics,

along with skills and materials developed for embryo

Analysis of the records: It is useful, if possible, to transfer, have opened up new diagnostic possibilities.

examine the breeding records before visiting the herd.

There is every reason to believe that new equipment

If there are no records then establish a recording

and concepts will continue to be produced, which pres-

system. The objectives of record analysis in connection

ents problems as well as opportunities for the veteri-

with a herd fertility problem are the following:

narian. Most of the new techniques do not require

specifically veterinary skills and so may be used by a

(1)

To assess the current level of fertility in the herd

wide range of operators, although for best effect knowl-

and to establish whether a problem exists, and if

edgeable interpretation is needed. Choices have to be

so to determine the seriousness of the situation.

made about the lasting value of each new step forward

(2)

To look for clues to aetiology, by looking at the

as investing capital and training in inappropriate tech-

fertility of subgroups within the herd:

nology is unproductive.

•

Bull, semen or inseminator;

The relatively new aids to diagnosis can be classified

•

Age (lactation) group;

as:

•

Yield group;

Box 36.13

History taking in determining herd fertility

cases there may be no comparative data on the bull's

problems.

fertility; the problem could be due to poor insemination

technique or to improper semen handling.

• General aspects of the herd and farm

Number of breeding stock (male and female)

Stocking density

Examination of the animals: It is very useful to examine Type of housing

as many cows as possible to obtain a current picture of

Details of grazing

the herd, to observe the condition of the cows and to

Targets for reproduction and production

detect or confirm the incidence of obvious reproductive

Other enterprises

abnormalities. It also reveals the (in)accuracy of the

Information about the stockworkers

information supplied by the farmer or farm staff.

• Definition of the perceived problem

Advice should be given about culling of individuals that

Anoestrus

have a very poor prognosis.

Return to service

By this stage the clinician should have a good idea of

Vaginal discharges

the type of problem; how the investigation then devel-

Other manifestations

ops is a matter of clinical judgement which cannot be

• Duration of problem

detailed further.

• Proportion of herd affected

• Reproductive management

Calving management

Service management: cows and heifers (heat detec-

***Treatment** (see Chapter 42)*

tion, timing of AI, technician or DIY AI)

Bulls

The veterinarian is faced with some difficulties when

• Nutrition

Ration formulation

having to decide on appropriate and effective treat-

Feeding system

ments for cows that are presented as infertile. This is

Assessment of adequacy of nutrition e.g. yield, milk

partly because of the complex aetiology of return to

composition, condition score, metabolic profiles

service, but also because of the time that has passed

• *Details of 'herd health plan'*

since the factors that initiated the problem were

Disease monitoring

present. When using pharmaceutical products the

Intervention levels

reader is advised to consult the manufacturers' data

Preventive medicine initiatives

sheets for details of treatment, withdrawal periods,

Vaccination protocols

dangers and contraindications. Wherever possible the

Biosecurity

treatment should be followed up to see whether it has

• *Disease status of herd*

Details of herd status for infectious diseases known to

been successful or not and, if need be, repeated or

affect fertility, e.g. BVDV, BHV-1, leptospirosis

changed.

Incidence of conditions that have a direct effect on fer-

tility, e.g. retained fetal membranes, endometritis

Other diseases and conditions in the herd, e.g.

Ovulation failure

lameness

The most important cause of ovulation failure is cystic

ovarian disease. Treatment is based on whether the cyst

has been diagnosed as follicular or luteal. In most cases

the condition is probably caused by hypothalamic–

•

Seasonal effect;

pituitary dysfunction and it is, therefore, logical to treat

•

Familial effect;

the condition systemically. There is little or no benefit

•

Relevant infectious disease: e.g. non-specific *in rupturing the cyst manually, which also involves a risk*

endometritis after calving, Campylobacter

of causing haemorrhage and ovarian adhesions. Nor

fetus, Leptospira hardjo, Neospora caninum, does there appear to be any benefit from administra-BHV-1, BVDV, etc.

tion of drugs directly into the cyst.

Analysis and interpretation of herd fertility records

Many cystic structures found less than 42 days after

are discussed in much more detail in Chapter 41a,b.

calving are transient and benign, and in general these

Once a cause of the infertility is suspected, a valuable

do not require to be treated. Only if abnormal behav-

technique is to group the records of all animals that are

iour indicates that they are pathological or if there

influenced by the suspect factor and compare these with

is some pressing management need should they be

the records from all other cows. It can be difficult to

treated.

identify the cause of a problem where farmer insemi-

For follicular cysts the three therapeutics of choice

nation is associated with poor pregnancy rate. In these are human chorionic gonadotrophin (hCG),

gonadotrophin-releasing hormone (GnRH) or GnRH

up to three days before, can improve predictability of

analogues, such as buserelin, and progesterone-

the oestrous response. If fixed time insemination is used

releasing intravaginal devices (PRIDs) and controlled

and oestrus is observed later the animal should be

internal drug release (CIDR) (Dobson et al., 2001a).

inseminated again.

They all work in different ways to achieve the same end,

i.e. to put the animal under the influence of proges-

Fertilization failure

terone. One effect of this is to allow a build-up of LH in

the pituitary so that enough endogenous LH is available

Delayed ovulation: For many years one of the standard

after removal of the progesterone devices or regression

ways of treating apparently normal repeat breeders on

of the (induced) corpus luteum. This leads to normal

the farm has been to administer hCG or GnRH on the

preovulatory follicle development and ovulation, and in *day of service. The theory behind this was that many*

all cases the cow should be served at the first heat after

of these cases were thought to be due to lack of an

treatment. The duration of exposure to exogenous or

adequate gonadotrophin surge delaying ovulation,

endogenous progesterone is thought to be important in

although controlled trials of this type of treatment are

the non-recurrence of the cystic condition, with 14 days

lacking and a better approach may be to inseminate the

being preferable to seven (Nanda et al., 1989). There is cow again 24 hours after the first insemination.

also evidence to suggest that the success of treatment of

follicular cysts depends on whether the cyst is producing

Interference with transport of egg or spermatozoa:

oestradiol or not, as reflected by the presence or absence

When this is due to bilateral blockage of the uterine

of other follicles >5 mm in diameter. Following treat-

tubes (or other parts of the female tract), there is no

ment with an intravaginal progesterone releasing device

simple treatment. In some cases the diagnostic dye test

or GnRH, animals had a pregnancy rate to all insemina-

may remove a minor blockage and attempts have been

tions of 91 per cent when other large follicles were

made to achieve this by adding antibiotics and corti-

present in addition to the cyst, compared with 69 per cent

costeroids to the dye, which is introduced into the

if no other follicles were present at the time of treatment

uterine tube end of the uterus under gentle pressure

(Tebble et al., 2001).

using a cuffed catheter.

Human chorionic gonadotrophin has an LH-like

In valuable animals the use of ovum pick-up tech-

direct action on the ovary to induce luteinization of the

niques using transvaginal ultrasound-guided oocyte

cyst or follicles. GnRH stimulates the release of LH

aspiration can be used to harvest oocytes for in vitro

from the pituitary to achieve the same result. In both

production of embryos. One or more of these embryos

cases the lifespan of the luteal tissue produced is vari-

could then be implanted back into the uterus of the

able, ranging from about six days to about 18 days, and

donor, although it is probably more advisable to *oestrus can be expected about 8–22 days after treat-*

implant valuable embryos derived in this way into other

ment. It is desirable to examine the treated cows about

healthy heifers. In those animals that are not considered

seven days after treatment for the presence of luteal

of high enough genetic merit to be used as oocyte

tissue. If luteal tissue is found, treatment with PGF2a or

donors, but which the farmer simply wishes to get back

an analogue is a suitable way of increasing the pre-

in calf so as to induce another lactation, the implanting

dictability of the following oestrus. Service should be at

of a low cost embryo may be used as a treatment. This

that oestrus and aids to oestrous detection should be

has now become commercially feasible and technically

used. If there is no satisfactory response to the first

achievable for repeat breeders with no uterine or

treatment, the cow should be re-examined and treated

endocrine abnormalities; single step (in straw) embryo

again.

thawing, using embryos frozen in ethylene glycol, is

For cysts containing functional luteal tissue as judged *used, which allows embryo transfer with little more*

by ultrasound examination or milk progesterone assay,

equipment and skill than that required for AI (May,

injection of PGF2a or an analogue followed by insemi-

1996).

nation at observed oestrus is the most suitable

Other factors that can cause failure of fertilization

treatment.

are:

An alternative treatment, suitable for both types of

cystic ovarian disease, is the insertion of a PRID/CIDR,

• Service at the wrong time;

which can be left in position for 12 days, and after with-

• Poor-quality semen;

drawal the cow should be served, either at a fixed time

• Infertile bull;

or preferably at observed oestrus (Douthwaite &

• Problems with artificial insemination.

Dobson, 2000). If the type of cyst cannot be diagnosed

accurately, then administration of PGF2a or an ana-

These are dealt with elsewhere under Prevention, in logue, either on the day of PRID/CIDR withdrawal or

Chapter 38 on the bull, or by common sense.

Embryonic death

further 30 days later. Taylor (2002) describes in some

detail the technique for collecting samples by preputial

Although the aetiology of early embryonic death is

washing.

listed under nine headings (Box 36.7) only non-specific

Although there is no natural immune response in the

endometritis (already dealt with in Chapter 34), specific

bull, one successful form of treatment depends on vac-

metritis caused by C. fetus (see p. 582) and a variety of cination (Clark & Dufty, 1982). The vaccine is licensed

other infections and possibly maternal endocrine envi-

for use in a number of countries but not in the UK,

ronment are suitable for conventional treatment. All

although one can be made under licence in the UK for

the other conditions should be corrected by manage-

specific herds.

ment improvements or are dealt with in different chap-

Treatment of cows with local or systemic antibiotics

ters of this book.

is unreliable and because cows develop resistance to the

A number of different Campylobacter spp. are asso-

infection it is usually best to wait for this to develop.

ciated with infertility and abortion in cattle, the specia-

Whatever course is followed an infected cow should be

tion and subspeciation of which is complex and

regarded as potentially infective for at least two gesta-

currently under review using modern molecular tech-

tions after initial infection. Even after this time a few

niques. However, it is clear that the most common iso-

cows may remain infected. As it takes only one cow to

lates associated with fertility problems in the UK are C.

infect a bull when natural service is practised, it is clear

fetus subsp. venerealis and C. fetus subsp. fetus (Newell that it is hazardous to allow natural service of any cows

et al., 2000). Infection with either of these subspecies that have ever been infected. Vaccination of cows

should be thought of as a herd problem. In the case of

(where permitted) is widely and fairly effectively prac-

C. fetus subsp. venerealis the natural habitat of the tised in range conditions.

organism is the bovine reproductive tract and it does

On a herd basis, when campylobacteriosis is diag-

not multiply in the intestinal tract; it is thus transmitted

nosed the best advice is that natural service should stop

only as a venereal disease (Taylor, 2002; see also p. 582).

and all services should be by AI using semen from non-

In the bull, in which infection with C. fetus subsp.

infected bulls. Recently infected cows will continue to

venerealis is limited to the surface of the prepuce and return to service for some time. In suckler herds where

penis, spontaneous cure does occur but is erratic and

the use of AI to observed natural oestrus may be prob-

unreliable. Moreover, if the bull continues natural

lematic this approach can be facilitated by the use of

service of infected cows he will be re-infected as the

repeated oestrous synchronization and fixed-time arti-

superficial nature of the infection does not stimulate an

ficial insemination as described by Penny et al. (2000).

immune response in the bull. The organism colonizes

There is a management alternative, which is

the crypts of the preputial epithelium which increase in *extremely difficult to carry out successfully over a long*

both size and number as the bull ages. This means that

period and should be advocated only under special

the prepuce of the older bull provides favourable con-

circumstances. This is to segregate the herd and use the

ditions for the persistence of the organism, giving a

infected bull(s) on infected cows and AI or non-

higher incidence of carrier bulls among those over 5

infected bulls on non-infected cows and heifers. How-

years of age. Diagnosis and treatment are also more

ever, this depends on the accurate identification of the

difficult in the older bull (Taylor, 2002).

infection status of all animals.

The usual treatment of the bull involves preputial

Manipulation of the maternal endocrine environ-

lavage with streptomycin in a viscous oily medium and

ment post insemination by the exogenous administra-

parenteral treatment with the same antibiotic. Taylor

tion of progesterone or progestagens has been tried as

(2002) recommends daily systemic (e.g. intramuscular)

a treatment of repeat breeder cows or where herd con-

treatment with a combination of streptomycin and ception rates are particularly poor. However, the results dihydrostreptomycin, each at 150 mg per ml as sul- of such studies are variable and seem to be affected by phates at a dose rate of 10 mg per kg body weight. the time of progesterone administration and the initial Taylor (2002) gives a detailed description of the tech- fertility levels. A meta-analysis of 17 progesterone sup- nique of preputial lavage. It is important that both sys- plementation studies showed that treatment during the temic and local treatments are carried out thoroughly first week of pregnancy resulted in an increase in preg- and are repeated daily for three consecutive days. This nancy rate, especially on farms with poor fertility, while needs to be combined with further sampling for the treatment during the second and third weeks of preg- organism not less that 30 days after treatment has fin- nancy gave no overall significant increase (Mann & ished to confirm success of treatment. In a confirmed Lamming, 1999). At the present time treatments of this outbreak of campylobacteriosis, the bulls should be

type cannot be recommended as a means of improving
sampled twice, not less than three days and not more
conception rates, and more research is needed to iden-
than seven days apart, and this should be repeated a
tify suitable hormonal treatment strategies.

An alternative post-insemination treatment involv-
Results of treatment reported by different workers
ing the administration of GnRH (or GnRH analogues
are rarely comparable because different criteria for
such as buserelin) to the cow around 11 days after
selection of cases and assessment of success may have
insemination has become popular in recent years. In
been applied. In many cases self-cure is a phenomenon
some studies this has been shown to give very good
and because controlled studies are rare, interpretation
results. For example Sheldon and Dobson (1993)
of results is problematic. Accordingly it is suggested
achieved an improved pregnancy rate to first service of
that, as well as reading published reports, clinicians
approximately 10 per cent. A recent meta-analysis of

should analyse their own practice records of diagnosis,

studies of the effect of GnRH 11–14 days after insemi-

treatment and outcome.

nation concluded that while results were not consistent

The most common situation is the cow presented

across all studies, there was a significant improvement

after a few unsuccessful inseminations (or services),

in pregnancy rate amongst 2541 cows across six studies

which on examination appears to be normal. These

(Peters et al., 2000). However, post insemination hor-

apparently normal repeat breeders have an expected

monal treatments remain an unpredictable means of

pregnancy rate at the first service after examination that

improving pregnancy rate on any one given farm, and

is about the same as the first service pregnancy rate in

in most instances resources would probably be better

the herd, as indicated in Table 36.6.

targeted at improving the management of the herd

This is not to say that the factors influencing fertility

rather than instigating such treatment regimens.

in first service and repeat breeder cows are the same.

In the first service cows, fertility may be affected by

closeness to calving and the stress of peak yield. The

Stage of failure unknown: non-specific endometritis

population returning to service will have overcome

The two most common therapeutic approaches are (i)

these problems, but will include a higher proportion of

promotion of the cow's normal resistance to infection

cows that will never become pregnant. Unfortunately

by inducing oestrus and (ii) the use of antibiotics. There

before their ultimate disposal, cows in the last group

is a tendency for spontaneous elimination of the infec-

will have had two or three different treatments and

tious agents from the uterus, most likely due to the cow

several examinations at regular visits. In most cases

going through successive periods of oestrus. The current

there is no reliable way of identifying these problem

practical approach to treatment is discussed in detail in

cows.

Chapter 34 (see p. 521).

Where economics allow the hospitalization and

intensive investigation and therapy of repeat breeder *cows in referral centres (now very uncommon in the UK), the owner should be given a definite prognosis as soon as possible to minimize the cost involved in keeping and treating cows over several weeks. Much of this cost is due to the fact that once an animal has been served there is little positive that can be done except to monitor changes until pregnancy or non-pregnancy is confirmed. With modern diagnostic methods such as ultrasound scanning it is now possible to reduce the waiting time from service to diagnosis of non-pregnancy to a minimum of 25–30 days, and milk pro-*

Prognosis

From the client's point of view successful treatment means that the cow becomes pregnant; this is a two-stage process. Firstly, the cow has to return to normal reproductive function and secondly she has to conceive and remain pregnant. While the first stage is mainly the responsibility of the veterinarian, the second stage often depends on the farmer and farm staff. Where poor husbandry (i.e. feeding, housing or breeding management) is thought to be causing return to service, prog-

gesterone analysis can be used to give an indication of

nosis must be guarded because it is often a difficult

pregnancy status as early as 19–20 days post service.

and slow task for the veterinarian to effect a marked

Other methods of early pregnancy diagnosis such as

improvement.

assays for bovine pregnancy-associated glycoprotein

Table 36.6

Response of apparently normal repeat breeders served without treatment.

Number of cows

Treatment

Percentage pregnant at first

Reference

AI after examination

191

None

59.7

de Kruif (1975)

141

None

60.0

Refsdal (1979)

(bPAG) may also be used to speed up pregnancy diag-

In general, three factors affect the outcome:

nosis (Skinner et al., 1996). If the prognosis is

• The time that has elapsed since calving. Cases of

favourable, costs are reduced if the cow is returned to

cystic ovaries that occur up to six weeks after

the owner's farm where the local veterinarian can treat

calving have a good chance of spontaneous recov-

her.

ery. Cases that are first seen six months after calving

Accurate prognosis with long-term repeat breeder

have a very poor prognosis.

cows is also difficult. The prognosis for natural concep-

• The accuracy of diagnosis. If the type of cyst is

tion must always be regarded as poor, but particularly

misdiagnosed, selection of inappropriate treatment

so in cases with blocked uterine tubes, persisting

may give poor results.

endometritis and anomalous steroid hormone produc-

• The aetiology of the condition affects the outcome.

tion from the ovaries. For example, of 33 chronic repeat

If the cyst is caused by a temporary environmental

breeders treated by Boyd et al. (1984) only eight

influence such as poor nutrition, then the prognosis

became pregnant. However, the use of embryo transfer

is good even without treatment, once this environ-

techniques to maintain animals for subsequent lacta-

mental influence is corrected. At the other extreme,

tions may offer some hope and has been shown in some

if it is one of the minority of cases caused by defi-

studies to give reasonable results. May (1996) reports

ciency of LH receptors in preovulatory dominant

pregnancy rates in the region of 50 per cent using-single

follicles, the prognosis may be poor in the short

step (in straw) embryo thawing, with embryos frozen in

term as this may be the consequence of events

ethylene glycol. Furthermore, nowadays it is also pos-

occurring up to months previously.

sible to harvest oocytes from valuable animals for in

vitro production of embryos, and thus offspring, using The results presented in

Table 36.7, in most of which

transvaginal ultrasound-guided oocyte aspiration of

diagnosis and outcome were checked by progesterone

ovarian follicles.

assays, are typical of earlier published field trials.

The two most commonly diagnosed specific patho-

However, these data do not illustrate the ultimate

logical causes of return to service are cystic ovarian

benefit of treatment, which should be measured in

disease and purulent endometritis.

terms of calving or treatment to conception intervals

and culling rates (see Table 36.8).

Guenzler and Schallenberger (1981) treated 66

Cystic ovarian disease (see p. 526)

cows in which luteal cysts had been diagnosed by

In data collected from a number of veterinary practices

rectal palpation. After treatment with an analogue of

Bartlett et al. (1986b) recorded that culling rate for PGF2a, complete luteolysis occurred in the 35 cows

cows that had cystic ovarian disease was 26.6 per cent,

with mid-cycle levels of progesterone and all but three *compared with 21.6 per cent for other cows. Cows with*

of these started normal cycles. The first service

cystic ovarian disease that conceived had an interval

pregnancy rate for these cows was 40 per cent. The two

from calving to conception 33.5 days longer than cows

groups of cows with lower levels of progesterone

without cystic ovarian disease. More recently cystic

cycled erratically after treatment and had first service

ovaries were associated with 6 to 11 more days to first

pregnancy rates of 20 and 24 per cent. Nanda et al.

service and with 20 to 30 more days to conception in a

(1988) treated 77 luteal cyst cases with an analogue of

meta-analysis of papers published between January

PGF2a and 65 per cent of these exhibited initial recov-

1987 and January 1999 (Fourichon et al., 2000).

ery, i.e. the cyst regressed and a corpus luteum formed;

Table 36.7

The treatment of follicular cystic ovarian disease with GnRH.

Number of

Type of

Confirmed by

Treatment

Successful result:

Reference

cows

cyst

progesterone

progesterone rose

assay

within 14 days

104

Follicular

Yes

GnRH

73 (70%)

Nakao et al. (1983)

30

Follicular

Yes

GnRH

25 (83%)

Ax et al. (1986)

12

Follicular

Yes

None

3 (25%)

Ax et al. (1986)

116

Follicular

No

GnRH

61 (53%)

Nanda et al. (1988)

55

Follicular

Yes

GnRH

40 (73%)

Booth (1988)

44

Follicular

Yes

hCG +

32 (73%)

Booth (1988)

progesterone

Table 36.8

Fertility parameters of cows treated for follicular and luteal ovarian cysts (mean ± SE).

Treatment

Follicular

Matched

Treatment

Luteal cysts

Matched

(n cows)

cysts

controls

(n cows)

controls

Calving to

PRID

93 ± 27

90 ± 37

PRID

132 ± 49

93 ± 52

conception (days)a

(n = 22)

(n = 14)

Treatment to

PRID

24 ± 19

PRID

60 ± 67

conception (days)a

(n = 22)

(n = 14)

Culling rate (%)a

PRID

41

4

PRID

11

7

(n = 22)

(n = 14)

Calving to

GnRH

82 ± 7

70 ± 6

PGF2a

141 ± 15

68 ± 9

conception (days)b

(n = 16)

(n = 22)

Treatment to

GnRH

48 ± 9

PGF2a

20 ± 5

conception (days)b

(n = 16)

(n = 22)

Culling rate (%)b

GnRH

44

PGF2a

9

(n = 16)

(n = 22)

Calving to

PRID

125 ± 17

70 ± 6

conception (days)b

(n = 21)

Treatment to

PRID

33 ± 8

conception (days)b

(n = 21)

Culling rate (%)b

PRID

29

(n = 21)

a From Douthwaite and Dobson (2000).

b From Tebble et al. (2001).

not all became pregnant and in 18 per cent the cyst

than in normal cows. Time from treatment to concep-

recurred.

tion was about 75 days.

More recent results from Douthwaite and Dobson

Factors that affect prognosis have been quantified by

(2000) and Tebble et al. (2001) are summarized in Table Anderson (1985) who modified a system proposed by

36.8. In these studies the overall interval from calving

Studer and Morrow (1978), which was based on a

to conception was significantly greater than that of

careful analysis of clinical and laboratory observations.

matched controls irrespective of cyst type or treatment.

Anderson took into account (i) the time since calving,

Cows treated for luteal cysts took significantly longer to

(ii) whether oestrus had occurred since calving, (iii) the

get in calf than those treated for follicular cysts, again *amount of pus, (iv) the size of the cervix and (v) the*

irrespective of treatment. Cows treated for follicular

diameter of the larger affected horn. By giving points

cysts had a higher culling rate than those with luteal

for these factors a cumulative score was calculated that

cysts. It would seem that at least in the herds used in

gave a useful prediction about the eventual outcome of

these studies, farmers and veterinarians were prepared

the case. Cows that had been in oestrus had a poor

to persevere with cows diagnosed with luteal cysts, even

prognosis, presumably because they had not responded

at the expense of an extended calving to conception

to the normal defence mechanism.

interval, whereas cows with follicular cysts tended to be

Pepper and Dobson (1987) found that the relative

culled earlier.

amount of pus in the discharge gave a (non-significant)

indication of the pregnancy rate after treatment and

that time from calving to treatment was significantly

*Purulent endometritis/metritis (**see pp. 519, 521**)*

related to pregnancy rate after treatment. Cows treated

Ott and Gustafsson (1981) reviewed reports on over

with PGF2a or oestrogen within 40 days of calving had

600 cases and showed that in 85 per cent the uterus was

a pregnancy rate of about 55 per cent compared with

emptied within a few days of treatment with PGF2a or

a significantly poorer result for cows treated later.

an analogue. In most reports the authors stated that

From Anderson's (1985) data it appeared that in suc-

pregnancy rate after successful treatment was lower

cessfully treated cows there was a high incidence of

periparturient problems at the resultant calving and a

(d)

checking the fertility of the bulls;

very high culling rate in this group of animals in the year

(e)

checking the efficiency of the inseminators,

after treatment, observations that warrant further

and the quality of the semen used;

study. The treatment and control of endometritis and

(f)

understanding the causes of fertility varia-

metritis are discussed in more detail in Chapter 34.

tions in a specific herd.

As regards the outlook for herds with a return-to-

(5)

Avoidance of service contact outside the herd and

service problem prognosis varies and obviously is

ensuring veterinary examination, isolation and

related to the diagnosis. Some episodes of herd infer-

testing of bought-in breeding stock, especially

tility are of short duration and normal fertility returns

bulls will reduce the risk of introducing venereal

spontaneously.

diseases and other diseases affecting fertility. (See

In cases where a definite infectious cause is identi-

also Chapter 57 for a more in-depth discussion of

fied, such as campylobacteriosis, the outcome can be

biosecurity.)

completely satisfactory with the elimination of the

(6)

Good housing environment and cattle handling *infection and the return to a normal herd pregnancy*

will help to avoid stress, lameness, discomfort and

rate. This depends on treatment being carried out care-

fear in the herd.

fully and the subsequent control of breeding manage-

(7)

Consideration should be given to reproductive

ment being optimized.

dysfunction with a hereditary component, e.g.

Where the problem is related to poor husbandry

cystic ovarian disease.

caution should be expressed until clear signs of

(8)

Interventions that may cause embryonic death

improved management are noted.

should be avoided, such as drastic changes in

feeding and environment, herd medication and

the administration of vaccines in the weeks after

Prevention

service. In the case of vaccines the manufacturer's

recommendations should always be followed.

Improvement in pregnancy rates is achieved by encour-

(9)

Drug therapy, using either antibiotics or hor-

aging good husbandry and avoiding factors that have an

mones, in the post partum phase has been advo-

adverse effect on fertility. While it is possible to achieve

cated as a way of improving pregnancy rates. The

a very high fertilization rate (up to 100 per cent), some

doubtful value of this is discussed below.

embryonic death is inevitable, which is why it is rare for

a herd to achieve a pregnancy rate of greater than 70

Where specific drug therapy is applied selectively in

per cent.

cows identified as likely to have poor fertility this is

There are a number of items, listed below, which con-

obviously a suitable approach. However, it has been

tribute to good fertility, but deficiency in any one of

proposed that routine treatments should be applied to

these is likely to produce poor pregnancy rates.

all cows, normal and abnormal, and this is much more

questionable. For example in one study post partum

(1)

Accurate heat detection.

administration of PGF2a 21 days after calving reduced

(2)

Proper nutrition and maintenance of suitable

the interval to first oestrus and first service by about 10

body condition before and after calving.

days. Pregnancy rates to first service were increased and

(3)

Avoidance of dystokia and post partum abnor-

the number of services to conceptions was reduced

malities and timely veterinary intervention where

from 2.0 to 1.3 (Schofield et al., 1999). However, a

indicated. This should reduce the incidence of

number of trials have given conflicting results. Meta-

delayed involution, non-specific endometritis

analysis of 24 trials where PGF2a was administered to

(Chapter 34), blocked uterine tubes, cystic ovarian

cattle within 40 days of calving reported no beneficial

disease, etc. (see Chapter 34).

effect on first service pregnancy rate, although there

(4)

The proper use of records can help to achieve a

was a small reduction in days open for treated cows

good pregnancy rate and to avoid long interser-

(Burton & Lean, 1995). It is now becoming socially

vice intervals. This is done by:

unacceptable to administer hormonal products to cattle

(a)

not serving cows too soon after calving (not

as 'routine' treatments, and some sectors of the indus-

before 42 days);

try such as organic milk producers and many consumers

(b)

being aware of the expected return-to-

would rather that hormone preparations were not used

service date (for example, by using a three-

at all, or that their use were restricted to individual cows

week calendar);

with particular problems that cannot be treated by any

(c)

ensuring early pregnancy diagnosis via trans-

other means.

rectal ultrasound and milk progesterone

The routine use of antibiotics in both normal and

assays;

abnormal cows after calving or at the time of

insemination should be strongly discouraged; results

Ax, R.L., Bellin, M.E., Scheinder, D.X. & Haase-Hardie, J.A.

have shown no benefit to normal cows. Antibiotic usage

(1986) Reproductive performance of dairy cows with cystic

should be restricted to those animals where there is a

ovaries following administration of Procystin TM1. Journal specific therapeutic indication, and where failure to

of Dairy Science, ***69****, 542–5.*

treat may compromise the animal's welfare.

Ayalon, N. (1978) A review of embryonic mortality in cattle.

Journal of Reproduction and Fertility, ***54****, 483–93.*

In order to overcome problems with oestrous detec-

Bane, A. (1964) Fertility and reproductive disorders in

tion, oestrous synchronization and fixed time AI may

Swedish cattle. British Veterinary Journal, ***120****, 430–41.*

be employed; Lane et al. (2001) have reviewed methods

Barrett, D.C. (2001) Cattle fertility management in the UK.

of synchronization. The technique is best suited for

Cattle Practice, ***9***, *59–68.*

dairy heifers and beef suckler cows. For best results

Bartlett, P.C., Kirk, J.H., Wilke, M.A., Kaneene, L.B. & Mather, the farmer, the veterinary surgeon and a member of

E.C. (1986a) Metritis complex in Michigan Holstein–

the insemination organization should discuss the

Friesian cattle: incidence, descriptive epidemiology and esti-

whole operation well beforehand. The best results are

mated economic impact. Preventive Veterinary Medicine, ***4***, *obtained when only reproductively normal cows at least*

235–48.

six weeks after calving (preferably longer) or maiden

Bartlett, P.C., Ngategize, P.K., Kancene, J.B., Kirk, J.H., Anderson, S.M. & Mather, E.C. (1986b) Cystic follicular disease heifers are included, although it is possible to synchro-in Michigan Holstein–Friesian cattle: incidence, descriptive

nize cows that have had a shortened post partum period

epidemiology and estimated economic impact. Preventive

(Penny et al., 2000; Penny & Lowman, 2002). First

Veterinary Medicine, ***4***, *15–33.*

calvers and animals in poor body condition tend to give

Beghelli, V., Boiti, C., Parmigiani, E. & Barbacini, S. (1986) poor results and may need additional hormones such as

Pregnancy diagnosis and embryonic mortality in the cow.

equine chorionic gonadotrophin and nutritional treat-

In Embryonic Mortality in Farm Animals (ed. by L.M.

ments. Results following synchronization of dairy cows

Sreenan & M.G.

Diskin),

pp.

159–67.

Nijhoff,

can be satisfactory (Biggadike & Mawhinney, 1996;

Dordrecht/Boston/Lancaster.

Jobst et al., 2000) and cost-effective (Esslemont & Biggadike, H. & Mawhinney, I. (1996) Planned breeding

Mawhinney, 1996), but currently still need insemina-

routine in dairy cows using a treatment regimen involving

tions at observed oestrus for optimal results. Stress and

GnRH and PGF2a. A multi site study (interim report).

*Cattle Practice, **4**, 289–91.*

any change in management and diet should be avoided

Bon-Durant, R. (1997) Pathogenesis, diagnosis and manage-

during preparation and for three to four weeks after

ment of trichomoniasis in cattle. Veterinary Clinics of North insemination. As far as possible other interventions

*America: Food Animal Practice, **13**, 345–61.*

such as vaccination should be avoided during the same

Booth, J.M. (1988) The milk progesterone test as an aid to the period. Some of the oestrous synchronization regimens

diagnosis of cystic ovaries in dairy cows. Veterinary Record, may be used for the repeat synchronization of cows not

***123**, 437–9.*

in calf to the first service (Penny et al., 2000; McDougall, Boyd, H. & Reed, H.C.B. (1961a) Investigations into the

2001; Penny & Lowman, 2002); this allows repeated

*incidence and causes of infertility in dairy cattle – Fertility fixed time insemination. However, if repeat synchro-variations. British Veterinary Journal, **117**, 18–35.*

nization is not to be used it is essential that preparation

Boyd, H. & Reed, H.C.B. (1961b) Investigations into the inci-is made to deal with the cows that return to oestrus,

dence and causes of infertility in dairy cattle – influence of some management factors affecting the semen and insemi-such as an intensive period of heat detection approxi-

*nation conditions. British Veterinary Journal, **117**, 74–86.*

mately 19–24 days after the initial service. If natural

Boyd, H., Renton, J., Munro, C., Harvey, M., Isbister, J. & Kelly, service is to be used on these returns it is essential that

E. (1984) Clinical studies of a series of long (term) repeat

the 'sweeper bull' is not presented with an excessive

breeder cows and heifers. Vlaams Diergeneeskundig

number of cows in oestrus over a very short period of

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time (see Chapter 38).

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Chapter 37

Fetal Loss

G. Caldow and D. Gray

Introduction

577

(Bolin & Alt, 1998) can cause embryonic death or death

Pathophysiology

577

that occurs shortly after birth. Such embryonic loss or

Placentitis

578

early abortion is difficult to detect and increased neona-

Causes of abortion

578

tal mortality may not be immediately associated with

Viral causes of abortion

578

disease processes that affect the fetus.

Bovine viral diarrhoea (BVDV)

578

It is also important to define what is normal or

Bovine herpes virus 1 (BHV1)

579

unavoidable loss. Spontaneous chromosomal abnor-

Other viruses

579

Bacterial causes of abortion

580

malities are commonly held to account for the bulk of

Brucellosis

580

unavoidable wastage and a loss of 20 per cent of

Leptospirosis

580

embryos by day 45 of gestation has been estimated

Bacillus licheniformis

581

(Roche et al. , 1981). After this period losses are far Listeria monocytogenes

581

lower: an abortion rate of 6.5 per cent was calculated

Salmonellosis

582

by Forar et al. (1995) who reviewed 26 published

Campylobacter

582

studies. Stillbirth losses of 4 to 6 per cent have been

Miscellaneous bacteria

584

quoted (Miller, 1988) and a study of more than 2000

Protozoal causes of abortion

584

beef cow calvings found a mortality rate of 4.5 per cent

Trichomoniasis

584

within 24 hours of birth (Nix et al. , 1998). In contrast, Neosporosis

584

the target used in beef production in Britain for live

Other infectious agents causing abortion

586

Chlamydia and rickettsia

586

calves born is 94 per cent (MLC, 1998) and the estimate

Mycotic abortion

586

of 1.9 to 2.0 per cent losses after day 42 of gestation

Non-infectious causes of abortion

586

(Sreenan & Diskin, 1986) may be a more realistic target

Investigation

587

for unavoidable fetal loss. This is further supported by

Conclusion

589

a survey of Irish dairy cows that found an abortion rate

of 1.7 per cent (Mee, 1992). From this it would seem

justifiable to use an interference level of 3 per cent

Introduction

for abortions or losses after confirmation of pregnancy

at around 6 weeks and one of 2 per cent for deaths at

The failure of the cow to carry a calf to full term or to

parturition and in the neonatal period.

produce a live calf causes financial loss through disrup-

tion of the normal pattern of milk production, the loss

of genetic material or an absolute loss in output for the

Pathophysiology

beef cow. These losses can have a profound effect at the *herd level. For example, neosporosis has been reported*

The clinical manifestation of disease of the conceptus

to cause abortion rates of 26 per cent (Wouda et al. , is largely the consequence of the stage of develop-1999). Losses on this scale may be relatively unusual,

ment when exposure to the agent occurs (McGowan &

but annual losses of 10 per cent are not uncommon.

Kirkland, 1995), the difference in virulence between

Assessing the scale of these losses is made difficult by

strains of recognized fetal pathogens (Dubovi, 1992)

the definitions used and the differing clinical manifes-

and the degree and duration of exposure in the case of

tations. In Britain abortion is described as the birth of

non-infectious causes. The corpus luteum is necessary

a live or dead calf before 271 days' gestation and still-

for maintenance in the first half of gestation (Wendorf

birth as the production of a dead calf after 272 days of

et al. , 1983) and destruction of the corpus luteum during gestation (Noakes, 1986). However, agents that infect

that time will usually result in the termination of preg-

the conceptus, such as bovine viral diarrhoea virus

nancy and the expulsion of a fresh fetus and mem-

(McGowan & Kirkland, 1995) or leptospira organisms

branes. However, fetal death may either cause lysis of

the corpus luteum and the expulsion of an autolysed

of the virus to cause abortion in the early stages of

fetus some days later or the corpus luteum may persist

gestation, at a time when both finding the fetus and

and the fetus and membranes then undergo mummifi-

achieving a diagnosis are more difficult, suggest that the

cation. If bacterial infection is present maceration

true rate of fetal loss due to BVDV may be higher.

of the fetus is the result. As a consequence, early

Infection is most often introduced into the herd by

abortions are rarely observed and when they are the

the purchase of a persistently infected (PI) breeding

advanced autolysis limits the examinations that can be

replacement and can be maintained in the herd by

carried out.

the birth and survival to breeding age of further PI

The fetus and placenta maintain the pregnancy in the

animals. In the beef herd infection can be maintained *later stages. Fetal death removes this support and abor-*

within successive calf crops as the calves are kept

tion follows after a period of a few days. Autolytic

with the cows during the breeding period and beyond

change is a feature in these cases too, characterized

the first trimester of pregnancy. Persistently infected

by the presence of bloody fluid in the body cavities

animals produce the largest amount of virus, particu-

(Dillman & Dennis, 1976) and a loss of microscopic cell

larly in their nasal secretions, while acutely infected

detail. However, fetal death is not the only consequence

animals are also infectious to others for at least 15 days

of disease processes affecting the fetus and placenta.

(Duffell & Harkness, 1985). Both persistently infected

Fetal stress primarily due to anoxia will trigger the

bulls (Meyling & Mikel-Jensen, 1988) and bulls under-

steroid response necessary for normal parturition

going acute infection (Paton et al. , 1989) can pass the (Knickerbocker et al. , 1986) and a relatively fresh fetus virus in semen.

can be expelled in these circumstances; indeed, calves

Acute infection during the breeding season and in *may be born alive and survive from day 260. Signs*

the first trimester of pregnancy can result in a range

of prolonged fetal stress include staining of the per-

of outcomes from reduced conception rates or fetal

ineum by meconium and inhalation or ingestion of

death to the persistence of infection in the fetus

meconium.

(Kirkland et al. , 1997). Infection in both the first and the second trimester can cause abortion or developmental

abnormalities, particularly of the nervous system

Placentitis

(Baker, 1987). The virus appears to be less pathogenic

to the fetus in the third trimester and from 100 to 120

Placentitis is the principal lesion in several infectious

days of gestation the fetus can mount an immune

disease processes associated with fetal loss, and in cattle

response to the virus, a response that becomes more

the placenta is often retained after abortion in the

effective as the pregnancy progresses.

second half of gestation. The precise reasons for pla-

Following acute infection, the virus multiplies in the *cental retention are not known, but this is a further*

placentome, but does not cause placentitis, before

factor limiting the investigation of many cases.

moving into the fetus. In the first trimester lesions in the

fetus include meningitis with cerebellar cortical

destruction and necrotizing bronchiolitis (Casaro et al. , ***Causes of abortion***

1971), but these are rarely observed due to autolysis.

Sublethal damage in the first trimester and beyond can

A wide range of infectious and non-infectious causes of

result in the birth of calves with lesions such as retinal

abortion have been reported, many of which are asso-

dysplasia and cerebellar hypoplasia. The difference in

ciated with only occasional or sporadic fetal loss. The

virulence between strains described for both type 1 and

following discussion concentrates on the more preva-

type 2 viruses (Dubovi, 1992), along with stage of ges-

lent conditions in British herds, with only occasional

tation at which individual cows are exposed to infection

reference to exotic causes.

and the variation in the level of herd immunity, explain

the wide differences seen in the outcome of BVDV *infection in breeding herds.*

Viral causes of abortion

The virus can be isolated from an aborted fetus

although the success of this is limited by autolysis. It can

also be demonstrated in fixed tissues using immunohis-

Bovine viral diarrhoea (BVDV) *(see p. 853)*

tochemistry. This allows the agent to be associated with

Laboratory diagnostic rates of 5.4 per cent (Kirkbride,

lesions observed on histological examination (Ellis

1992a) and 6.5 per cent (Caldow et al. , 1996) have been et al. , 1995). Nested reverse chain transcriptase poly-reported, but the widespread evidence of infection in

merase chain reaction (PCR) techniques have been

English dairy herds (Paton et al. , 1998) and the ability used to detect viral RNA in tissues and may, in future,

become the diagnostic technique of choice (Nettleton

attributed to natural infection with BHV1, fetuses show

& Entrican, 1995). As maternal antibody cannot cross

no typical gross lesion, but histological examination

the bovine placenta, antibody detected in fetal fluids

consistently reveals multifocal coagulative necrosis in *indicates fetal infection. However, when antibody is*

the liver and less frequently in the lung, lymph nodes,

detected in late abortions without the presence of spe-

kidney and placenta (Kirkbride, 1992b). These changes

cific pathology BVDV may not have been responsible

and the absence of fetal antibody suggest an acute

for fetal death (Brown et al. , 1979).

infection and appear to conflict with the prolonged

Maternal immunity to infection is not life-long. Infec-

period between experimental infection and abortion.

tion with heterologous strains of the virus can also

Virus can be isolated from up to 50 per cent of fetuses

overcome natural immunity. Control should therefore

that show histological lesions typical of BHV1 infection

be based on a programme that includes best practice

with the placenta being the most useful tissue for

biosecurity, identifying and removing persistently in-

culture (Kirkbride, 1992b). Other diagnostic techniques

fected breeding animals from the herd and screening

that have been described include fluorescent antibody

purchased replacements for the presence of PI animals.

staining on cryostat sections of fetal tissues, immunos-

Vaccines (p. 1011) now available in Britain have been

taining of lesions observed in fixed tissues and PCR

shown to prevent fetal infection (Brownlie et al. , 1995), techniques (Rocha et al. , 1999).

but vaccination should not be relied upon as the sole

It seems likely that active immunity ensures that re-

preventive strategy. The success of eradication and

infection does not result in significant clinical disease

biosecurity as a means to control BVD can be meas-

and the use of a live modified vaccine has been shown

ured by the progress made by the countries that have

to prevent abortion following experimental challenge

embarked on national or regional control programmes

(Cravens et al. , 1996). However, it remains unclear how (Hult & Lindberg, 1998)

long after infection cows are protected from the abor-

tifacient effects of the virus.

As BHV1 is an insignificant cause of fetal loss

Bovine herpes virus 1 (BHV1) *(see also p. 289)*

in Britain there is little financial incentive to control

In Western Europe there is little to suggest that BHV1 *the disease in breeding herds for this reason alone.*

is a significant cause of abortion. In contrast, in North

However, the virus may be found in the semen of

America BHV1 has been shown to be the most fre-

infected bulls and it is illegal to sell semen from

quently diagnosed viral cause of abortion (Kirkbride,

antibody-positive bulls to third countries within the

1992a; Anderson et al. , 1997) and experimental chal-

European Union (EU). Several continental European

lenge models to test vaccine efficacy have resulted in a

countries have successfully eradicated the disease or

high rate of fetal loss (Miller et al. , 1995). This differ-have national control programmes in place and indi-

ence may be the consequence of a variation in virulence

vidual herds within these countries are unable to import

between the strains of the virus found on the two

seropositive animals. There is therefore a sound argu-

continents.

ment for pedigree and high genetic merit herds to

BHV1 exists as two distinct subgroups and causes

eradicate the disease by a test and cull programme *two clinical syndromes: infectious bovine rhinotra-*

supplemented by biosecurity measures. Gene deleted

cheitis (IBR) and infectious pustular vaginitis (IPV).

vaccines offer an alternative to a test and cull pro-

Neither clinical syndrome is exclusively associated

gramme and have been used in the Netherlands

with a particular genotype of the virus and abortions

(Kaashoek et al. , 1995). Even where breeding herds

have been observed with both subgroups (Barr &

do not sell semen or pedigree animals, the apparent

BonDurant, 1997). As with all herpes viruses the agent

difference in virulence between European and North

is maintained in a latent form in infected animals, but

American strains of the virus makes it prudent to

can be re-activated at times of stress (Kaashoek et al. , exclude exotic strains of BHV1 by implementing biose-1996). In young animals epidemic IBR often follows the

curity measures.

introduction of market purchased animals to the herd.

Similar outbreaks of clinical disease may be seen in

Other viruses

adults, but subclinical disease is more common in this *age group. Infection in breeding herds tends to become*

While a range of other viruses have been isolated from

endemic, with young cows infected as they enter the

aborted fetuses there is little to support their role as

breeding herd (Pritchard, 1992).

important causes of fetal death. The exceptions are

Experimental infection with the virus at 25 to 28

bovine herpes virus 4 (BHV4) and Akabane virus.

weeks of pregnancy resulted in abortions between 17

There is epidemiological evidence of an association

and 85 days later (Miller et al. , 1991). In abortions between BHV4 seropositivity and abortion in cows in

Belgium (Czaplicki & Thiry, 1998) and in the USA the

are pursued. Vaccination has been used in many

virus was the third most frequently isolated from fetal

national or regional eradication programmes, often in

submissions to a diagnostic laboratory over a 10-year

the early stages of control (see p. 1013).

period (Kirkbride, 1992b). There is no published record

of the agent's involvement in British cattle and rele-

Leptospirosis *(see also p. 735)*

vant diagnostic tests are rarely used. It may be of

value to consider BHV4 when the usual investigative

The disease in cattle is caused by the organisms col-

procedures in problem herds have been unsuccessful.

lectively referred to as Leptospira hardjo (L. borg-Akabane virus is an arthropod borne virus that has

petersenii serovar hardjo and L. interrogans serovar been shown to cause a range of congenital abnormali-hardjo, previously named Leptospira interrogans seroties that include arthrogryposis and hydranencephaly as

vars hardjobovis and hardjoprajitno, respectively).

well as abortion. The virus occurs in Australia, Japan,

These are host-adapted serovars responsible for disease

South East Asia, Africa, Israel and Turkey and it would

in cattle. In New Zealand there is little evidence that

appear to be maintained in a range of mosquito and

these are significant pathogens of cattle and their

culicoides species (Charles, 1994). The significance of

importance lies in their zoonotic impact (Bolin & Alt,

Akabane virus to British herds is limited, but the trade

1998). Conversely, disease surveillance figures from

in live animals that would follow inclusion of countries

New Zealand have found Leptospira pomona, a serovar

such as Turkey to the European Union could render this

that is not adapted to cattle, in 1.3 per cent of abortion

virus something other than an exotic curiosity.

cases examined (Thornton, 1991). In Victoria, Australia,

experimental infection of pregnant heifers with a

Bacterial causes of abortion

locally isolated strain of L. interrogans serovar hardjo failed to cause abortion or to establish fetal infection

(Chappel et al. , 1989). In Britain and Ireland lepto-

Brucellosis *(see also p. 461)*

spirosis is associated with infertility, abortion and

According to EU criteria Britain is officially free of

milk drop. As it is difficult to detect evidence of infec-

Brucella abortus infection, but animals from areas with tion in the fetus it is also difficult to determine the true

a lower status for this disease are imported and as a con-

significance of leptospirosis as cause of fetal death,

sequence the government continues to carry out post

however diagnostic rates of 1.7 per cent have been

import checks and routine serological monitoring of the

observed in Scotland (Caldow et al. , 1996) while in *herds in Britain.*

Northern Ireland 42 per cent of aborted fetuses showed

The organism is an intracellular pathogen that is

evidence of infection (Ellis et al. , 1982). The disease is spread in infected uterine discharges. After infection

widespread in the national herd and bulk milk antibody

has occurred, usually by ingestion, an animal remains

testing showed 75 per cent of samples from dairy herds

infected for life and the principal sign of this infection

in England and Wales to have antibody present

is abortion due to placentitis. This is characterized as a

(Pritchard, 1999).

purulent intercotyledonary placentitis with necrosis

Infection is through exposure to contaminated urine

of the cotyledons. Live calves are produced from sub-

and leptospires penetrate intact mucosal surfaces to

sequent pregnancies although the uterine discharges

establish a bacteraemia. The agent localizes in the

remain a source of infection. Apart from the severe

urinary and reproductive tracts and is passed in large

effects on cattle production the disease is also an impor-

numbers in the urine in the early stages of the disease

tant zoonosis.

and may be passed intermittently for prolonged periods

In Britain there is a legal obligation for farmers to

thereafter. Spread of infection within a herd is most

notify the government's animal health service of any

rapid during the grazing season, an observation that has

bovine abortion and it is then at their discretion to

been explained by the longer survival times for the

require the collection of diagnostic material by the

organism that occur in the moist neutral pH conditions

farmer's veterinary surgeon. Microscopic examination

found at pasture in contrast to the more acid environ-

of smears made from vaginal swabs, bacteriological

ment that prevails when animals are housed, particu-

culture of milk and vaginal swab and a range of sero-

larly where ensiled forage is fed.

logical techniques can then be employed to screen for

Infection is generally considered to be introduced to

evidence of the disease. It is important for both farmers

a herd through the addition of infected cattle, but both *and their veterinary surgeons to recognize that these*

sheep and horses can maintain the infection and one

procedures are not used to test for other abortion

study has suggested that sheep, the use of natural

agents.

service and the presence of water courses that have

Control of the disease is the preserve of the State

run through other farms may all be risk factors for

Veterinary Service in Britain and test and cull policies

leptospirosis infection (Pritchard et al. , 1989).

As with several other infections, abortion occurs as a

the sale of breeding replacements accredited free of

chronic sequel, following up to 12 weeks after what is

infection.

often a subclinical acute infection of the dam. Aborted

fetuses and placentas do not show any characteristic

Bacillus licheniformis

pathology that is of diagnostic value, but the time

Bacillus species are saprophytes that are widely dis-

course of infection is such that the fetus may have been *tributed in the environment and with the exception of*

able to mount an immune response and produce anti-

Bacillus anthracis are generally considered to have little body. This antibody can be detected in fetal fluid by the

pathogenic potential. Species differentiation is not easy,

microscopic agglutination test (MAT). Isolation of lep-

but the principal isolate from bovine abortions is Bacil-

tospires from fetal tissues is a preserve of the specialist

lus licheniformis. Bacillus organisms have been isolated laboratory and is not routinely used as a diagnostic test.

from 9.8% of fetal specimens (Caldow et al. , 1996) and The fluorescent antibody test performed on cryostat

outbreaks of abortion associated with this agent are

sections or impression smears of fetal tissues found

commonly observed (David, 1993). Just how an organ-

favour for some time but inherent difficulties of such

ism that is considered to have little pathogenic poten-

techniques in autolytic tissues mean that these tests too

tial can appear to be such an important fetal pathogen

are now less frequently used. Once again the detection

is not clear. It has been suggested that the risk of abor-

of specific DNA may well become the technique of *tion may be related to the weight of infection in the*

choice and several PCR methods have been described

environment, either in silage or in other forage or in

(Smith et al. , 1994).

contaminated water. However, other factors may be

The literature on maternal serological response is

important and in 45 per cent of fetuses where a diag-

extensive and serves to underline the diagnostic limi-

nosis of Bacillus licheniformis abortion was made evitations of serological techniques. The MAT has long

dence of fetal infection with Neospora caninum was

been the standard test and principally detects antibody

also found (Caldow et al. , 1996). Despite this the ex-of the IgM class. These antibodies are produced as

perimental infection by the intravenous route alone

an early response to infection and may have fallen to

has resulted in placentitis and abortion with lesions

undetectable levels by the time the animal aborts.

similar to those observed in naturally occurring

The enzyme linked immunosorbant assay (ELISA) can

incidents (Agerholm et al. , 1999).

be designed to detect a specific subclass of antibody

Usually abortion occurs relatively late in pregnancy

or a mixture, but the commercially available ELISAs

and lesions of a necrotizing placentitis are observed

usually detect predominantly IgG. After infection an

with thickening of the intercotyledonary areas and

animal produces detectable levels of IgG by 21 to

adventitious placentation. Suppurative bronchopneu-

28 days and these persist for prolonged periods.

monia and occasionally pericarditis can be found in the

Serology does not allow the differentiation between

fetus. The organism is readily isolated from the pla-

vaccinal titres and those that follow natural infection.

centa, fetal lung and fetal stomach contents, but on

For these reasons maternal serology is of little value

occasion the organisms can no longer be cultured from

in the individual animal that aborts and is best used as

the fetus despite isolation from the placenta and the

a herd diagnostic technique on the understanding

presence of typical pathology.

that it may have limited applications in vaccinated

There is no indication that the bacteraemia that pre-

herds.

cedes the abortion is associated with any clinical disease

In dairy herds a principal reason for controlling the

in the dam and no serological test has been developed.

infection by vaccination is to reduce the risk of zoonotic

In herds experiencing outbreaks group treatment

disease in those milking the cows, but one study has

with antibiotic is sometimes advocated, but there is no

claimed an improvement in fertility indices after vacci-

evidence of efficacy. It is prudent to screen cows for the

nation (Dhaliwal et al. , 1996). In beef herds the risk of presence of other agents that may be acting as cofac-zoonotic infection is low and there is no published study

tors as well as to carry out bacterial counts on silage. A

to demonstrate the value of vaccination, although this is

threshold of 104 colony forming units/g has been sug-

a commonly used control strategy. Similarly the use of

gested above which forage should not be fed to preg-

quarantine, serological screening and antibiotic treat-

nant cows (David, 1993). Other potential sources of the

ment of animals that are seropositive are measures that

organism should also be investigated, including drink-

have been recommended (BCVA, 1992). A successful

ing water.

national herd control programme based on the appli-

cation of biosecurity and test and cull exists in the

***Listeria monocytogenes** (see also p. 904)*

Netherlands. In Britain a programme of accreditation

of freedom of disease has operated since 1989 (MAFF,

There are similarities between listeria and bacillus as

1989). Both approaches offer the benefit of allowing

causes of abortion, although Listeria monocytogenes is

generally considered to be a more significant pathogen.

wildlife. The carrier state is particularly important in the

It may be associated with clinical disease in the dam,

spread of the disease and S. dublin shows a greater ten-but is usually only a sporadic cause of cattle abortion.

dency towards the carrier state than S. typhimurium in Listeria monocytogenes is a small Gram-positive rod

cattle. Studies on the epidemiology of S. typhimurium

that grows rapidly in aerobic or microaerophilic condi-

determinant type 104 have also demonstrated the

tions at temperatures of between 3 and 45°C. It can tol-

important role of newly introduced animals in the

erate pH values as high as 9.6, but is inhibited by pH

spread of this disease (Evans & Davies, 1996). While it

values lower than 5.6 and exists as a plant saprophyte

remains unclear how important wildlife are in initiating

or as an animal pathogen (Low & Donachie, 1997). It

new outbreaks, infection was found to be maintained in

is these characteristics that are crucial to the epidemi-

rodent and wild bird populations after an outbreak.

ology of the disease in ruminants, allowing growth of

Infection of the placenta follows bacteraemia and

the organism in poorly fermented silage and infection

extension to the fetus can follow from this. However,

by ingestion.

neither infection of the fetus nor indeed placentitis is

The clinical syndromes most commonly observed in

required to cause fetal death or abortion. Where fetal

cattle are iritis and meningoencephalitis, with abortion

infection has occurred gross lesions are non-specific;

an uncommon sequel of either of these. Silage feeding

histological lesions of fetal septicaemia may be found *is associated with a risk of listeriosis, however disease*

and the organism may be isolated from fetal tissues and

can occur when animals are grazing pasture. In addi-

the placenta. If the cow is showing signs of septicaemia

tion to L. monocytogenes, the closely related Listeria at the time of abortion it is advisable to attempt to

ivanovii is also isolated occasionally from cattle fetuses isolate the organism from faeces. Serological tests for

(Alexander et al. , 1992).

salmonellosis are available, but are not used routinely

In listeric abortion the aborted fetus is often

for diagnostic purposes in the investigation of bovine

autolytic, but non-specific lesions of placentitis and fetal

abortion.

septicaemia may be seen (Barr & Anderson, 1993) and

Once a diagnosis of salmonellosis has been made

the organism can be readily isolated from fetal viscera,

control rests on efforts to minimize further spread of

stomach contents and the placenta. Serological tests for

infection within the herd through improved hygiene

exposure to listeria exist, but are not used in the diag-

and thorough cleaning and disinfection. There are *nosis of bovine abortion.*

conflicting reports of the effectiveness of vaccination

The same restraints on treatment and control of

against S. typhimurium in the face of an outbreak

bacillus apply to listeria. High-risk forages, which in this

(Davies & Renton, 1992; Mee & Malone, 1995), but a

case are poorly preserved silages with a pH greater than

S. dublin vaccine is available and has been used suc-

5, should not be fed to pregnant cattle. In addition to

cessfully in endemically infected herds (Wray et al. , ensuring conditions that promote good anaerobic fer-1989). The removal of S. dublin carriers after an outmentation during the ensilage process, measures should

break appears to be an attractive course of action, but

be taken to reduce soil and faecal contamination of the

this approach is impractical as excretion is periodic.

grass prior to and during harvesting.

Faeces must be cultured with negative results on three

occasions at 14-day intervals before an animal is con-

sidered to be free of infection. In addition, animals must

***Salmonellosis** (see also Chapter 15; p. 850)*

be individually housed or stall-tied with this method as

According to British diagnostic data, salmonella organ-

there is the possibility of passive excretion if animals

isms were isolated from 159 to 300 cases of bovine abor-

are loose housed or at pasture (Radostits et al. , 1994).

tion in each of the years of 1994 to 1998 (MAFF, 1998a).

Farmers should be aware of the risks that purchased

During this period Salmonella dublin made up 82 per

breeding replacements pose and added animals should

cent of these diagnoses. In contrast, S. dublin accounted be placed in quarantine and screened by culture as

for 31 per cent of the non-abortion salmonella cases

above.

in adult cattle whereas the figure for Salmonella

typhimurium was 54 per cent (MAFF, 1998b). These

Campylobacter *(see also p. 568)*

data suggest that S. dublin is more likely to manifest as a primary abortion problem than is S. typhimurium.

Venereal campylobacteriosis is considered to be an

There is a variation in the number of S. dublin cases important cause of bovine infertility wherever natural

diagnosed on a regional basis, indicating an endemic

service is used and abortions are a feature of this

problem in some areas.

disease. Recent observations have suggested that the

Salmonella organisms are members of the Entero-

condition may be more prevalent in beef herds in

bacteriaceae and as such can be found as part of the

Britain than has been widely presumed (Caldow &

intestinal flora in many species of domestic animals and

Taylor, 1997).

C ampylobacter fetus is a microaerophilic, motile

Diagnosis of C. fetus as a cause of abortion rests on bacterium that has two recognized subspecies: C. fetus

the isolation of the organism from the fetus. As faecal

subsp. venerealis and C. fetus subsp. fetus. Differentia-contamination of the placenta may occur after the abor-

tion has been based on the variation of antigenic and

tion, isolation from the placenta should not be consid-

biochemical characteristics of the subspecies, notably

ered diagnostic unless reinforced by histopathology.

that C. fetus subsp. venerealis will not grow in 1 per cent After venereal infection in the cow, antibody is

glycine whereas C. fetus subsp. fetus will. This differen-secreted in the uterine and vaginal fluid. Of this IgG is

tiation is important, as C. fetus subsp. venerealis is con-the most important *component and can be detected*

sidered to be adapted to the bovine reproductive tract

eight weeks post infection, but is largely undetectable

and to be the cause of venereal campylobacteriosis,

by six months. IgA is produced by three to five weeks

whereas C. fetus subsp. fetus is a gut commensal caus-and is still detectable for up to a year after infection

ing sporadic abortion in cattle. However, strains of

(Corbeil et al. , 1974). Despite recovery, the developthe latter vary in their biochemical characteristics

ment of immunity and the establishment of normal

and strains identified as C. fetus subsp. venerealis have pregnancies, C. fetus has been isolated from the vaginal developed tolerance to glycine (Chang & Ogg, 1971).

mucus more than a year after infection (MacLaren &

In addition, strains identified as C. fetus subsp. fetus, Agumbah, 1988), creating the potential for cows as well

when used in experimental studies, have resulted in

as bulls to maintain the infection in the herd from one

disease indistinguishable from that caused by C. fetus

year to the next.

subsp. venerealis (Schurig et al. , 1973) and field The sampling technique most frequently used in bulls

outbreaks of venereal campylobacter infertility asso-

in Britain is the collection of sheath washings (BCVA,

ciated with C. fetus subsp. fetus have been identified 1995) and phosphate buffered saline (PBS) is adequate

(MacLaren & Agumbah, 1988). It would therefore

for the lavage fluid provided samples are relatively free

appear that strains of both subspecies are capable of

from gross contamination and transported to the labo-

causing venereal infertility and whenever C. fetus is iso-ratory within four to six hours. However, where imme-

lated from abortion material the possibility of herd

diate delivery to the laboratory cannot be achieved the

venereal infertility should be investigated.

use of transport enrichment medium (TEM) has proved

In the case of sporadic abortion not associated with

to be effective in maintaining the viability of the organ-

venereal infertility, invasion from the intestinal tract is

ism (Hum et al. , 1994). A fluorescent antibody test is the probable route of infection.

available, but does not allow differentiation between

The venereal form of the disease is usually intro-

the two subspecies and it is of limited value in the diag-

duced to the herd via an infected mature bull and while *nosis of the disease. Vaginal mucus should also be col-*

younger bulls or breeding females are less likely

lected without gross faecal contamination and this can

sources, any animal that has previously been mated con-

best be achieved by using pipettes with the end closed

stitutes a potential source of infection. The use of hired

off and perforations made in the last few centimetres.

bulls is considered to be a particularly high-risk prac-

Twenty ml of PBS are injected through a 60 ml syringe

tice. Infection in the bull follows natural mating with an

and then aspirated back, bringing with it vaginal mucus

infected cow, but is not associated with clinical signs

(Lander, 1983). As with sheath washings, TEM can

or pathological changes. In mature bulls infection

be used if there is to be a delay of more than six

becomes established in the lumen of the epithelial

hours between sample collection and the inoculation of

crypts of the prepuce, while bulls younger than 6 years

media.

of age are more resistant to infection (Clark, 1971). In

In the vaginal mucus agglutination test (VMAT) anti-

natural service the spread of infection is from the penis
gens prepared from C. fetus are used to detect agglu-
to the anterior vagina, where the organism becomes
tinins in the vaginal mucus. Immunoglobulin A is the
established before entering the uterus to cause a mild
antibody present in the mucus, but where serum or
endometritis and salpingitis. Pathological changes are
blood contaminates vaginal secretions false positives
most pronounced at 8 to 13 weeks after infection and
can arise as serum antibody to C. fetus is common in
have resolved by four to five months (Dekeyser, 1986).
cattle (Wilkie & Winter, 1971). In addition, where cattle
Where conception has occurred embryonic death and a
are in oestrus, large amounts of mucus is produced, IgA
delayed return to oestrus, abortion or the birth of a live
is diluted and false negatives can occur. Problems have
full term calf can follow. Of the abortions that are
been reported with the test and it has been suggested
detected the gestational length is usually around four
that only 50 per cent of infected animals will be posi-
to five months. A marked placentitis and pericarditis

tive by VMAT and of those 50 per cent will be nega-

may be seen on gross examination of the tissues and

tive six months after infection. An enzyme-linked

histological findings are of fetal septicaemia and

immunoassay has been developed to overcome some of

pneumonia.

the problems experienced in using the VMAT (Hewson

et al. , 1985; Hum et al. , 1991), but the test is not currently The second category includes Yersinia pseudotuber-used in Britain.

culosis, Mannheimia haemolytica, Erysipelothrix rhu-As a consequence of the delay between infection and

siopathiae and Staphylocccus aureus where infection of investigation in most herds and the cows' ability to clear

the fetus follows bacteraemia in the dam. Arcanobac-

the infection as well as the limitations of the vaginal

terium pyogenes may also gain entry to the conceptus

mucus agglutination test it is necessary to sample a

in this way and experimental infection via the intra-

minimum of 12 cows. Where endemic infection is sus-

venous route with this organism has resulted in abor-

pected animals in their first year in the breeding herd *tion (Semambo et al. , 1991).*

should be sampled to offer the best chance of achieving

These infections are unlikely to represent a herd

a diagnosis. Bulls should be sheath washed in the course

problem and as such do not merit further discussion.

of a herd investigation, but a negative result is of little

value as the screening is a relatively insensitive test.

Artificial insemination using semen from

Protozoal causes of abortion

campylobacter-free studs offers a simple and successful

method of control, but for some herds, particularly

Trichomoniasis

where mating occurs at grass, this may not be practical.

Vaccination is used in many countries where the disease

Bovine trichomoniasis is caused by the protozoan par-

occurs in range cattle and a vaccination programme

asite Tritrichomonas fetus and is a venereal disease

to eradicate infection from within a herd has been

responsible for early embryonic death, infertility,

described (Hum & MacInnes, 1987). Antibiotic treat-

pyometra and abortion. It is a particular problem in *ment of the bulls is suggested as an additional measure*

range cattle, where as many as 50 per cent of the herds

(Hum et al. , 1993). However, there is no licensed

may be infected (Dennet et al. , 1974). There is no recent vaccine in Britain and an emergency vaccine must

report of the disease from within Britain, but there is

be produced under the authority of the Veterinary

no biological barrier that would prevent the disease

Medicines Directorate (see Chapter 59).

from occurring here and diagnostic laboratories in

Prevention can be achieved by maintaining a strict

Britain do not routinely use techniques that would

closed herd policy, but in practical terms the purchase

identify the presence of this agent. Therefore tri-

of virgin heifers and virgin bulls does not constitute

chomoniasis should be considered in the differential

a risk. Difficulties arise where bulls have to be re-

diagnosis in herds using natural service where infertil-

placed at short notice. In these situations a syn-

ity, abortions and pyometra are observed.

chronization and insemination programme would offer

Although most pregnancies are lost at around 17

the safest course of action with a young unproven

days after conception, one review reported that death

bull used to sweep up. If mature bulls are used these

can occur at any time up to the fifth month of gestation

should be screened and treated with antibiotics

(Yule et al. , 1989), and fetal infection has also been (BCVA, 1995).

demonstrated in late abortions and in full term calves

(Rhyan et al. , 1988).

No specific gross changes are seen in the abortion

Miscellaneous bacteria

material. Histological examination reveals lesions of

Species of bacteria associated only with sporadic abor-

placentitis and pyogranulomatous bronchopneumonia

tions can be split into those that can be readily isolated

with evidence of tissue invasion with the parasite

from the posterior reproductive tract of the normal

(Rhyan et al. , 1995). The organism can be cultured

animal and those that cannot.

from vaginal discharges, preputial smegma and fetal

The former category includes organisms such tissues by using a specific medium in a pouch system

as Haemophilus somnus, Arcanobacterium pyogenes, (Kvasnicka et al. , 1996).

Streptococcus dysgalactiae, Mycoplasma bovis and Ure-Trichomoniasis can be controlled through the use of

aplasma diversum. These may gain entry to the uterus

artificial insemination and commercial vaccines are

through the cervix as a sequel to some other disease

available in the countries where the disease is endemic.

process affecting the fetus. It is possible that strain

differences in virulence exist, but at the present time

Neosporosis (see also p. 283)

these agents should be considered to be of minor impor-

tance. Ureaplasmas have been suggested as important,

Protozoal abortion has been recognized as a problem

but isolation methods for these organisms are rarely

in the dairy herds of California since the mid 1980s

employed in diagnostic laboratories (Sanderson &

(Anderson et al. , 1991) and around the same time a

Chenoweth, 1999).

protozoan parasite of dogs was identified in Norway

(Bjerkås et al. , 1984). This was subsequently named

the lesions is considered significantly characteristic

Neospora caninum (Dubey et al. , 1988) and the link was to warrant a diagnosis and immunohistochemistry

made to the infection of cattle (Thilsted & Dubey,

gives further specificity to this. Autolysis often hampers

1989). Since then N. caninum has been identified as a examination although tissue cysts do survive and may

cause of abortion in many parts of the world and a

be recognized. The fetus is capable of mounting an

major volume of research publications has been gener-

immunological response to neospora infection and

ated (Dubey, 1999). Serological studies have found evi-

detection of specific antibody in fetal or precolostral

dence of exposure to the organism in 16 per cent of

sera is a reliable indicator of fetal infection, but not of

aborted fetuses in Scotland (Buxton et al. , 1997) and in infection causing fetal death (Otter et al. , 1997). At 13 per cent of cows that aborted in Northern Ireland

present, despite the availability of molecular biological

(McNamee et al. , 1996). Outbreaks described range

techniques for the detection of neospora DNA they are

from 11 per cent of cows that aborted in one herd in *not routinely used for diagnostic purposes.*

England (Dannatt et al. , 1995), to as many as 57 per cent Maternal infection is followed by the production of

of a herd in The Netherlands (Wouda et al. , 1999). While antibodies within 14 days that peak by 46 days and in

neosporosis is a recently recognized disease there is

most cases the time lag between maternal infection and

nothing to suggest that the parasite or the disease is new.

abortion is such that antibody production will have

Neospora caninum is an apicomplexan protozoan

peaked before the abortion and may occasionally have

closely related to Toxoplasma gondii and although the fallen to undetectable levels by two months after

complete life cycle of the parasite is still to be deter-

the abortion (Wouda et al. , 1999). In the congenitally mined dogs have been shown to be a definitive host and

infected individual there is fluctuation in antibody level

to pass small numbers of oocysts in faeces from 8 to 23

and at times antibody is undetected. The observations

days after experimental infection (McAllister et al. , that congenitally infected animals have been found to

1998). Tissue cysts and tachyzoites have been found in

have a higher risk of abortion at their first gestation *cattle, sheep, goats and horses and it is possible that the*

compared to the second gestation and that abortions

intestinal stage of the life cycle is not limited to the dog.

occurred at an earlier stage in the first gestation than

Vertical transmission occurs in addition to the point

subsequently suggest the possibility of a protective

source outbreaks, where cows are presumed to be

immunity developing in infected animals (Thurmond &

infected for the first time and abort. As post natal infec-

Hietala, 1997). Given the close relationships between

tion rates are probably as low as 1 per cent (Hietala &

neospora, toxoplasma and sarcocystis species there

Thurmond, 1999) most cases are due to vertical trans-

were concerns that serological cross-reaction could

mission where an infection rate of 95 per cent has been

occur, however it has been shown that such cross-

found (Davison et al. , 1999). Infection of the fetus may reactivity is negligible and of no importance

often be a relatively benign event and care should be

diagnostically (Dubey et al. , 1996).

taken in attributing significance to evidence of infection

The lack of a complete understanding of the life cycle

in an aborted fetus (Thurmond et al. , 1997). Co-

and knowledge of the range of definitive hosts has led

infection with other agents is often found and potentia-

to a cautious approach to control, but there seems a

tion or the presence of factors that cause immune

clear argument emerging in favour of culling seroposi-

suppression in endemically infected herds may explain

tive animals from the herd. These have been shown to

some of the cases that appear as epidemics (Bartels

have lower levels of production and suffer a higher risk

et al. , 1999).

of abortion than seronegative cows within the herd. By

Experimental infection of pregnant cattle has re-

using information from the literature in a mathemati-

sulted in fetal death and lesions indistinguishable

cal model it has been shown that annual culling of

from those seen in naturally occurring outbreaks (Barr

seropositive animals was the most effective and rapid

et al. , 1994). Abortion most frequently occurs in the method of control. Effective control at a slower rate *second half of pregnancy and the commonly observed*

could be achieved if the action was limited to excluding

lesions are limited to placentitis, focal non-suppurative

the offspring from seropositive cows from the breeding

encephalitis, non-suppurative myocarditis and myositis

herd (French et al. , 1999). At the present time the ques-and widespread non-suppurative infiltrates in other

tion of the cost-benefits of these strategies has not been

organs (Anderson et al. , 1991). The tissue cysts are well addressed, but given the large outbreaks that can occur,

tolerated and the host response is limited to the tachy-

action to prevent a sudden catastrophic, albeit low-risk,

zoites. Histological examination of the fetus is impor-

occurrence might be justifiable. Irrespective of culling

tant in order to determine the severity and therefore

practices, all fetuses, placentas and cattle carcases

the significance of the lesions in terms of fetal death

should be disposed of in a way that prevents recycling

(Thurmond et al. , 1999). The histological appearance of of N. caninum infection through definitive hosts.

Other infectious agents

immunity after infection or whether the cow is likely to

causing abortion

return to normal fertility.

Prevention of mycotic placentitis is by reducing the

Chlamydia and rickettsia

degree of fungal contamination pregnant cows are

exposed to, particularly in preserved forage. Fungal

Q fever, Chlamydophila abortus and Cytocoetes

growth occurs in other feedstuffs and bedding ma-

phagocytophilia have all been identified as occasional terials and after a diagnosis of mycotic abortion the

causes of bovine abortion. There is serological evidence

management system should be reviewed in order to

of exposure to the agent of Q fever in Britain (Paiba et

identify possible sources of these organisms. A visual

al. , 1999), but no recent report of abortion in cattle due examination of suspect materials may be sufficient, but

to this agent. Occasionally a purulent placentitis and

where doubt over the source remains it is also possible

the presence of elementary bodies in modified Ziehl

to use quantitative culture methods to assess the degree

Neelsen stained smears of placenta and stomach con-

of fungal contamination and to identify the organisms

tents are observed. Establishing the precise aetiology in

present.

these cases can be difficult, but Chlamydophila abortus

has been isolated from such material and in one report

the strain was found to be identical to that responsible

for chlamydial abortion in sheep (Griffiths et al. , 1995).

Non-infectious causes of abortion

The outbreak may have been the result of close contact

between cattle and an infected sheep flock on the same

The failure to identify an infectious cause in many cases

premises.

has led to the suggestion that non-infectious causes are

Cytocoetes phagocytophilia, the cause of tick borne

of importance (Norton & Campbell, 1990). Nutritional

fever (TBF), will cause abortion in cattle when first

factors that may be involved include excess dietary

exposure to ticks occurs during pregnancy. Diagnosis

protein or non-protein nitrogen and selenium or iodine

can be difficult to confirm, as there is no longer para-

deficiency. Twin pregnancies are associated with shorter *sitaemia by the time the abortion occurs. A presump-*

gestation lengths and an increased rate of abortion

tive diagnosis may be based on the herd history and the

(Echternkamp & Gregory, 1999). Various poisonous

presence of ticks and antibody to the TBF agent.

plants have been implicated, but none is indigenous

to Britain. Ponderosa pine (Pinus ponderosa) and

locoweeds (Astralagus sp.) cause significant problems in

Mycotic abortion

some areas of North America. Deaths due to aflatoxi-

Mycotic abortion with placentitis and fetal infection is

cosis and to nitrate toxicity may be preceded by abor-

reported throughout the world. In one detailed study 7

tion, suggesting that either the fetus is marginally more

per cent were mycotic abortions and Aspergillus fumi-

sensitive to any toxic effect than the dam or that fetal

gatus infection accounted for 62 per cent of these

death is the consequence of the clinical disease in the

(Knudtson & Kirkbride, 1992). Other species of fungi

dam.

have been reported and it would appear that most are

However, the literature fails to support non-infec-

opportunist pathogens. The source of these infections is

tious causes as a numerically significant cause of abor-

often poorly preserved hay or ensiled feed that has

tion in cattle (Norton & Campbell, 1990) and in the UK

undergone aerobic fermentation.

only iodine deficiency, manifest as hyperplastic goitre in

Placentitis follows a septicaemia that has resulted

full-term stillborn calves, is of importance. The condi-

from either ingestion or inhalation of spores from the

tion is mainly reported in beef herds or in dairy heifers

environment. The placenta is frequently thickened and

and is thought unlikely to affect dairy cows due to ade-

may be of a leathery appearance. White plaques on the

quate dietary iodine intake. A threshold of 15 g for the

skin of the fetus are an occasional feature of this

weight of the intact gland, above which goitre is sus-

disease, but apart from this gross lesions are seldom

pected, has been in common use. A better indicator is

observed. At the microscopic level hepatitis, pneumo-

the ratio of thyroid weight to fetal body weight where *nia and placentitis are evident and Grocott's stain can*

the threshold value is 1 : 3000. However, oedema of the

be used to reveal fungal hyphae in fixed sections.

head and neck in stillborn calves can render this unre-

Fungal elements can be seen on direct microscopy of

liable (Gee et al. , 1989) and histological examination of the placenta and the stomach contents, the latter being

the gland to confirm the presence of a colloid goitre is

diagnostic. These organisms are readily cultured from

recommended (Capen, 1993). There does not appear to

the fetus and the placenta, but environmental contam-

be any suggestion that goitrogenic factors should be

ination after the abortion has occurred may explain iso-

considered and the inclusion of iodine in an oral

lation from the placenta alone.

mineral supplement should prevent the condition (see

There is little information on the development of

pp. 257, 301).

Investigation

Examination of the fetus and placenta

In the ideal situation, the entire aborted calf and fetal

In abortion outbreaks in cattle herds abortions are fre-

membranes with the appropriate samples from the dam

quently irregular and the single abortion may mark the

should be delivered directly to a veterinary diagnostic

start of an outbreak that does not become apparent for

laboratory. Where transport difficulties or other delays

several weeks. An observed abortion may also repre-

preclude this, the field veterinarian should collect ap-

sent a more extensive underlying herd problem and

propriate samples while carrying out a necropsy of the

therefore there is justification for investigating every

fetus.

abortion. However, there are concerns over unneces-

A standard approach to the examination should be

sary costs and the diagnostic rate has been found to be

adopted and the appropriate information recorded. The

higher in cases where there has been more than one

measurement of the crown–rump length can give an

abortion in the herd previously (Caldow et al. , 1996).

approximation of gestational age. A formula to

Since there is a statutory requirement to report all abor-

estimate the fetal developmental age from the

tions in Britain there is the opportunity to discuss the

crown–rump measurement is $x = 2.5(y + 21)$, where y is

problem with the client and to carry out the investiga-

the crown–rump length in centimetres and x is the ges-

tions considered necessary in each individual case.

tational age in days. Measurement of the weight of the

Investigations should follow a standard pattern:

carcase is particularly important in stillbirths to explore

(1)

History

the possibility of dystokia due to fetal maternal dispro-

(2)

Clinical examination of the cow

portion and for comparison with thyroid weight, for the

(3)

Necropsy of fetus

diagnosis of hyperthyroidism.

(4)

Collection of samples for the laboratory

Other important features to be aware of include the

(5)

Interpretation of results

presence of white plaques of fungal hyphae on the skin

of fetuses where there is fungal involvement. Meconium

staining of the perineum or the presence of meconium in

History

the airways or fetal stomach indicate fetal anoxia con-

The use of a standard form allows the systematic col-

sistent with placentitis or the prolonged parturition of

lection of the important details of the individual cow as

dystokia. Haemarthrosis of the shoulder or hip joints

well as production system, cow numbers, age structure,

may be seen in dystokia cases. Traumatic lesions in

biosecurity measures, replacement policy and source of

fetuses where dystokia has not been the problem are

replacements (Fig. 37.1). Details on the feeding system

occasionally observed and while trauma may be the

and how feeds are stored are also of relevance. This can

cause of the abortion other causes should not be

usefully be expanded to include details on herd fertil-

excluded too early in the investigation. Lesions of peri-

ity, retained membranes and any background clinical

carditis, pleurisy, pneumonia or hepatitis can all be found

problem that may be of relevance. Careful evaluation

on the gross examination, but none of these changes is

of the information is essential to guide the investigation

specific. In calves that have lived for a short time after

and to indicate the diagnostic tests to be employed.

birth it is important to record whether the calf has fed as

this prevents useful bacteriological examination of the

stomach contents, but also means that maternal antibody

Clinical examination

may have been absorbed, interfering with fetal serologi-

cal tests.

In most cases examination does not yield useful infor-

When the placenta is available as much of the surface

mation, but it is important to exclude conditions such

area of the allantochorion as possible should be exam-

as acute salmonellosis, summer mastitis or tick borne

ined. Lesions can be focal and may be overlooked if

fever and to allow treatment if the cow is ill. At this time *insufficient care is taken. Commonly observed lesions*

a blood sample for serology should be collected and if

are intercotyledonary thickening, necrosis of cotyle-

salmonellosis is suspected a faeces sample as well.

dons and adventitious placentation. The last lesion is

Where stillbirth is the problem the body condition of

considered to be a chronic response to insufficient

the cow should be assessed and other cows in late ges-

placental area and is seen following placentitis.

tation can also be examined in this way. Where the

majority of animals in the group have scores of 3.5 and

above there is cause for concern over excessive body

Collection of samples for laboratory investigation

condition.

Even when it has been decided to limit diagnostic

If samples are collected in the course of a necropsy on

tests to those required for brucellosis, a serum sample

the farm, the collection and transport of samples to the

can be stored frozen for possible retrospective

laboratory should have been discussed with the labora-

examination.

tory personnel. The samples required and the means of

Reference Number: C2…………………………………

CASE HISTORY

Date of Abortion/Stillbirth………………………………

Ear no. of dam……………………………………………………………

Age of dam………………………………

Due on……………………

Source of dam……………Home bred

Purchased

Breed……………………………………… Dam………………………………………… Sire………………………………………

Vaccination: BVD

L. hardjo

IBR

Other…………………………………

No. of abortions……………………

No. of stillbirths……………………

No. of weak calves……………………

Calving starts………………………

Group size…………………………

Total cows………………………………

Replacements:

Home bred

Bought in

Mixture

Method of service

AI only

Natural only

Both

Have hired bulls been used? Yes No

Production: Beef Dairy

Body condition score of cows/heifers: …………………………………

HOUSING/MANAGEMENT

Roughage

Concentrate

Mineral/trace element supplements

HERD FERTILITY (Dairy)

Average days to conception

All serves pregnancy rate

% barren after p.d. positive

HERD FERTILITY (Beef)

No. of barren cows

Length of breeding/calving season

DETAILS OF PARTURITION

Degree of assistance required/use of calving aid:
………………………………………………………………………………………

Calf alive at onset of assistance: YES NO

Placenta expelled with calf:

YES NO

Vet involved with calving:

YES NO

Other information:
………………………………………………………………………………………

………………………………………………………………………………………

Fig. 37.1

A standard form to collect systematically important information when investigating fetal losses.

preservation are determined by the causes of abortion

precedes abortion so that paired serology is valueless.

that occur in an area and on the diagnostic facilities

As many of the infections of importance tend to be

available to the laboratory. Nevertheless, basic rules do *endemic and circulating antibody may persist for long*

apply.

periods the presence of maternal antibody at the time

The minimum sample required for bacteriology is

of the abortion can only be taken to show that the cow

fetal stomach contents. These can be collected using a

has been exposed to the agent. The converse applies

sterile vacutainer and needle through the unopened

when the MAT is used for leptospirosis as the IgM anti-

abomasal wall. Where the placenta is available a cotyle-

body response can be so transient that the dam may be

don representative of the lesions observed should

seronegative at the time of abortion.

also be submitted fresh. Samples may also include

In essence, serology tests in the dam are of more

fetal liver and lung, allowing slightly higher diagnos-

value when used to exclude infection with negative

tic success for some bacterial causes of abortion . It results than to attempt to confirm a diagnosis with pos-has been suggested that in cases where the fetal mem-

itive results. This should not discourage the use of these

branes have been retained a placentome is removed *techniques to establish whether or not there is evidence*

manually per vaginum (Johnson et al. , 1994) for of these diseases in the herd, as control strategies may

bacteriological and histological examination. How-

still be required.

ever, this is not required when the fetus is available for

Evidence of the involvement of several infectious

examination.

agents is often found in the course of an outbreak,

Fetal blood or fluid can be collected from any body

underlining the importance of proper evaluation of the

cavity, again by using a vacutainer. This sample is used

results, but also raising the question of a potentiation

for serological tests for BVD, neospora and leptospira.

effect amongst agents.

Fetal thyroid, spleen, kidney and brain are all tissues

that can be used for virus isolation for BVD, while the

Prognosis

placenta is the sample of choice for BHV1.

Histopathological examination is particularly useful

For the individual cow the prognosis is usually *to determine the significance of fetal infection with N.*

favourable as long as any systemic disease or uterine

caninum or BVD, to confirm the significance of appar-

infection is detected and treated. After abortion,

ent thyroid enlargement and for further investigations

oestrous cycles start quickly and, in general, subsequent

where the standard screen for infectious disease is

pregnancy rates are satisfactory. Prognosis for the rest

negative. The tissues of most value to collect are brain,

of the pregnant animals in the herd is a more serious

lung, liver, thyroid (in stillbirths) and a cotyledon. It is

consideration and varies with the diagnosed cause of

important to be guided by the pathologist as to how

abortion.

these samples should be fixed. Tissues for histology

must never be frozen.

The minimum samples are fetal stomach contents for

Conclusion

bacteriology and fetal blood or serum for serological

tests. These may be the samples of choice when inves-

Abortions are often the most obvious manifestation of *tigating what appears to be a single abortion. If subse-*

an underlying herd problem that may be of significant

quent abortions occur then the range of tests can be

financial importance to the owner of the cattle herd.

extended.

Failure on the part of the veterinary surgeon to pursue

or advise correctly could have a severe penalty for the

producer.

Interpretation of results

When evaluating results it is important to consider

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them in relation to the diagnostic criteria for each

disease. Hence, while the presence of antibody to BVD

Agerholm, J.S., Jensen, N.E., Jensen, H.E. & Aarestrup,

or to N. caninum is considered to indicate fetal infec-F.M. (1999) Experimental infection of pregnant cows with

tion, it must be remembered that infection of the fetus

Bacillus licheniformis bacteria. Veterinary Pathology, ***36****, 191–201.*

need not necessarily be lethal, especially as gestational

Alexander, A.V., Walker, R.L., Johnson, B.J., Charlton, B.R. & age increases. Similarly, the isolation of foetopathic

Woods, L.W. (1992) Bovine abortions attributable to Liste-

bacteria or fungal organisms from the placenta in the

ria ivanovii – 4 cases. Journal of the American Veterinary absence of histopathology is of no value as they may

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arise from environmental contamination after the pla-

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Chapter 38

Bull Infertility

D.N. Logue and W.M. Crawshaw

Introduction

cial insemination (AI) has proved to be one of the most

Bull use in the UK

595

successful reproductive technologies and it became a

The role of the veterinarian in bull use

596

commercial reality in the UK just before the end of the

Preventing infectious infertility and other diseases

596

Second World War. AI has fulfilled two objectives:

Preputial washing

597

firstly, it set in motion more focused genetic improve-

Infectious disease control

598

ment coupled with the widespread use of good bulls and

Investigation of bull infertility

598

secondly, it has limited the spread of venereal diseases.

History

598

Examination of the bull for breeding soundness

599

Unfortunately, the expression of oestrus in the cow

Manifestations, aetiology, treatment and prognosis of bull

varies in time of occurrence, duration and intensity and

infertility

610

many farmers find accurate and, more particularly, effi-

Failure to mount

610

cient oestrous detection difficult and time consuming.

Failure to achieve intromission

612

Furthermore, particularly in large beef suckler herds

Failure to thrust and ejaculate after intromission

616

under essentially range conditions, oestrous detection

Normal service with a poor pregnancy rate

617

and the handling of cattle for AI are less practical.

Conclusion

624

These factors ensure that many farmers continue to use

natural service entirely or partially even though, due to

the genetic improvement from AI, dairy farmers in

Introduction

particular could afford to have a longer calving interval

and yet still expect to have the same financial returns

Since the domestication of cattle the bull has been a

(Hillers et al. , 1982; Stott et al., 1999).

talisman and the desire to own a special bull a parti-

The problem is illustrated by a study of UK national

cular urge in all stock rearing countries. The bull is a

cattle population statistics where only approximately

symbol of power in the East, where Indra the sky deity

half the cows are bred by AI (Logue & Isbister, 1992),

is represented in myth as a mighty bull, while in the

this figure being considerably higher for the dairy herd.

West as an example there is the Celtic legend of the

Although confidentiality has stopped many of these sta-

Brown Bull of Quelgny stolen by Queen Mae of

tistics being easily available in the UK we have no

Connacht from Dara in Ulster only to be retrieved by *reason to believe the proportion has changed.*

the hero Cuchulain. Time has not diverted man a great

However, this figure may increase following the 2001

deal from this interest in bull lineage and the perform-

foot and mouth disease outbreak. In the USA the pro-

ance of his offspring! The development of methodolo-

portion bred by AI is probably a little higher (70 per

gies to assess the transmission of superior economic

cent). In addition, there have been a number of factors

traits from bulls to their progeny over the last 50 years

that have counteracted the undoubted improvements in

has been one of the success stories of the cattle indus-

the efficiency of AI.

try. However, like the Brown Bull the truly outstanding

sire is still very rare and the purchase of a young

(1)

The economics of dairy and beef production have

unproven bull is a gamble. Despite this the repeated

resulted in a general trend to larger herds with fewer

need for young bulls (no bull is immortal) means that

staff and so less time available for oestrous detection.

many are bought with this vision in mind, despite the

Furthermore, the continuing financial pressure to cut

difficulties in achieving it.

costs has also made many dairy farmers economize by

When all breeding was by natural service the

changing from paying for a technician AI service to

potential for genetic improvement by a good bull was

inseminating their own cows (DIY AI). Many of these

very limited. Furthermore, selling, sharing and hiring

people keep a bull as a precaution against poor fertil-

animals resulted in the spread of venereal disease with

ity arising from a doubtful insemination technique.

some disastrous results for those affected farms. Artifi-

Unfortunately, no figures are produced for the number

Table 38.1

Number of cows in DIY AI herds (Anon. 1988).

England and

Northern

Scotland

Total

Wales

Ireland

DIY licences

3 300

1 000

700

5 000

Average herd size

69

37

89

–

Number of cows

227 700

37 000

54 300

319 000

Cows inseminated (assuming

170 775

27 750

40 725

239 250

75%) by DIY AI

Table 38.2

UK dairy cattle statistics (Anon. 1979, 1988, 1998).

increasing improvement in the health status of the

national herd in many countries there is less pressure

Year

Cow numbers ¥ 106

Herd size

for AI use for this reason alone. However, this confi-

dence is likely to be misplaced unless the farm takes

1960

4.01

20

adequate precautions when acquiring bulls.

1970

4.55

31

1980

4.69

55

1990

4.43

67

1997

4.41

72

Bull use in the UK

It is worthwhile defining the various types of herd

breeding policy since this will influence the manage-

ment of the bull and may give a guide to the needs of

of cows inseminated in the DIY AI sector in the UK.

the unit with regard to disease control.

However, census data, the number of DIY AI licences

Four basic types of policy can be recognized:

issued by area and the assumption that 75 per cent of

the cows in each herd are inseminated does allow an

(1)

Beef suckler herd. The principal demand is to

estimate (Table 38.1). It can be seen that DIY AI prob-

produce calves for finishing. The cows are mated while *ably accounts for less than one in five of all dairy cow*

suckling. For many years and in most geographical loca-

inseminations in the UK.

tions it has been axiomatic that this system operates at

(2)

The gradual increase in herd size has meant that

highest efficiency when there is a short (but efficient)

the added costs of keeping one or even several bulls are

breeding period (Kilkenny, 1978). Ideally this should be

relatively lower per unit of production. For example, in

less than 10 weeks and demands very high levels of fer-

the UK, dairy herd size has increased dramatically over

tility in both bull and cow.

the last 30 years (see Table 38.2), and this has been mir-

rored in Europe and in virtually all countries with an

(2)

Dairy heifers. A considerable proportion of dairy

advanced dairy industry.

herds use natural service when breeding heifers. This is

mainly to avoid oestrous detection and the need to

(3)

A further effect of the larger number of cows per

gather the individual heifer for AI when often these are

herd has led to a more predictable production of heifer

run on a more remote area of the farm.

replacements because the male : female ratio remains

nearer to the expected 50 : 50 as the numbers increase.

(3)

Sweeper bull. This term usually refers to the

This has meant that a definite block of heifers of similar

running of a bull after a fixed period of ‘AI-only’ breed-

age can be released for natural service.

ing. Generally, in dairy cattle, the bull used is a beef

breed and thus any calves born are easily distinguished

(4)

In many beef and dairy herds, calving, and thus

from purebred dairy calves. The use of synchronization

breeding periods, are concentrated into relatively short

and fixed-time AI with batches of maiden heifers using

periods of time for production and management

an easy-calving sire has to some degree replaced

reasons. This leads to a requirement for high oestrous *natural service in both dairy and beef heifers, but in*

detection rates and high fertility, both of which are best

many herds those heifers that return are served by a

achieved by using a combination of AI and natural

sweeper bull. The timing of the introduction of the

service.

sweeper is paramount since mating pressure will

(5)

Finally, in the past an important reason for using

obviously depend on the number of non-pregnant cows

AI was to reduce the introduction of disease. With the

or heifers left after the AI breeding period. Clearly a

drop in the pregnancy rates achieved with AI can result

damaging effects of infectious disease impacts signifi-

in an increase of mating pressure.

cantly on efficiency.

The most important source of infectious disease for

(4)

Modified sweeper. The sweeper bull is utilized

cattle is other livestock, particularly cattle. Uncon-

for mating selected cows throughout the breeding

trolled movement of a bull into a herd carries a signifi-

season, for example cows of low genetic potential,

cant risk of introducing disease. This can be minimized

repeat breeders, cows not exhibiting firm signs

by the following measures but presupposes that other

of oestrus and cows with a history of being difficult to

biosecurity precautions are in place:

get in calf. Subsequently, the bull is used as a 'true'

sweeper.

(1)

Bulls (and any other cattle) should be purchased

Finally, a minority of dairy herds still primarily use

only from herds certified free from specific diseases of

natural service.

concern by reputable cattle health schemes such as

those registered with the Cattle Health Certification

Standards (CheCS) body in the UK. While individual

The role of the veterinarian in

farm programmes can be undertaken or declarations

bull use

made by the farmer and his veterinarian to the effect

that a particular disease has not been seen, clearly these

will have less certainty. The latter point is illustrated by

The role of the veterinarian in the control and moni-

Kallis et al. (1999) who revealed by faecal culture that toring of bull fertility is three-fold (see Box 38.1).

40 per cent of 100 Dutch dairy herds considered to be

Veterinarians should be authoritative in these roles

free of Johne's disease on the basis of owner and vet-

for their clients or be able and willing to refer matters

erinary declaration were actually infected.

to another veterinarian with the appropriate resources

if the occasion demands.

(2)

Quarantine incoming cattle before entry into the

main herd to allow testing for diseases that may be

carried and development of any incubating diseases. In

Preventing infectious infertility and

most cases four weeks should suffice, but this depends

other diseases

on circumstances and the diseases under consideration.

Quarantine could also be applied to other species of

Before considering the reproductive performance of

livestock entering the farm that potentially carry dis-

the bull on the farm the first priority must be to keep

eases infectious to cattle.

disease out! No veterinarian or farmer should be

without some appreciation of the risks that are being

(3)

During the quarantine period an adequate testing

taken by the purchase of a bull (or even semen or

programme and/or prophylactic treatment against dis-

embryos). In addition to the notifiable diseases (such as

eases of concern should be employed. The latter may

foot-and-mouth disease) there are a whole plethora of

be necessary where testing is unreliable or gives an

others that can cause economic loss. Unfortunately in

equivocal answer (e.g. for venereal campylobacteriosis

the past, farmers in the UK, and for that matter else-

and Leptospira hardjo).

where, have been pretty cavalier in their attitude to

introducing disease. Veterinarians, by discussing these

The diseases of importance vary with country and

issues with their clients, can do much to reduce the risks

area and are determined by the economic or practical

of introducing disease and so protect the viability of

importance of the disease, an assessment of the risk of

their clients' farms. The loss of output arising from the

introducing the disease, the availability of low cost and

reliable tests and whether or not the disease is already

present in the herd. In the UK the following non-

Box 38.1

Role of the veterinarian in bull fertility.

statutory diseases are suggested as being worthy of

(1)

Preventing the introduction of infectious infertility and

consideration based on their prevalence and the

other diseases to the farm

economic impact that they may have on the herd.

(2)

Assessing fertility and the level of investigation that is

needed:

Bovine virus diarrhoea virus (BVDV)

(a)

before purchase

Infectious bovine rhinotracheitis virus (IBRV) (bovine

(b)

after purchase

herpes virus 1 [BHV-1])

(c)

before use each breeding season

Leptospira hardjo

(d)

after poor fertility results

Johne's disease (paratuberculosis)

(3)

Monitoring herd fertility (including the bull) by the

Venereal campylobacteriosis

assessment of breeding records

Salmonellosis (especially S. dublin)

Whilst neosporosis is a significant cause of bovine

enrichment medium. Negative laboratory results in the

reproductive failure any epidemiological role of the *face of a strong history of infertility and natural service*

bull is undetermined and the reliability of current lab-

and no other obvious causes should be viewed with

oratory tests for detecting carriers remains question-

suspicion.

able. However, the precautionary principle suggests it

is unwise to acquire bulls bred in herds infected with

Preputial washing

Neospora caninum at least until more is known about

this infection. Outside and unfortunately even within

The method of preputial washing used routinely by the

the UK, diseases considered notifiable in the UK

Scottish Agricultural College is summarized below.

such as brucellosis and tuberculosis also need to be

considered.

Protocol for sampling bulls for Campylobacter

The two most important true venereal diseases are

fetus sp. screen

trichomoniasis and campylobacteriosis, although there

is evidence for the venereal transmission of some

Materials required:

Ureaplasma sp., Mycoplasma bovigenetalium, BHV-1,

• Recovery fluid: 60ml phosphate buffered saline

brucellosis and even Haemophilus somnus. Bovine

(PBS) (sterile).

trichomoniasis is a venereal disease characterized by

• Sampling catheter: 10cm length of 3.5 ¥ 6.5mm

early to mid-gestation pregnancy losses, reduced

portex tubing (sterile).

calving rates and pyometra; it is caused by the flagel-

• 60ml syringe: attached to catheter (sterile).

lated protozoan Tritrichomonas fetus. As far as is

• 3 ¥ 20ml sterile sample bottles.

known, it is transmitted by venereal contact only.

• Individual set of sampling materials for each animal

Campylobacteriosis, which also presents as a large in-

sampled.

crease in returns to service with early to mid-gestation

pregnancy losses, is classically caused by C. fetus

Procedure:

venerealis. However, there is evidence that this organ-

• Clip preputial hairs.

ism does not always follow the classic laboratory iden-

• Wash preputial orifice with warm water. Do not

tification procedures and this has led to the proposition

disinfect.

of C. fetus intermediatus, which also appears to cause

• Load syringe with 60ml warmed PBS.

the same clinical problems in cattle. This organism has

• Insert catheter as far into prepuce as possible.

many of the properties of C. fetus fetus. In these two Clamp one hand over preputial orifice to seal

venereal infections the bull is the long-term carrier

around catheter and hold it in place (use hand

of the organism, apparently without ill effects (i.e. no

nearest bull's head to facilitate massage with the

visible lesions are evident in recently or chronically

other hand).

infected bulls) and a distinct correlation exists between

• Pass 60ml warmed PBS through catheter. Leave

age and infection, with older bulls being far more likely

syringe in place.

to sustain an infection than younger bulls. Infection

• Retain fluid and catheter in prepuce by continuing

of the female occurs at the time of coitus. Diagnosis of

to clamp one hand over preputial orifice and mas-

campylobacteriosis in the female is by examination of

sage thoroughly along full length of prepuce to scro-

vaginal mucus, collected by the method of Lander

tum for one minute.

(1983), for antibody by the vaginal mucus agglutination

• Collect fluid into the original syringe by withdrawal

test (VMAT) and for the bacterium by culture. Since

using the plunger as the catheter is slowly

antibody takes some time to appear after an infected

withdrawn.

service and false negative VMAT results are common,

• Dispense sample into sterile containers and label.

at least 12 cows should be sampled at least 50 days after

• If the bull urinates during collection the sample

a potentially infected service. Cows with blood in the

should be discarded and the process repeated.

mucus can give false positive results and cows in oestrus

• All samples should be submitted to the laboratory

are more likely to give false negative results and such

within 6 hours of collection.

animals should not be sampled. In the bull, demonstra-

tion of the Campylobacter fetus bacterium in preputial With preputial washings false negative results are

washings by fluorescent antibody test and culture is

again to be expected on a single screening, indeed four

used in the UK for diagnosis. Where samples of vaginal

screenings have been recommended (Dufty, 1967)

mucus or preputial washings are collected with a view

before a bull can be confidently declared free of infec-

to culture they should reach the laboratory within six

tion. A more practical approach to reducing the risk of

hours of collection due to the fragility of the bacterium.

introducing this infection may therefore be prophylac-

Alternatively, samples can be submitted in transport

tic treatment of purchased, previously bred bulls by

preputial lavage with penicillin and streptomycin

(BVDV, IBRV and Johne's disease in the UK). How-

antibiotic (Melrose et al. , 1957) during the quarantine ever, as some may remember, lack of appreciation of

period. This could be refined by employing prophylac-
the organism and its epidemiology meant that a pilot
tic treatment after a single negative preputial wash
attempt to control L. hardjo by MAFF was not suc-
screening. Nevertheless, the most reliable way to pre-
cessful. Some hard lessons were learnt which have been
vent introduction of this infection is to acquire only
applied to these new schemes.
unbred males and females. Control in infected herds
Another consideration is whether the bull might
is by disposal of infected bulls, suspension of natural
itself be at risk of being infected by cattle in the herd it
service and use of AI with uninfected semen for 2 years
is being introduced to and so having a period of infer-
(Clark, 1971) for all exposed cows, thus allowing the
tility as a result of illness. Completion of a vaccination
cows to develop immunity and eradicate the organism.
programme during the quarantine period for the bull
Where this is not practicable, use of autogenous vaccine
might be considered in light of knowledge of the disease
(there is no licensed vaccine in the UK), only using

status of the herd.

young bulls (<4 years) or operation of ‘clean’ and ‘dirty’

herds should be considered. The problems of diagnosis

and control of venereal campylobacteriosis should not

Investigation of bull infertility

be underestimated and the reader is referred to Caldow

and Taylor (1997) for a more detailed discussion of the

Bull infertility is presented as one, or a combination of

subject in suckler herds.

the four manifestations, namely:

(1)

Failure to mount

Infectious disease control

(2)

Failure to achieve intromission

(3)

Failure to thrust and ejaculate

Control of infectious disease is very dependent on an

(4)

Poor pregnancy rate with normal service

assessment of the risk of introducing the disease and *behaviour*

on the quality of diagnosis, either of the disease or the

carrier state, using laboratory tests. For example, in the

A wide range of conditions can cause each of these. Not

UK bulls are not usually tested for trichomoniasis as it

only are the aetiological factors varied and numerous

has not been diagnosed in home bred animals for many

but also the management of the bull can contribute to

years. However, other diseases such as BVDV are very

the infertility. Consequently only by obtaining a good

common and campylobacteriosis is not usual. In

history of the bull (including previous fertility) and

the first instance the background of the bull must be

his present circumstances can one gain an informed

considered with regard to whether it could have been

appraisal of the most appropriate way in which to

exposed and, as a consequence, be a potential carrier

conduct the assessment of fertility.

of any disease. Furthermore, when subsequent testing

Diagnosis is based upon a combination of bull and

is contemplated the limitations of laboratory testing *herd history, examination of the bull and the results*

regimes specific for each disease must be appreciated

of the various tests that are undertaken including an

before exclusion is considered. For example, testing in-

examination of a representative ejaculate of semen.

dividual healthy animals for antibody and/or by faecal

Even if the diagnosis is tentative and the aetiology

culture for the presence of infection with the bacterium

uncertain the findings will probably allow a prognosis

of Johne's disease leads to a high proportion of false

and may give a rationale for treatment.

negative results. Therefore, exclusion of this disease is

best achieved by purchase of bulls from herds moni-

History

tored free of Johne's disease under a reputable cattle

health scheme rather than by individual animal testing

All investigations of bull fertility are built upon the

and quarantine. Knowledge of the effects of disease,

usual prerequisite of obtaining a good history of the

methods of control and the laboratory technology to

problem. This clearly involves both records of any bull *detect disease is continually advancing. Understanding*

in question but should also entail assessment of the

and awareness of BVDV in particular have improved

herd as a whole. Usually the client will have given some

greatly over the last decade. The infection is widespread

information about the bull by telephone and, ideally,

in the UK and recent estimates of associated losses,

will have presented some farm records for perusal prior

which primarily arise from reduced fertility and abor-

to the examination. At the outset, ask and record the

tion, suggest that these can be over £45 per cow

answers to the questions in Box 38.2. One is looking for

annually in an infected suckler herd (Gunn et al. , 1998).

an estimate of the extent of the infertility by compari-

Relatively recently, truly cost-effective control schemes

son to other bulls, when it was first manifest, if it has

have become a realistic option for certain diseases

been continuous or varied and so on.

Box 38.2

Information required to define the problem.

less are more likely to be infertile or have a lower

than 'normal' fertility.

Type and breed of bull?

(3)

If the cause of the problem is not clear from

Age?

(1) and (2) above and/or the bull is under a sale

Demeanour?

Ringed?

agreement or insured for infertility then it is

Type of herd?

necessary to consider a full breeding sound-

Role of bull in herd?

ness examination. However this is not to be

When and where acquired and time with herd?

undertaken lightly and firstly we recommend

Calves previously born to the bull?

consideration of:

Extent and duration of problem?

(a)

Sale agreement: if the time period for a claim

More than one bull with a problem?

has not elapsed ensure the farmer has

Can the problem be related to introduction of a new male or

contacted the market or vendor, informed

female?

them of the complaint and checked that a

Are AI figures available for the same period?

full breeding soundness examination will

Is there an insurance/sale agreement status?

support the claim.

(b)

Insurance case: ensure that the farmer has

contacted the insurance company, informed

In cases where points (1) to (3) above apply it may

them of the complaint and checked that the

be possible to give a firm diagnosis and an accurate

policy covers infertility and that a full breed-

prognosis based on the history and visual examination

ing soundness examination will support the

of the bull when presented with a cow in season, i.e.

claim.

without even collecting and examining a semen sample.

However, depending on circumstances it may still be

The goal is to obtain a cost-effective resolution to

advisable at least to attempt to collect a semen sample,

the problem. It may be very attractive to examine

even if only to confirm the history.

the semen of the bull but is it really necessary? For

example, if there is a clear history of infertility and

Examination of the bull for

severe testicular abnormalities are found on physical

breeding soundness

examination of a commercial beef bull, then clearly one

is not going to recommend that the bull is used as a reli-

The objectives of the visit to the farm are:

able sire. Collecting and examining semen will be of

• To see the conditions under which the bull is ex-

little additional value to the client unless demanded by

pected to work.

the insurance company. Once it is clear that a full

• To confirm that the history is reliable and, if possi-

breeding soundness examination is required a decision *ble, to examine records.*

as to who will carry this out should be made. Referral

• To examine the bull. In order to study semen for

within the practice or elsewhere may be needed to

abnormal characteristics the operator must use a

access the necessary expertise and equipment.

technique to obtain and prepare semen for exami-

The order of events for the full breeding soundness

nation that will be representative of the ejaculate of

examination should be:

the bull in natural service.

• To ascertain the status of the bull as a possible

(1)

Define the problem.

vector of reproductive disease and possibly other

(2)

Prepare for the visit.

diseases of a less specific nature but just as impor-

(3)

Set up the on-farm laboratory.

tant from an economic point of view.

(4)

Assess the collection area and ability and relia-

bility of the farmer and other animal handlers.

Where an infertile bull is suspected the following

(5)

Introductory examination of the bull.

simple preliminary breeding soundness examination

(6)

Semen collection and assessment.

steps are worth considering before conducting a full

(7)

Observation of natural service.

breeding soundness examination which includes semen

(8)

Full physical examination of the bull.

collection.

(9)

Collection of other diagnostic samples.

(1)

Ascertain by personal observation or a reliable

(10)

Preliminary diagnosis, prognosis and advice (e.g.

report from the farmer whether or not the bull is

treatment or sexual rest).

serving normally.

(11)

Final diagnosis, prognosis and advice after all test

(2)

Physically examine the bull for any obvious

results are known.

genital or other abnormalities. Bulls aged 2 years

(12)

Further action for the herd and its future breed-

or more with a scrotal circumference of 30 cm or

ing management.

Define the problem

restraint and facilities. For experienced beef

bulls it is definitely a case of no cow in oestrus, no

This is often less easy than might be assumed and is

collection!

based on the answers to the questions in Box 38.2 and

(4)

There should be suitable facilities for restraint and

on the information derived from the preliminary breed-

examination of the bull, e.g. crush with removable

ing soundness examination steps described above. On

sides to allow access to the penis and prepuce.

occasion the history is vague and the farmer is uneasy

(5)

A suitable roomy fenced area with a non-slip

about this and the fact that his records may be inade-

surface and with an escape route for the collector

quate. Careful and sensitive questioning may be needed

should be available to allow collection of semen.

to avoid missing some obvious point. In most cases

This can be inside or outside.

where a full breeding soundness examination is being

(6)

Instruct the bull handler or those helping in the

carried out the manifestation will be poor pregnancy

sequence of events, especially in relation to the

rate with normal service behaviour. However, some *bull mounting for collection.*

remain undefined beyond infertility seen as ‘too many

(7)

Any cows that have been running solely with this

returns’ until semen collection is attempted.

bull should be nearby for pregnancy diagnosis

or sampling (vaginal mucus or blood) should the

Prepare for the visit

occasion demand it. Unfortunately, often another

bull will have remated these. However, even then

A full breeding soundness examination can go

examination may allow confirmation that the cows

smoothly and efficiently and be completed in a couple

have conceived to the second bull.

of hours or alternatively take most of the day and not

(8)

If possible, another bull should be available near-

achieve a collection. Furthermore, it is potentially

by. This can be useful to confirm the teaser

dangerous. Success, efficiency and safety all depend

on good organization and attention to detail. Generally *speaking a convenient date will be set for the examina-*

tion and all parties involved (man and beast) need to

Box 38.3

Check list for breeding soundness kit.

be organized accordingly. The following factors, if they

• Artificial vaginas, liners, cones, cord and adhesive tape

can be arranged, should help to make the visit go more

• Semen collection tubes (preferably graduated)

smoothly and efficiently:

• Lubricant for artificial vaginas (e.g. KY jelly)

(1)

For a full clinical examination and for semen col-

• Kettle and jug to fill artificial vaginas with warm water

lection it is desirable that the bull be restrained,

• Thermometers to measure artificial vagina temperature

that he can be led on a halter and, ideally, that he

• Electro-ejaculator(s)

• Two funnels and wire funnel holder for collection of

should be used to serving while being restrained

electro-ejaculated semen

by a halter or ring-rope. The reasons for this are

• Electric plug adapters and circuit breakers

obvious but in our experience with fewer staff on

• Electric extension cable

farms, bulls are much less used to being handled

• Microscope and light source

and therefore restraint is often counterproductive.

• Warm microscope stage

This leads to difficulties in reconciling the safety

• Heated cabinet

of the collector and handlers with the desire to

• Transformer packs

obtain a good semen sample.

• Stains: nigrosin–eosin, Giemsa and methylene blue

(2)

The bull should be sexually rested for at least

• Small test tubes and holder for use in staining and

one but preferably three weeks prior to the visit.

diluting semen for examination

This will enhance his libido and avoid depletion

• 2.9% sodium citrate, 0.9% NaCl and phosphate buffered

saline

of semen reserves, ensuring the best chance of

• Glass pipettes and rubber bulbs

obtaining a representative sample of semen.

• Slides, coverslips and slide holder box plus slide labels

(3)

A quiet cow in oestrus, preferably halter-trained

• Small sterile bottles for fresh semen samples

and that has not been served at that oestrus,

• Immersion oil

should be available as a teaser. Synchronization

• Paper wipes, cotton wool and swabs

with a progesterone releasing intravaginal device

• 50ml syringe with tubing, phosphate buffered saline and

of at least six females, in our experience, maxi-

sterile containers for preputial wash

mizes the chances of one or preferably more being

• Tape measure (for scrotal circumference)

available on the allotted date. While keen young

• Vacutainers, needle holder, needles and spirit

dairy bulls will usually mount a quiet non-oestrus

• Virus and Mycoplasma transport media

cow, our experience is that collection can still

• Record sheets, slide markers and pens

• Spare light bulb for microscope

prove difficult, particularly with inadequate

Fig. 38.1

The on-farm laboratory.

cow is in oestrus when the bull under test has

preferable to have a small portable cabinet specifi-

failed to mount.

cally designed for this type of activity.

(9)

Use a checklist of equipment and materials (see

• Stains. It is well worthwhile using more than one

Box 38.3).

stain routinely. The most commonly used are

nigrosin–eosin and Indian ink for sperm morphol-

ogy, methylene blue for examining the semen for

Set up the on-farm laboratory

extraneous cells and Giemsa for a combination of

the two. Nigrosin–eosin and Indian ink are used

This should be set up on arrival so that there is time for

directly, i.e. after preheating to 37°C they are mixed

the heated cabinet, solutions, glassware and warm stage

with the semen immediately after its collection and

to reach the required temperature. Select a small area

a smear is then made. The second stains are used on

of bench space, which is covered, has an electricity

a direct smear of the semen, which is air-dried and

supply and is not exposed to adverse weather (Fig.

then fixed before staining.

38.1). It should be as near the area of semen collection

• Solutions to dilute semen for examination of pro-

as possible. Given the standard of some farm electrics

gressive motility. A normal saline solution may suf-

a circuit breaker is a wise investment.

fice, although solutions commonly used for diluting

The on-farm laboratory should contain the following:

semen are phosphate-buffered saline or 2.9 per cent

• Microscope with facilities to examine semen by ¥50

trisodium citrate. These solutions should also be

to ¥100 (for initial motility) by ¥200 to ¥400 (for

preheated to as near 37°C as possible.

progressive motility) and ¥1000 (for morphology).

• Artificial vagina (AV). In general, inexperienced

• Warm stage (or equivalent). This is a prerequisite

bulls prefer rough liners and younger bulls a shorter

for the reliable estimation of motility. Ideally, it

artificial vagina, i.e. about 25 cm long. At least two

should be kept within 1°C of 37°C because either

should be assembled (Fig. 38.2) and be filled with

a high or low temperature can have considerable

warm water (prepared in an electric kettle for

artefactual effects upon sperm motility. Unfortu-

example) to a lumen temperature of about 60°C

nately, this equipment is quite expensive and there-

(they will often have cooled to around 45–48°C by

fore many veterinarians use a small prewarmed

the time they will be used). The lumen temperature

flat bottle or brass plate as an alternative. If this

should be between 42 and 50°C immediately prior

approach is used then it is best to have two so that

to semen collection and this must be checked with

they can be alternated and so kept at as steady a

a thermometer. In practice it is best to enter the col-

temperature as possible.

lection area with the AV at 50°C since there will

• Heated cabinet. While it is possible to use the farm

inevitably be some cooling before a collection is

kitchen oven to keep slides, coverslips, pipettes and

made. A sterile lubricant should be applied to the

stains, regulation of a reasonable temperature range

opening of the AV immediately before going to the

(35–40°C) is often difficult. For this reason it is

collection area.

Fig. 38.3

On-farm semen collection in a straw yard using an

artificial vagina (AV). The bull is searching for the vulva of the teaser cow. The collector is diverting the penis towards the AV.

surface such as grass or a firm straw bed rather than on *concrete (Fig. 38.3). However, in most circumstances*

the latter is the preferred surface since it generally gives

a sound secure footing. The bull falling causes most

injuries to collectors. It is for this reason that most

AI centres use service stocks and obviously if these

are available they should be used. However, whatever

Fig. 38.2

Assembly of the AV. A 30 cm long rubber AV cylinder

with latex liner and cone favoured by the authors for collection adaptation or compromise is used, the collector must

from adult bulls. A valve on the filling aperture conveniently remember that his safety and that of the others involved

permits air to be blown in to finely adjust the internal pressure.

is paramount. The main prerequisites are common

The graduated collecting tube is anchored to the cone by string sense, plenty of room and a safe footing. Listen care-and is protected thermally and physically by enclosure in a clear fully to all remarks about the demeanour of the bull.

plastic container secured with adhesive tape. A small (1–2 cm) Be aware that sometimes farmers may be carried away

slit can be made in the cone near the AV to act as a safety valve.

by the novelty of this examination. Try to discourage

This reduces the risk of disconnection of the cone or collecting bystanders!

tube that may occur during the thrust if there is too high a pressure in the AV. The AV cylinder is disinfected between bulls and the latex can be sterilized by *boiling.*

Introductory examination of the bull

If practical it is worthwhile giving the bull an initial

cursory examination prior to collection, gently running

one's hands over the bull, touching the prepuce and

genitalia. This allows the bull to get used to the per-

Assess the collection area and ability and reliability

sonnel involved, particularly the collector of semen, and

of the farmer and other animal handlers

also allows the collector to judge what size and pressure

of artificial vagina might be best and how the bull is

It is worth looking at where the farmer thinks it best for

likely to react to collection. Remember frightened bulls

the collection to take place. Remember that while he or

are dangerous.

she may not understand the needs of collection well

they do know the bull much better than you do! Some

bulls can be totally inhibited in the wrong surroundings.

Semen collection and assessment of ejaculate

Ideally, one should work in the place where the bull

normally serves the cows. A good surface will encour-

The libido of the bull and the likelihood of a successful

age a bull to mount, for example a bull with laminitis

semen collection can be enhanced by allowing him to

or an old bull will often work better on a relatively soft

have sight and sound of one or more oestrous cows

without physical contact for a short while before col-

prepuce guide the erect penis towards the opening of

lection is attempted. It is important to interfere as little

the artificial vagina held in the other hand. Touching the

as possible with the normal service behaviour of the

penis directly will generally cause the bull to dismount.

bull to obtain a representative ejaculate. The best tech-

The bull will vigorously seek the vulva by rapid back-

nique for the collection of semen is therefore the use of

ward and forward movement of the penis. The tempta-

an artificial vagina. The teaser cow should be restrained

tion to force the AV over the penis at this point should

in the collection area. The bull is held separately, but

be avoided as this can reduce the quality of the service.

nearby, from where he can be introduced for the col-

The bull should mount, clasp the cow, erect fully and lection and returned immediately afterwards to avoid search for the vulva with the penis, and, on finding the repeated service of the teaser between collections. The artificial vagina in its place, thrust and ejaculate in one teaser cow is an important factor in obtaining a repre- movement. The search should not take more than a few sentative semen sample. A teaser cow in oestrus will seconds and a good thrust takes both hind legs off the stand to be mounted. This is very important, particu- ground in a forward direction. The sound of an explo- larly with an experienced beef bull, which will generally sive exhalation indicates ejaculation. It is important refuse to mount if the cow does not stand steadily when that the bull makes a firm thrust as this reflects stimu- the bull 'tests' her. Furthermore, since many bulls are lation of the full complement of ejaculatory fluids and not used to being handled and therefore have to be so ensures that the sample is as representative of the allowed to mount free of control it is wise to have some- natural ejaculate as possible. A poor quality ejaculate

thing that they are more interested in than the collec-
associated with a poor thrust may not be representative,
tor! The cow must be physically capable of bearing the
often showing relatively poor motility, and semen col-
weight of the bull and ideally she should be restrained
lection should be repeated. The ejaculation should take
in the collection area by at least a halter. Unfortunately,
place at the end of the AV, ideally within the cone itself,
many cows have never been haltered so they tend to
and thus the semen should be unaffected by the tem-
object to this and thus, by struggling, put the bull off
perature of the AV. However, in some cases this is not
working. Furthermore, in other cases their stubborn
what occurs and the sample may have to be allowed to
lack of initial movement is itself off-putting to the bull
run down from the AV, which is held vertically after col-
and if nothing is happening it is worthwhile trying to
lection. In such a case it may not only be affected by
lead the cow in front of the bull. In some cases, where
the AV temperature but also more contaminated than
it is deemed safe, collection can only be achieved with

usual with preputial detritus.

both the cow and bull running loose and a roomy col-

Because of the rapidity of service in experienced

lection area is essential for this to avoid the collector

bulls and the necessity of examining the semen sample

being knocked over or crushed.

as soon as possible after collection it is often difficult to

examine the penis fully and collect semen at the same

Introduction of the bull to the teaser cow: When the bull time. However, an appreciation of its firmness is possi-is brought into the collection area for service the

ble, as is a quick visual assessment of both the penis and

collector should watch only the bull and make the

the prepuce. Should a more thorough examination be

following mental notes:

indicated, mounting can be repeated later without a col-

lection being made, the penis (that part within the

• Demeanour – is he interested in the cow?

prepuce) being directed toward the examiner, thereby

• Gait – is he lame, if so where?

exposing the protruded portion for a more prolonged

• Libido – is he keen to work? Watch for the pumping

examination. This posture can often be held for a few
of the ischiocavernosus muscle (this will be appar-
seconds as long as the tip of the penis does not contact
ent by a rippling tail–head movement) and the drip-
the cow. Wherever possible, more than one collection
ping of clear pre-ejaculatory fluid from the prepuce.
should be made, especially if the first is of poor quality.
The penis may also be seen protruding a little from
Moreover, in some cases an even greater number of col-
the prepuce: does this appear normal? Usually
lections may be required to satisfy the collector that the
before mounting an experienced bull will grunt and
bull has worked well and that the series of samples
make a quick movement at the rear of the cow just
obtained is as representative as possible. Only experi-
to test if she will stand. If the cow is not in season
ence allows this judgement.

she will move, even if restrained, and this may be
quite sufficient to stop the bull mounting.

Experience of collector: There are considerable varia-
tions between how bulls cope with the use of an artifi-

Penile erection and ejaculation: As soon as the bull
cial vagina and the experience of the collector can help
mounts the cow the collector should move forward
considerably in obtaining a good ejaculate as opposed
quickly, but without panic, and with one hand on the
to a poor one. It is difficult to rationalize just what the

collector does to ensure a good collection. Firstly, there
tractions with each series of pulses and these increase
is the judgement as to whether to try and collect when
in strength with voltage. The bull may raise his tail, rock
the bull first mounts. Quite often the first mount will be
gently to and fro and, if the probe is incorrectly posi-
'premature' with a poor erection of the penis and in
tioned, lift one hind leg and, if excessive stimulation is
most cases it is best just to deflect the penis by using
applied, the bull will go down. It has been suggested
pressure on the prepuce and let the bull dismount.
that the bull be sedated in some circumstances.
While this carries the risk of putting the bull off mount-
However, our experience is that the danger of the bull

ing again, this is unlikely in bulls with normal libido.

going down means that the technique is best used

Time and effort spent in teasing (even to the point of

without sedation. Sexual rest before electro-ejaculation

removing the bull or the cow from the scene temporar-

seems to improve the likelihood of obtaining a repre-

ily) are usually rewarding and eliminate any doubts that

sentative sample.

can arise when a poor sample is obtained at the very

In our experience the latter techniques are only of

first mount. Secondly, there is the process of actually

value if one obtains an ejaculate with motile spermato-

allowing the penis to enter the artificial vagina. In some

zoa and can study their morphology. Failure to obtain

cases, where the bull will not immediately thrust, it may

an ejaculate does not mean the bull is infertile! Even

be induced to do so by a short, quick, back and forward

then concentration is so variable that at least in our

movement of the artificial vagina. This should be firm

experience it cannot totally be relied upon as repre-

but gentle. Related to this is the decision as to the *sentative of naturally ejaculated semen.*

length of the artificial vagina, the pressure of the water

in the liner, the type of liner and temperature. For

Assessment of ejaculate: While there has been, and still example, few bulls will thrust well with an artificial

is, considerable research into the prediction of fertility

vagina temperature less than 42°C, but equally there is

on the basis of tests upon semen (Linford et al. , 1976; no need for it to be more than 55°C. The use of a very

Miller & Hunter, 1987), the general form of on-farm

warm artificial vagina with a rough liner can leave the

semen examination is still largely based on the pio-

penis looking very red! It is vital to remember that the

neering work of the early AI industry. In particular, the

tip of the penis is highly sensitive, and that an ejacula-

reader is referred to the study by Bishop et al. (1954).

tory thrust is usually induced immediately it enters a

A full ejaculate examination generally entails

properly prepared AV.

observing and recording the following:

• Volume

Other techniques of semen collection: Occasionally, the

• Initial motility of semen

collection of an ejaculate by artificial vagina proves

• Progressive motility of spermatozoa

impossible and it is deemed necessary to examine a

• Morphology of spermatozoa

semen sample. In such circumstances, if the bull will

• Presence of other cells

mount and serve an oestrous cow then the removal of

• Concentration of spermatozoa

semen and vaginal mucus from the vagina of the cow

• Final overall assessment

and examination of the spermatozoa in the mucus is, in

our opinion, more sympathetic to the bull's welfare

The first three measurements above are usually

than electro-ejaculation. It is for this reason that the

carried out on the farm, followed by an initial assess-

cow should not be served prior to the visit. Semen can

ment of the results. Smears of semen are also prepared

be collected by massage of the ampullae per rectum

on farm, but not necessarily examined; this is essential

(McGowan et al., 2002) and can be done without a

for the nigrosin–eosin stained smears. Samples and

teaser cow in oestrus.

smears are then returned to the laboratory for comple-

In the last resort, and in our opinion only if it is felt

tion of the other tests followed by the final overall

absolutely necessary, one should collect semen by

assessment. The ejaculate should be returned to the on-

electro-ejaculation. This technique depends on electri-

farm laboratory as quickly as possible after collection.

cal stimulation of the sacral segments of the spinal cord,

It must not be allowed to become chilled until after the

which are mainly parasympathetic nerves emerging

first three steps and preparation of the nigrosin–eosin

from the pelvic plexus. This stimulation will often cause

smears are completed.

a form of erection (possibly incomplete) and ejacula-

***Volume:** Use a graduated collecting tube.*

tion. The ejaculate often differs from a 'normal' ejacu-

***Initial motility of semen:** A small drop of semen is*

late by having a considerably greater volume and a

placed on to a warm slide, which is put on a warm *lower sperm concentration (even in the ‘sperm-rich’*

microscope stage (35–37°C) and examined (¥100) as

portion). This is due to the excessive contribution of the

soon as possible after collection. It is scored on a scale

accessory glands, in particular the seminal vesicles.

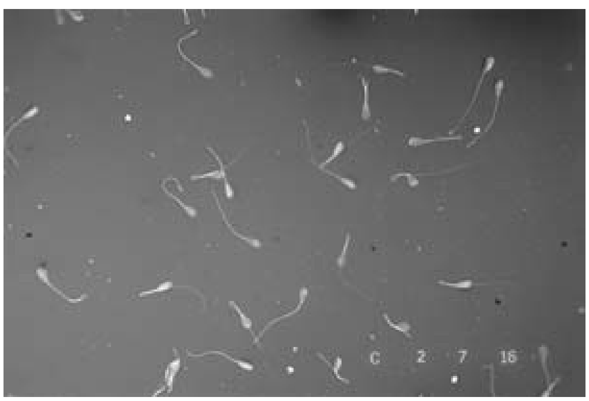
of 0–5, ranging from 0 being completely static to 5 being

Another disadvantage of this technique is that, at

vigorously active. In the bull the major criterion of

least with some machines, the animal shows tetanic con-

scoring initial motility is wave motion, which is a func-



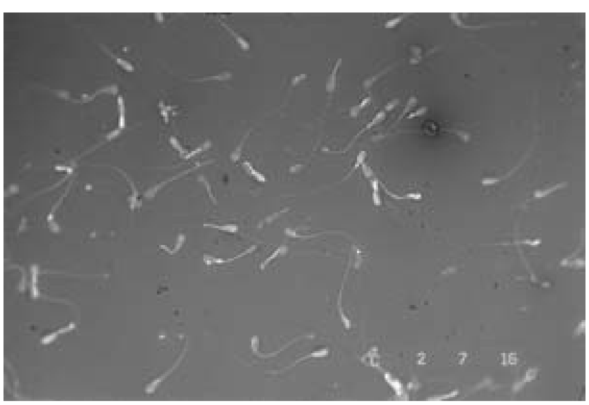


Table 38.3

Guide to assessment of initial motility.

Score	***Motility***	***Approximate % live, where density and morphology are normal***
5	*Rapid vigorous waves*	*90+*
4	*Good wave motion*	*80*
3	*Sluggish wave motion*	*60*
2	*Active sample, but no wave*	*40*
1		

Some motile sperms

20

0

No movement

0

Fig. 38.4

Spermatozoa morphology (nigrosin–eosin ¥ 400).The

reflected tails are artefactual, possibly due to chilling during tion of concentration, proportion of motile sperm and

staining and smear preparation. There is no evidence of cyto-

their activity (see Table 38.3). This simple test, if applied

plasm in the bend of the tail and Giemsa-stained air-dried

correctly, correlates quite well with fertility. Any bull

smears did not show the defect.

that consistently produces semen with a score of less

than 2 should be suspect.

***Progressive motility of spermatozoa:** Progressive*

motility, the percentage of motile spermatozoa moving

in a forward direction, is best estimated by diluting the

semen (roughly 1 : 50 depending on concentration) in a

prewarmed (37°C) physiological solution (see p. 601) *and examining this at ¥400 magnification under a warm cover slip. A figure in excess of 50 per cent is certainly desirable. High percentage progressive motility generally also means rapid progressive movement. Examination at this power (¥400) will also allow some initial observation of the morphology of the spermatozoa and the presence of unusual cells in the semen.*

Morphology of spermatozoa: *The morphology of the spermatozoa is closely related to testicular function and*

Fig. 38.5

Spermatozoa morphology (nigrosin–eosin ¥ 400). A

the appearance of head, midpiece and tail should all be

range of defects including proximal cytoplasmic droplet, dag

studied. A general morphological examination entails

defect, reflected tail, detached head and microhead.

the observation of spermatozoa (and other cells) under high power (¥1000), noting any abnormalities and expressing these as the number of abnormal spermato-

in the preparation of a blood film) and allowed to dry

zoa/100 spermatozoa counted. This is best done quietly in the warm cabinet or on the warm stage. Chilling *away from the farm although a cursory on-farm look at*

¥

during preparation can lead to artefactual effects on

400 will allow tentative prognosis for the owner and

sperm morphology. This stain will also allow the com-

also satisfies the collector that the smear is acceptable.

putation of the live : dead ratio since eosin is a vital dye,

The use of at least two different staining techniques is

staining so-called dead (or immotile) spermatozoa

recommended: one entailing dilution of the semen prior

pink, but leaving live spermatozoa unstained and pale,

to making the slide and the other using a direct smear,

almost white. The percentage live figure correlates

which is stained after fixation. These are described more

well with percentage progressively motile and not

fully below.

surprisingly gives similar correlation coefficients with

(1)

Nigrosin–eosin stain (Figs 38.4, 38.5). Freshly col-

fertility.

lected semen should be mixed with prewarmed stain in

(2)

Indian ink smear. This can be prepared in the same

a small test tube roughly according to spermatozoa con-

way but does not show 'vital staining'.

centration (average 1[semen] : 10 [stain]) and allowed to

incubate at 35–37°C for one minute. One small drop is

(3)

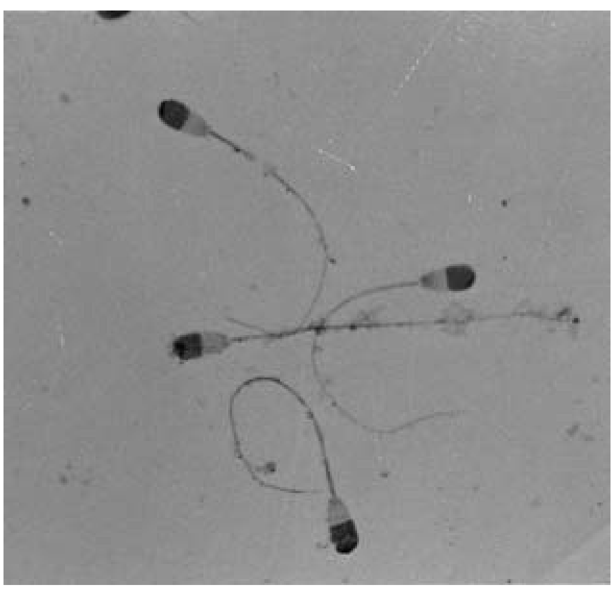
Giemsa (Fig. 38.6) and methylene blue stains. In

then taken and smeared thinly across a prewarmed

this case at least three direct smears of the semen are

slide (using the same technique as would be employed

made on warmed slides and allowed to air dry and this



Box 38.4.

Spermatozoa abnormalities.

Head abnormalities

Microhead

Macrohead

Pyriform

Acrosome defect

Neck abnormalities

Detached head

Detached tail

Fractured neck

Other

Midpiece

Double

Swollen

Abaxial

Curved

Distal mid piece reflex

Other

Tail

Coiled (dag defect)

Tail reflected

Fig. 38.6

'Knobbed sperm', an inherited defect of the Friesian

Proximal cytoplasmic droplet

breed (Giemsa) (¥700).

Distal cytoplasmic droplet

would usually be done on the farm. On return to the

Table 38.4

Visual criteria for estimating semen concentration

laboratory one is fixed using 10 per cent formal saline

(¥106 spermatozoa/ml) (from Logue & Greig, 1987).

(buffered), one using methanol and the third by gentle

heat. After the first two have been washed in water they

Appearance

Estimated number of

are stained in a simple buffered 10 per cent Giemsa

spermatozoa (¥106)

solution for approximately three hours. Depending on

its source, ordinary tap water will do. This stain should

Thick cream

3000

highlight the acrosome and allow further identification

Cream

2000

of any abnormalities of this region in particular. If one

Milk/cream

1000

brings the slides back to the laboratory before fixation

Milk

500

Water/milk

250

the use of the two different fixes can be of particular

Cloudy

100

value, since often one gives a better resolution of the

acrosome than the other, presumably due to differences

in the relationship of thickness of the smear, time of air

drying and the fix. The heat-fixed slide is stained by

inherited, for example the knobbed sperm. Results of

methylene blue (see p. 601). Comparison of direct

morphological analysis should be presented in tabular *smears with those prepared following mixing of semen*

form, showing the proportions of the various abnor-

and stain (e.g. nigrosin–eosin) allows detection of arte-

malities seen (Box 38.4).

factual morphological effects that can arise from faulty

***Presence of other cells:** A variety of cells are nor-*

technique in preparing the latter (Fig. 38.4).

mally found in semen and these cells are best observed

Considerable experience is required before reliable

either in the direct smear stained by Giemsa and/or a

counts of morphological abnormalities can be obtained

direct smear heat fixed and stained by methylene blue.

and the reader is referred to Barth and Oko (1989) for

The latter demonstrates leukocytes particularly well.

authoratative guidance on the procedures required.

Most of the cells are of preputial or urethral epithelial

Overall one is aiming for at least 70 per cent normal

origin and are of little consequence. However, the pres-

spermatozoa. However, this needs to be qualified as the

ence of large numbers of leukocytes, small darkly stain-

effect upon the fertility of the semen depends upon the ing cells that appear to be degenerating spermatids,

type and extent of abnormality (Barth & Oko, 1989);

multinucleate giant cells and so-called ‘round’ cells is

thus head and midpiece abnormalities (including cyto-

indicative of spermatogenic disruption.

plasmic droplets) are more important than simple

Concentration: This can be estimated using the cri-

reflected tails. Some abnormalities are known to be

teria in Table 38.4. When a more accurate measurement

is needed then resource to a calibrated turbidity meter

analysis semen samples tend to fall into one of three

or a simple haemocytometer is needed.

categories. Firstly all parameters are well above the

Final overall assessment: There has been little study

minimum reference figures in Table 38.5 (the semen

of the correlation of these commonly measured semen

should be of normal fertility). Secondly the important

parameters with the fertility of bulls used under natural

parameters fall well below (the semen is likely to be

service conditions. For semen collected by AV and used *subfertile or sterile). Thirdly the important parameters*

for artificial insemination there is evidence for correla-

are mostly at or just below the minimum reference

tion of motility and percentage dead spermatozoa with

figures. It is the third category that causes difficulties. If fertility and that is why we have described these tests

there is a history of infertility and there are no other

(Bishop et al. , 1954). In North America, the New Society significant findings, the bull could be re-examined after

for Theriogenology Breeding Soundness Evaluation

three months to see if there is improvement in the

System (Hopkins & Spitzer 1997) is based on examina-

semen parameters. If the semen picture is normal at this

tion of semen collected by electro-ejaculation and may

time this suggests the bull was recovering from some

not be applicable to AV collected samples. Our experi-

form of testicular degeneration at the first examination.

ence with an electro-ejaculator is that in some cases

If the semen quality has deteriorated further the prog-

perfectly normal bulls fail to give a good sample.

nosis is very poor. However, if the quality is similar then

However, the Society suggests that to be classified as *test mating to at least ten fertile females followed by*

satisfactory the 'gross motility' must be at least 'fair', the pregnancy diagnosis is the only recourse.

'individual progressive motility' at least 30 per cent and

Ancillary tests: *Research into other attributes of*

morphology analysis should show at least 70 per cent

semen, and particularly spermatozoa, that correlate

normal sperm cells. The Society's 'gross motility' is

well with fertility has been consistently directed to the

equivalent to the initial motility assessment described

development of simple cheap methods to improve the

here except that a cover slip is placed on the drop

accuracy of our predictions. Unfortunately, to date, such

of semen; 'fair' ('generalized oscillation') probably

an addition suitable for on-farm use by a practising

equates with a score of 2 and 'individual progressive

veterinarian has not been found. The most widespread

motility' is equivalent to progressive motility. Therefore

tests have been the use of sperm motion analysis using

the measurements that correlate best with fertility are

a variety of computer based packages, cervical mucus *generally believed to be initial and progressive motility, penetration tests and zona pellucida (ZP) penetration percentage dead spermatozoa and percentage morpho- tests (the simplest of these being the number of acces- logically normal spermatozoa. However, volume and sory sperm 'trapped' within the ZP). All these measure density are usually also recorded. Table 38.5 shows the ability of the spermatozoa to gain access to the egg minimum reference figures used by the authors when for fertilization more objectively. However, only a more assessing bull semen. They are based on published work accurate evaluation of the acrosome using phase con- and experience and are offered as a guide. However, it trast microscopy seems applicable to the practical must be appreciated that correlation of findings in examinations that we are discussing here and even this semen and the fertility of natural service bulls is an seems more relevant to studying the effects of process- inexact science due to the paucity of published infor- ing damage upon spermatozoa stored for either AI or mation available, which reflects the difficulties of small* *other reproductive technologies. Finally there are a scale on-farm investigations of fertility. In the final number of laboratory investigations showing the value of a variety of fluorescent stains which can allow evaluation of the chromosome content (X or Y), DNA variability, membrane integrity, mitochondrial function and vital function (for review see Garner, 1997). In the long term some of these tests may allow an improvement in*

Table 38.5

Minimum reference figures (with range) for assessment of ejaculate.

the accuracy of assessment of semen, but until that time it is still an inexact science!

Volume (ml)

4 (2–12)

Appearance

White (some

Observation of natural service

samples have a

yellow tinge)

Finally, after semen collection is completed it is very

Density (¥109/ml)

1.0 (0.3–2.5)

worthwhile standing back and observing the bull

Initial motility (0–5)

≥2

serving the cow naturally. Obviously, this is only possi-

Progressive motility (%)

>50

ble with a cow in season and the consent of the owner,

Total dead spermatozoa (%)

<50

who may not wish to have the cow served. This proce-

Total morphological abnormalities (%)

<30

dure avoids the risk of declaring a bull fertile on the

basis of normal semen findings when the bull is actually

• Spermatic cords

unable to complete natural service.

• The scrotal sac itself.

The testes should exhibit freedom of movement

Full physical examination of the bull

within the scrotum and all structures should be of

We have already suggested that the first opinion vet-

normal size, shape, and free from inconsistency in

erinarian may undertake a full examination of the bull

outline, i.e. bumps and nodules. A simple objective

as a preliminary to any further investigations. We rec-

measurement of testicular size is scrotal circumference.

ommend that even if this was done previously it is

This is determined by measuring the circumference of

always worthwhile going through the examinations

the scrotum at its largest point with a tape measure

again. Hard experience has taught that no one is infal-when the testes are in (or manipulated into) a normal

lible and defects can either be missed or could have

fully descended position. In the normal adult bull this

become more apparent between examinations! In any

should be between 33 and 45 cm, depending on breed

event a full examination of the reproductive tract is

and mature size (see Table 38.6). More recently, the use

essential, as is the examination of several other aspects *of real-time ultrasound has been employed as a further*

of the clinical appearance of the bull. Obviously, where

diagnostic aid (Figs 38.7, 38.8). It remains to be seen

lameness or some other defect is apparent during

precisely how valuable it will be. However, it is now

collection the relevant area should now be examined

being used by a number of veterinarians, including

more thoroughly.

the authors, and has highlighted a variety of defects

including orchitis and calcinosis.

Mouth: Assess the age of the bull by examining the

incisor teeth. This is often very helpful in impressing

Pelvis: A rectal examination is needed to examine the

upon owners how immature their young bulls are.

accessory sex glands. Some of these are found just

Many bulls of continental breeds have still no adult

under the hand after it has been fully inserted through

incisors at two years of age.

the anus and the ampullae of vas deferens and seminal

vesicles can be identified. The prostate and bul-

Eyes: It is also worthwhile examining the eyes, at the bourethral glands cannot *normally be distinguished.*

very least to rule out congenital cataracts. Severe

The main part of the former is found at the beginning

cataracts can lead to unpredictable behaviour of the

of the root of the penis, while the latter is found just

bull and are found in all breeds. A good ophthalmo-

anterior to the ventral bend of the root at the bul-

scope is needed to diagnose less obvious abnormalities

bospongiosus muscle. Again ultrasound has an obvious

such as colobomata of the retina.

application, in particular for the examination of seminal

vesicles.

Penis and prepuce: Palpate around the orifice of the

prepuce, the sheath itself and the penis as it runs back

Confirmation of identity: The breed and physical

to the scrotum. It is also worthwhile examining the

description of the bull should be recorded along with

umbilicus for evidence of a hernia.

ear tag numbers and any tattoo numbers where legible.

Scrotum: Palpation of the scrotum allows definition of Collection of other diagnostic samples *the following structures:*

The composition of the collection is influenced in part

• *Testes*

by the health status of the national herd and also by that

• *Epididymes (head, body and tail)*

of the herd the bull is in or has been introduced to. The

Table 38.6

Suggested minimum scrotal circumference measurement (cm) to exert selection pressure for increased testicular size for bulls by breed and age in North America (Reproduced from Coulter et al., 1987 with permission from Elsevier Science).

Age of bull

Simmental

Angus and

Hereford and

Limousin

(months)

Charolais

Shorthorn

12–14

33

32

31

30

15–20

35

34

33

32

21–30

36

35

34

33

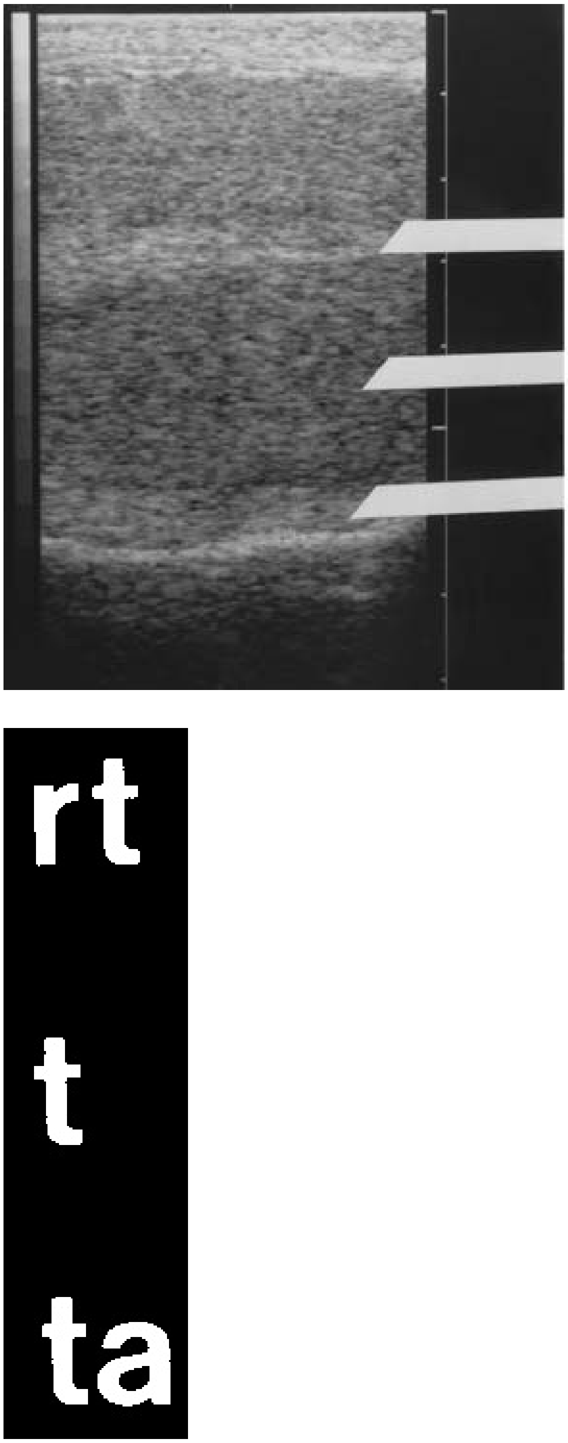
Over 30

37

36

35

34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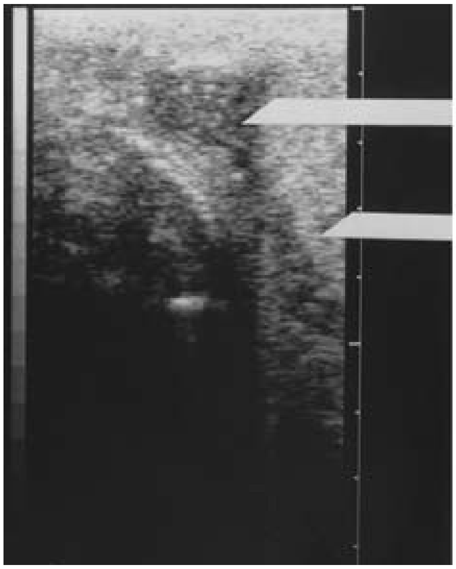
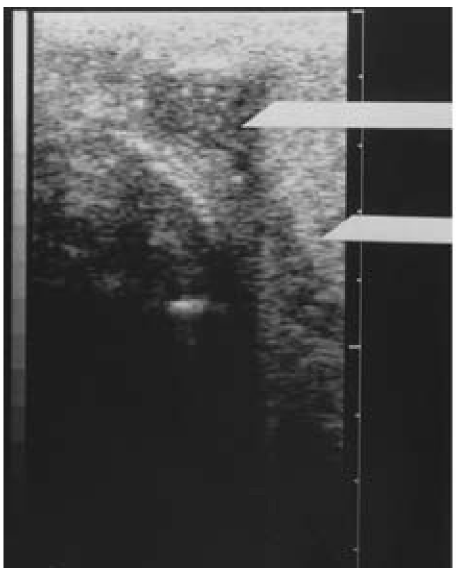




ep:t

t

Fig. 38.9

Samples for further laboratory investigation routinely

returned from the farm by the authors. From three ejaculates in this case: nigrosin–eosin stained smears, air-dried smears and raw semen; also heparinized blood and preputial wash.

(2)

Blood for BVDV antigen and antibody, unless bull

previously tested.

If indicated by history, semen findings and/or clinical

Fig. 38.7

Real-time ultrasound of the testis. rt, rete testis; t,

signs collection of further samples, as detailed below,

parenchyma of testis; ta, tunica albuginea.

should be considered:

• Semen for culture of bacteria, virus or Mycoplasma

sp.

• Blood for serology for IBRV, Leptospira hardjo or Johne's disease.

• Blood for biochemistry (e.g. albumin or liver enzymes) or routine haematology.

• Faeces for examination for helminth eggs, culture for Salmonella sp. or smear or culture for the bacterium of Johne's disease.

In some cases sampling of the females involved may also be required, e.g. vaginal mucus for VMAT for C. fetus sp. antibody.

Preliminary diagnosis and prognosis

Prior to leaving the farm and before all the examinations of semen and further laboratory tests have been concluded the farmer will be keen to hear a verbal preliminary diagnosis and more importantly a prognosis

Fig. 38.8

Real-time ultrasound of the tail of the epididymis.

and some advice about what should now be done with

ep : t, tail of epididymis; t, testis.

the bull. These can usually be given, with the proviso that they are pending the outstanding test results, since *any major abnormalities of the semen or physical*

minimum routine employed by the authors in the UK

abnormalities in the bull should be apparent before

is as follows (Fig. 38.9):

leaving the farm. Nevertheless, it is wise not to be too

(1)

Preputial washing for culture and fluorescent

dogmatic, particularly with reference to the presence or

antibody test for Campylobacter fetus sp.

absence of any form of infectious infertility.

Final diagnosis, prognosis and advice after all test

• Season

results are known

• Social factors

Having obtained the history of the bull, examined it

• Overwork

fully for breeding soundness (and any cows if neces-

• Nutrition

sary) and with knowledge of all relevant laboratory test

• Orthopaedic abnormalities and housing conditions.

results, a written report should be prepared. This should

summarize the history, findings and any laboratory test

Age

results. It should then reach a conclusion, which should

The age at which a bull is capable of mounting, pro-

include a diagnosis, however tentative, and, if available

truding the penis fully and ejaculating semen (puberty)

an appropriate treatment and/or management regime

varies with the bull and breed (see p. 479). However,

to prevent or control the problem should be offered.

one would normally expect a bull of a high production

Finally a prognosis should be given. A discussion of

dairy breed to be capable of serving a cow at 12 months

the aetiology of the problem can also be included. In

of age, although usually semen production would have

general, the most important aspect of this conclusion is

commenced some two months earlier. Indeed mount-

the prognosis. Effectively there are three alternatives:

ing behaviour would be normal in the prepubertal state.

(1)

No abnormality can be detected and the bull

However, one would not advise use for breeding before

should be of normal fertility. If the history is of

15 months of age. Continental beef breeds tend to

poor fertility recommend a 'test-mate' with at

mature at a later age than most dairy breeds and so

least 10 fertile females.

more care is needed with such animals when attempt-

(2)

An abnormality consistent with a history of poor

ing to use them at a young age, for example less than

fertility has been found and the bull is considered

18 months. From a behavioural point of view young

long-term infertile or unlikely to return to normal

bulls often display naivety and awkwardness in their

fertility.

approach to an oestrous cow. There is evidence that this

(3)

The bull is infertile or of questionable fertility, but

can be affected by how young males are reared, so that

it may recover. In this case, depending on the

young bulls raised with female calves are less likely to *diagnosis, the value of the bull and the manner in*

exhibit sexual naivety than those kept in the presence

which the farm use him the bull can be kept,

of their dams until weaning (Kilgour, 1984).

treated if necessary and the situation re-evaluated

In extreme cases young bulls may go through a pro-

in two to six months.

nounced phase of showing no sexual interest even when

presented with a cow in oestrus. This 'sexual inhibition'

may be heightened by the presence of another bull.

Further action for the herd and its future

While the condition often indicates an inherently poor

breeding management

libido, the problem may correct itself with time. Simi-

Where any findings made in the bull are likely to impinge

larly, despite being clinically normal, bulls can show a

on the rest of the herd, now or in the future, this should

considerable lowering of their sexual drive beyond

obviously be mentioned in the report. Examples would

eight to ten years old (Chenoweth, 1983).

include the presence of significant infectious agents or

Low sexual drive may also be due to overwork or

evidence of overworking a young bull.

pain, either from an orthopaedic problem or possibly

emanating from the reproductive tract (see p. 611).

Manifestations, aetiology, treatment

Genetic factors

and prognosis of bull infertility

There is evidence from work with identical twins that

many aspects of mating behaviour, in particular sexual

The aetiology, treatment and prognosis of infertility in

drive and mode of approach to service, are inherited

the bull are discussed in more detail below under each

(Bane, 1954). Furthermore, despite the wide variation

of the four manifestations.

between individuals there is plenty of evidence that

some types and breeds of bulls display better libido

Failure to mount

than others. For example, dairy breeds tend to show a

stronger sexual drive than beef breeds and there is

The following factors have an influence on the ability

now evidence of a quite high heritability for libido *to mount.*

(Chenoweth, 1983).

• Age

However, there is little evidence that variation in

• Genetic factors

libido is due to differences in circulating hormone

Bull Infertility • 611

concentrations (Bane, 1954). This was demonstrated

direct relationship between nutrition and fertility in

dramatically in an endocrinologically abnormal bull

working bulls. Nevertheless, it is widely believed by

with a 60, XXY chromosome complement, in which the

farmers that performance testing young working bulls

mating behaviour was normal (Logue et al. , 1979).

is detrimental to their longevity as working sires.

There is little firm evidence of any relationship

between poor libido in the bull and poor oestrous

Orthopaedic abnormalities and housing conditions

expression in female offspring, but there is some evi-

dence of a relationship in sheep. Thus libido is a factor

Often the bull will show intent to mount, moving to the *that should not be ignored in any selection programme*

cow and standing behind her, but does not mount

(Chenoweth, 1983).

because of painful or physically limiting orthopaedic

abnormalities. Obviously, the level of libido of the bull

mediates the extent of this effect and on some occasions

Season

the frustration becomes so great that the bull will strike

There is conflicting evidence about the effect of season

the cow.

of the year, largely because of the environmental con-

A large number of orthopaedic problems are liable

ditions in which the bulls were kept. A sluggish sexual

to interfere with the ability to mount and serve a cow.

drive has been related to periods of extreme heat, cold

The most common problem areas are in the foot, the

and light reduction (Vincent, 1972; Foote et al. , 1976; hock, the stifle and the back.

Gwazdauskas, 1985).

The treatment and prognosis of failure to mount

depends very much on the diagnosis of the clinician.

Many of these problems result from injuries to muscles,

Social factors

tendons and joints caused by the bull slipping when

Age, genetics and season all interact in the herd situa-

attempting to serve on poor underfoot conditions or

tion where the bull is running with a group of cows

foot lameness (see Chapter 31). Thus, adequate housing

either as the only male or along with several other bulls

and service management are prerequisites of good bull

as a mating team. Thus generally the oldest and largest

fertility. The specific requirements of the bull for service

bulls are dominant and spend most of their time in

should be borne in mind and thus any prognosis should

the presence of the sexually active oestrous females

be guarded. This is because many bulls are prepared to

(Chenoweth, 1983). Subordinate bulls spend consider-

mount before a healing process is complete, thus exac-

ably less time with that group and in some cases their

erbating the condition, and also because frequently the

attempts to serve will be totally disrupted by the dom-

bull produces soft, dystrophic bone in and around the *inant bull.*

site of injury resulting in added healing difficulties with

subsequent arthritis (Bartels, 1975; Weaver, 1997).

Some injuries appear to be more specific bull problems,

Overwork

such as spinal changes (Bane & Hansen, 1962), stifle

Bulls do become satiated. This state varies with the indi-

injuries (Bartels, 1975) and delayed spastic paresis (Fig.

vidual and the herd structure and in temperate climates

38.10).

seems more likely to present during the winter than in

It should also be remembered that other less specific

longer daylight periods. In simple terms, introduction of

conditions can cause poor libido simply due to the bull

a young, totally inexperienced, 18-month to two-year-

feeling unwell or being in pain. This is particularly

old bull to 20 cycling cows is considered to be risking

relevant if the penis and/or prepuce has been damaged

overwork, while introduction to as many as 40 is fool-

(see below). Finally, other diseases such as bovine

hardy! Finally, poor female fertility can compound the *spongiform, encephalopathy (BSE) (see p. 909) and*

problem because of returns to service.

progressive ataxia (see p. 179) of Charolais cattle

(Palmer et al. , 1972) should be borne in mind.

As already mentioned, it is most important to intro-

Nutrition

duce the bull gradually to an adult workload and to

High planes of nutrition result in puberty and maturity

monitor his progress closely at every stage. In particu-

being reached at an earlier age (Salisbury & Van

lar, the bull should be introduced initially to quiet adult

Demark, 1961). There is also some evidence that high

cows which are clearly in season and virtually hand-

energy intakes in early development are detrimental to

mated until the bull and his owner are confident that he

subsequent libido. This effect has been described in

can work reliably and fertility is confirmed by early

both dairy and beef bulls, but without looking closely at

pregnancy diagnosis of those females using real time

whether the regime caused the physical defects such as

ultrasound after day 26. Table 38.7 gives some general *laminitis in the bulls. There does not appear to be a indications of workload.*

preputial defects and orthopaedic problems. It is important not to belittle the problems of diagnosis, for example an early manifestation of either corkscrew penis or a venous drainage defect could conceivably be masked by the overzealous application of an artificial vagina. Observation of the natural service behaviour of the bull should generally avoid this error although some young bulls can display penile abnormalities intermittently. As ever prognosis, treatment and prevention depend upon the exact diagnosis.

In order to understand penile problems fully a brief

discussion of the anatomy and physiology of erection in

the bull (Fig. 38.11) is necessary.

Intromission can only be achieved if the penis is fully

erect. This is a stiffening process brought about by the

filling of the corpus cavernosum penis with blood

pumped in by the ischiocavernosus penis muscle. Since

drainage of the corpus cavernosum penis is very slow

in normal bulls, blood pressure in the corpus caver-

nosum penis builds up well in excess of that in a car tyre

Fig. 38.10

Delayed spastic paresis in the bull.

(over 200 psi) (Beckett et al. , 1974). This is sufficient to harden and straighten the penis and it is consequently

forced out of the sheath. The latter, owing to its elastic

Table 38.7

Recommended workload of bull with age (running

nature, envelops the erecting penis up to the start of

loose with females).

the free end of the penis. As the penis protrudes and

reaches the point of ejaculation, it stiffens still fur-

Age

No. of cows

ther and spirals in an anticlockwise direction. This

'corkscrew' is caused by the fibrous architecture of the

<2 years

10 cows

glans, in particular the dorsal apical ligament and spiral

2–3 years

20 cows

distribution of collagen fibres along the tip of the penis,

3 years

30 to 50 cows depending on bull

allied to the rise in blood pressure in the corpus caver-

nosum penis at ejaculation. Further distortion may be

caused by the very transitory erection of the erectile

tissue at the tip of the penis. It is believed that this may

The prognosis for poor libido of indefinable origin

be caused by pressure waves in the corpus spongiosum

must be extremely guarded, since, despite any mitigat-

penis (Ashdown, 1973).

ing circumstances, it is likely that this problem is inher-

Clinically, we suggest that there are two major pre-

ent in the make-up of the bull and will recur. In young

sentations associated with failure to achieve intromis-

bulls of around 18 months to two years of age the prog-

sion and each can be further subdivided as follows.

nosis is more hopeful, but a maximum time scale of six

months in which to show some evidence of overcoming

(1)

The penis cannot be protruded sufficiently:

the condition is appropriate.

(a)

Balanoposthitis

Attempts to treat low libido by a variety of hor-

(b)

Short penis

mones, either alone or in combination, have rarely

(c)

Rupture of the corpus cavernosum penis

proved of value and there is a dearth of recommenda-

(d)

Persistent frenulum.

tions apart from sexual rest in any of the common texts.

(2)

Failure to locate vulva or enter vagina:

In fact, matters remain as described by Lagerlöf in

(a)

Psychogenic problems

1951!

(b)

Penile problems: fibropapillomata, drainage

defects, corkscrew penis, deviations.

Failure to achieve intromission

The penis cannot be protruded sufficiently

The majority of bulls that are presented as being able

to mount, but then fail to gain intromission, suffer from

Balanoposthitis: Some cases of inflammation of the

a variety of conditions, which include penile or

epithelium of the penis and prepuce can result in inabil-

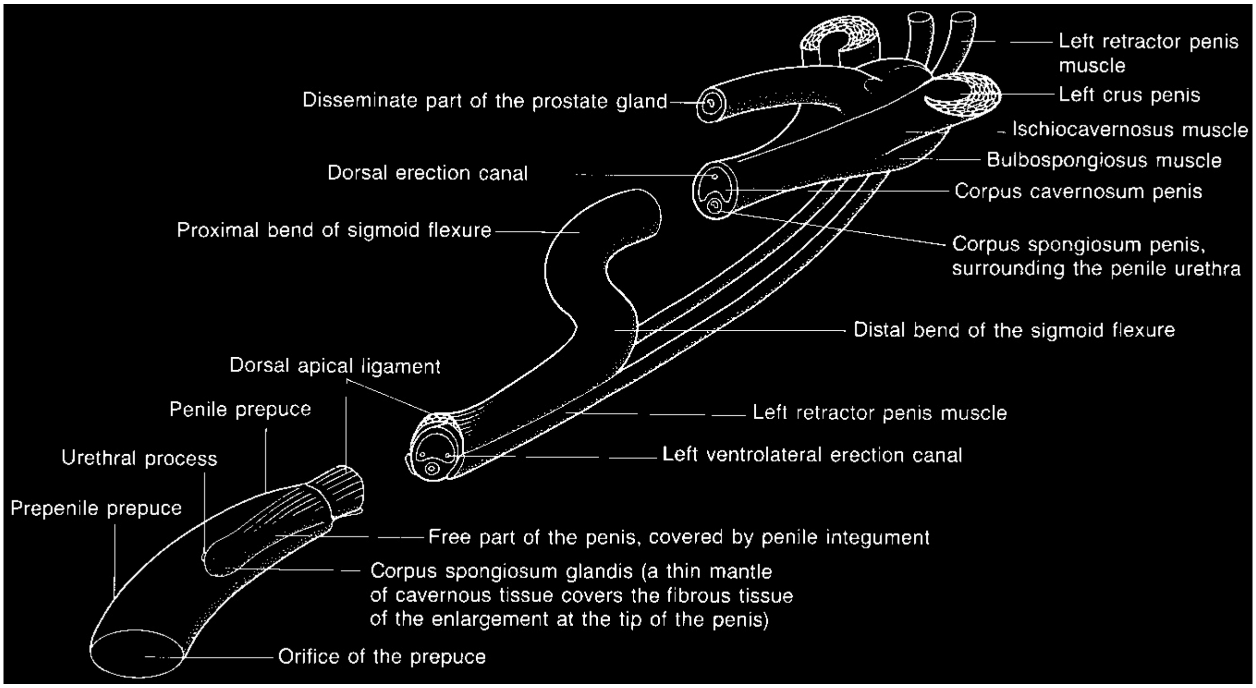


Fig. 38.11

Diagram to show the anatomy of the penis and prepuce of the bull. (Courtesy of Dr R.R. Ashdown.) infection (Memon et al. , 1980–85). An example is where the bull everts his preputial epithelium, which is then

damaged and infected (Long & Dubra, 1972; Fig. 38.12).

The breeds most commonly affected are the Aberdeen Angus and polled Hereford, which have no retractor preputiae muscle, and the Bos indicus breeds and crosses (Larsen & Bellenger, 1971). Ubiquitous organisms such as Arcanobacterium (Actinomyces) pyogenes and Staphylococcus aureus can often be isolated from such lesions. The smegma produced by the bull is very tacky and the authors know of at least one case where the problem was caused by the firm matting of the hairs over the preputial orifice due to this substance, with

Fig. 38.12

Abcess formation of the preputial epithelium in the

resultant failure to protrude the penis. Others have

bull.

described hair rings around the free end of the penis,

although this usually produces an annular constriction

ity to mate because of pain or physical interference.

a few centimetres behind the tip of the penis.

There are three areas of damage:

***The penile epithelium**: This can be damaged*

either traumatically, or by infection, in particular by

• *The region around the preputial orifice.*

the virus of infectious pustular balanoposthitis

• *The penile epithelium.*

(BHV-1). Damage with subsequent scar tissue can

• *The reflected prepuce which, by virtue of its*

result in a failure to protrude or deviation.

extreme elasticity and mobility, stretches and

***The reflected prepuce**: This area is extremely im-*

reflects itself along the extended erect penis.

portant because it must function properly to allow the

***The region around the preputial orifice**: Problems in*

penis to protrude (Ashdown & Pearson, 1973a). Any

this area may be the result of trauma with subsequent

traumatic damage with resulting scar tissue formation

Fig. 38.13

Severe tear of

prepuce.

tends to be self-perpetuating since the scar tissue often

usually in such cases some of the penis can be pro-

limits movement, resulting in further tearing. Further-

truded. A severe drainage defect problem could also

more, infection at such sites is common with subsequent

possibly present in this manner (see later). Diagnosis is

abscessation. An extreme example of such damage can

based on the increasing difficulty of the bull to protrude

occasionally be seen after collection with an artificial

the penis after mounting. The penis should be felt to

vagina and in some of these cases the tear is very large

confirm a firm erection because the condition should

indeed (Fig. 38.13). Usually the bull in question is a

be differentiated from either a drainage defect of the

young inexperienced animal or one returning to work

corpus cavernosum penis or a longstanding bal-

after a prolonged layoff (Monke, 1980). Treatment

anoposthitis. In our experience the prognosis is hope-

of this condition is largely symptomatic; however, in less.

cases with severe scar tissue formation, surgery is the only course of action other than salvage (Larsen & Rupture of the corpus cavernosum penis: As mentioned Bellenger, 1971; Walker, 1980). Although a guarded earlier, the pressures erecting and firming the penis are prognosis is necessary the chances of recovery will immense and in some unfortunate cases the tunica depend on the site, extent and aetiology of the condi- albuginea ruptures (Fig. 38.14). It is possible that in tion. Even in less severe cases sexual rest for at least some cases the tunica albuginea is unable to sustain three months is recommended to ensure adequate integrity because of the pressure alone, but it is more healing. Prevention is best effected by good bull man- likely that it ruptures under additional strains caused by agement, regular monitoring of the bull when he is a sudden penile deflection due to an unexpected move- serving a cow and recording of his performance. Should ment by the cow while service is taking place, or the bull *the bull be part of an AI stud then the importance of*

slipping while the penis is in the vagina. Rupture gen-

collection technique must be re-emphasized.

erally occurs in the region of the sigmoid flexure. It is

most common on the dorsal aspect of the distal bend of

Short penis: As the bull grows so the penis should also the sigmoid flexure but can also occur on the dorsal

develop. In some cases it would appear that this does

surface of the penis between the root and proximal

not occur and the bull becomes less and less able to pro-

bend of the sigmoid flexure. Such rupture results in a

trude the penis sufficiently to achieve intromission. The

haematoma, which subsequently organizes and pre-

exact aetiology of the problem is obscure and this pres-

vents the full erection and protrusion of the penis. Diag-

entation may even be due to several different condi-

nosis is based on a sudden onset of an inability to serve

tions, but it does not appear to be a defect of erection

coupled with swelling, usually in the inguinal region just

since the penis appears to firm up quite normally.

above and anterior to the scrotum. Often the bull also

Fibrous metaplasia of the retractor penis muscle has

presents with a prolapse of the prepuce and because the

been described (Arthur, 1960) and this has been suc-

condition can be painful he may walk stiffly. Where this

cessfully treated by myectomy. However, since the con-

condition is presented in the acute phase and the sur-

dition appears to be heritable surgery is probably not

gical approach is adopted, immediate sexual rest fol-

advisable. At its simplest, a grossly enlarged pendulous

lowed by surgical removal of the haematoma some five

abdomen may be a cause of the problem, although

to seven days later, before it can organize (Walker,

Failure to locate vulva or enter vagina

Psychogenic problems: There would appear to be two distinct problems:

- *Neck or side mounting;*
- *Normal mounting, but without success, the bull being incapable of inserting the penis into the vagina despite a good erection and apparently normal seeking movements, even to the extent of touching the vulva.*

The aetiology for both these conditions, especially the former, is obscure though neck mounting is not uncommon in young inexperienced bulls. However, they usually quickly move round to the rear of the cow. For the latter one could hypothesise either that this could be an early manifestation of a premature partial drainage defect of the corpus cavernosum penis or that there was an inadequate sensitivity of the penile tip (possibly acquired traumatically or by infection) resulting in a lack of appreciation of the position of the penis relative to the vulva.

A diagnosis of psychogenic depression of libido must

be tentative because it is based on a failure to obtain

Fig. 38.14

Rupture of the corpus cavernosum penis.

any other. One should always bear in mind that this

condition may be the result of penile damage or an

early manifestation of a drainage defect of the corpus

cavernosum penis, or may be of orthopaedic origin.

1980), is indicated. In more chronic cases and in those

There is no known treatment apart from initial sexual

acute cases where surgery is not adopted gradual

rest for at least three to four weeks followed by hand-

teasing may eventually result in adhesions being broken

mating after some considerable teasing. Often collec-

down sufficiently to allow mating. Progress may also be

tion by a small artificial vagina using a rough liner may

assisted by frequent gentle massage in the area of the

obtain an ejaculate and start the bull working. The

haematoma. Recurrence is quite common and, if possi-

prognosis is very guarded.

ble, identification of the site of rupture is advisable *because the prognosis is more hopeful for a rupture at*

Penile problems:

the distal bend of the sigmoid flexure rather than at the

***Fibropapillomata**: These are generally found on or*

proximal bend. This is because the latter is associated

near the tip of the penis (Fig. 38.15). They are caused

with drainage defects of the corpus cavernosum penis

by a virus and are thus transmissible. They can occa-

(Ashdown & Glossop, 1983). Prevention is clearly dif-

sionally also cause considerable problems in the female

ficult but the introduction of young sexually inexperi-

(Meischke, 1979). In the bull they usually only affect the

enced bulls to heifers, especially at grass, should be done

penis of young animals less than four years of age and

with care. Service in slippery surroundings should be

generally regress after a period of two to six months.

avoided if at all possible.

In some cases, however, they persist much longer and

some become eroded and infected (Walker, 1980).

Persistent frenulum: The penile frenulum,

which

Treatment depends on the extent and severity of the

normally attaches the free end of the penis to the

tumour. A small single pedunculated tumour is clearly

prepuce of the prepubertal bull, is normally 'lost' during

much easier to deal with than a large, sessile,

early puberty, possibly breaking during play and/or

cauliflower-like lesion. Most authorities advise surgery

masturbation. Occasionally, this does not occur and

in severe cases, but it is essential to avoid weakening or

its persistence prevents the tip of the penis straigh-

rupturing the tunica albuginea (Walker, 1980), since this

tening on erection. It is usually bent ventrally and

can result in blood escaping at service and this setback

caudally. Although this is not a common condition

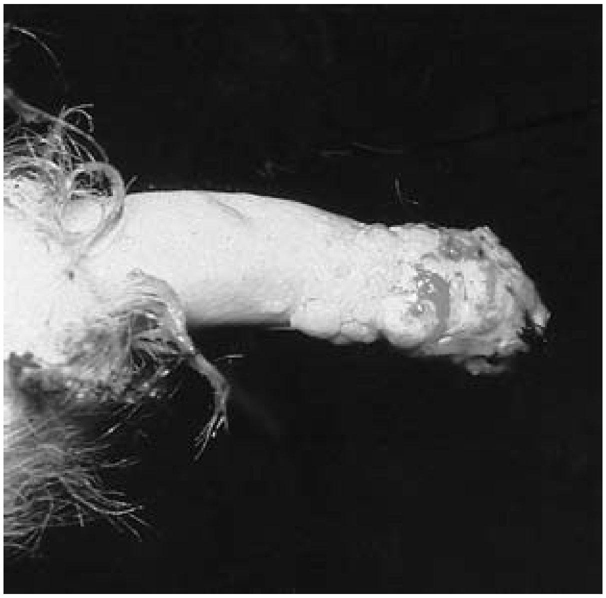
to surgery has been seen by one of the authors. Note

diagnosis is easy, as is treatment, which involves simple

that possible leakage from the corpus spongiosum penis

surgery.

(CSP) into the terminal part of the urethral lumen has



defects is largely academic at present since there is no treatment and the prognosis for all of these is hopeless.

***Corkscrew penis**: This is one of the most dramatic defects and is often diagnosed by the client. Spiral deviation of the penis within the vagina at ejaculation is physiological but in the clinical condition the spiral deviation precedes intromission and so prevents service. This is most commonly seen in beef bulls of around four years of age (Blockey & Taylor, 1984). In all cases the spiral is anticlockwise and can almost comprise a complete circle. However, it does present with* *varying degrees of severity from intermittent spiralling (which can present problems with diagnosis) to being so severe that spiral deviation occurs while the penis is still in the prepuce and it may then prevent protrusion. Usually it does not occur until the penis makes contact with the vulva of the cow. It should be remembered that spiral deviation has been described as occurring after entry into the vagina immediately prior to ejaculation*

Fig. 38.15

Fibropapilloma on the tip of the penis.

in bulls with apparently normal mating behaviour (Ashdown & Pearson, 1973b). The only known treat-ment is surgical and there are a variety of techniques, all of which depend on either fixing the dorsal apical also been described. This could also cause spurting of ligament to the dorsal aspect of the penis or addition-blood from the penis at service (Ashdown & Majeed, ally stiffening it by the insertion of fascia lata or carbon 1978). Since these lesions are transmissible, segregation fibres. The latter are placed between the ligament and of affected cattle, especially heifers, from a young bull *tunica albuginea (Mobini et al. , 1982). Postoperative is advisable. Contaminated bedding may infect young*

recurrence is quite common after apparent recovery.

bulls and sexual play between young bulls may result in

The problem is said to be heritable but there is

superficial abrasion of the penis and thus susceptibility

little evidence other than anecdotal to confirm

to infection. The use of an older bull on infected

this.

females reduces the risk of infection of the bull. Prog-

***Deviations of the penis**: These deviations are largely*

nosis should be guarded as regards both spontaneous

believed to be caused by scar formation such as that

recovery and return to service after surgery .

following balanoposthitis or surgery (Walker, 1980). As

***Drainage defects**: Careful anatomical studies of the*

with corkscrew penis, deviations are usually obvious.

normal and abnormal penis have revealed a number of

However, ventral deviations can be confused with a

arteriovenous shunts, which allow the venous cavities of

drainage defect of the corpus cavernosum penis and *the penis to drain more quickly than usual. This results*

must be differentiated from these. They can usually be

in an inability to erect fully or to sustain an erection

distinguished by the flexibility of the erect penis that is

(Ashdown et al., 1979). It is now considered possible to apparent in drainage defects. Some bulls can accom-distinguish four different venous drainage defects based

modate deviations surprisingly well and if they are not

on history and clinical findings. However, in the last

too pronounced, careful hand-mating may allow these

analysis all are associated with inadequate erection in

bulls to learn to serve again. Surgical treatment is again

the bull and a diagnosis of venous drainage defect is

a possibility (Walker, 1980) for more severe cases. A

probably sufficient in most cases (Logue & Greig,

guarded prognosis is advisable even for relatively dis-

1985). Diagnosis is dependent on a careful assessment

crete deviations.

of the history and a thorough clinical examination of

the bull while serving. It is advisable not only to attempt

Failure to thrust and ejaculate

to collect semen by artificial vagina but also to palpate

after intromission

the erect penis as much as possible as the bull attempts
to mate and finally, if at all possible, the bull should
Occasionally, one encounters a bull that is capable of
be allowed to attempt to mate naturally and his lack
placing the penis in the anterior vagina but then fails to
of ability to mate confirmed. Differentiation between
thrust vigorously and ejaculate. In some cases the cause
the various categories of corpus cavernosum penis
may be orthopaedic, but in other cases the cause may

be neural in origin, whether due to local receptor prob-
parties involved in the future of the bull. One theory
lems causing a lack of sensitivity of the penis, which may
for the relatively lower fertility seen in young bulls
be acquired or congenital, or due to a more general
when compared with adults is related to the develop-
psychosomatic defect. Another possibility is that this
ment of both testes and epididymis in the young bull,
problem might be due to either a slight defect in the
which has roughly half the sperm output of an adult, but

drainage of the corpus cavernosus penis itself or a

less than one-quarter of the storage available in the tail

defect in the corpus spongosum penis, or even of the

of the epididymis with probably only enough for two to

erectile tissue in the tip of the glans. The prognosis is

three days' sperm production. Hence it is much easier

poor. Finally, in some cases it may just be due to inex-

to deplete the young bull. Furthermore, it will be

perience where, given time, the problem may resolve

apparent that relative to the testes the epididymis, par-

but the prognosis should be guarded.

ticularly the tail, is still enlarging and just how this interacts with sperm maturation in these young bulls is not

well understood (Amann & Almquist, 1976;Amann and

Normal service with a poor pregnancy rate

Schambacher, 1983).

In summary, while the bull may be capable of repro-

The vast majority of conditions causing this manifes-

ducing quite early in life it is not until after three years

tation are related to problems associated with sperm

of age, or possibly even a little later in the case of late-

production and transport. An understanding of the
maturing continental bulls, that one can safely say that
complexity of the mechanisms involved in governing
the fertility of the bull is unlikely to improve further.
and modifying these processes is essential. There are
While detailed studies are not really available it does
two basic components in the ejaculate: spermatozoa
appear that fertility also diminishes with advancing age
and seminal fluid. The former are produced in the sem-
(Amann & Schambacher, 1983). In the older bull poor
iniferous tubules of the testes by spermatogenesis and
fertility is associated with degeneration of some of the
the latter from the testes, epididymes and accessory sex
seminiferous tubules and with the development of tes-
glands.
ticular calcinosis in the seminiferous tubules resulting
The clinician should consider the following items
in non-productive areas of testes. Testicular calcinosis
when presented with a bull that is serving normal cows
can be quite marked in some older bulls; however, it can
satisfactorily but achieving a low pregnancy rate.

also occur in young animals (Turnbull, 1977). Clearly

• Age

there is very little that the veterinarian or farmer can

• Overwork

do to influence this factor other than limit the mating

• Testicular hypoplasia (and testicular atrophy)

pressure to both young and old bulls as recommended

• Testicular degeneration and atrophy

earlier and this is discussed further below.

• Interference with storage and transport of

spermatozoa

• Abnormalities of accessory sex glands

Overwork

Much of the information about semen quality and work

rates come from AI centres. However, the demands

Age

upon bulls running and mating with a herd of cows are

In addition to the influence of age and experience upon

obviously very different from those at an AI centre

libido there is a gradual development towards max-

since young active bulls may serve a cow ten times or *imum fertility in the young bull and this is under*

more during oestrus. This sort of pressure (ten ejacu-

physiological control. A practical example of these

lates in two hours) results in a diminution of total sperm

effects can be seen in the increase in scrotal circumfer-

numbers per ejaculate by a factor of around ten

ence with age (Coulter & Foote, 1978). This parameter

(Salisbury & Van Demark, 1961), mainly due to a fall in

is quite valuable as an objective estimate of normal

concentration. Concentration in such circumstances

development of the testes and epididymes. Figures from

falls to as low as 100 ¥ 106 sperm/ml, a level that, in a

bull examinations suggest that while a scrotal circum-

semen evaluation as described here, would certainly

ference of 35–40 cm is desirable in a young bull (approx-

result in the fertility of the bull being questioned.

imately 18 months old), measurements below 30 cm are

However, theoretically, a complete rest of around two

likely to be linked to infertility or subfertility. However,

weeks should allow a return to normal sperm concen-

we have collected perfectly normal semen from young trations in the ejaculate. In practice this is generally the

well-grown bulls with scrotal circumferences around

case. In other words, the main effect of overuse is to

this size. We therefore recommend collecting semen

exhaust the epididymal reserves. However, at very high

from ‘borderline cases’ if there are likely to be other

and sustained mating pressures a slower return to

normal number of spermatozoa per ejaculate may be

found. Furthermore, it has also been noted that as the

number of ejaculates increases, sperm motility tends to

fall. In addition, the likelihood of an occasional

azoospermic ejaculate increases (Salisbury & Van

Demark, 1961). Finally, there is some information indicating that young bulls given a diet below maintenance for energy take considerably longer to replenish their sperm reserves. This is particularly relevant to young post sale bulls, which are purchased in very good body condition and then put outside with cows in a hard environment, thereby losing condition rapidly. By inference such bulls take considerably longer to replenish their sperm reserves (Salisbury & Van Demark, 1961). The

Fig. 38.16

Unilateral testicular hypoplasia in the Ayrshire

history, number of cows, frequency of working and the

breed. Note the adhesions on the normal testis caused by needle age of the bull will generally indicate this diagnosis. At

biopsy.

worst the semen picture will be of low concentration

(200 ¥ 106/ml or less), marginal initial motility (2/5),

but reasonable progressive motility (60 per cent +)

and morphology (<20 per cent abnormal). However,

is believed that chromosomal abnormalities may inter-

often the bull has been removed from the breeding *rupt the meiotic process to such a degree that infertil-*

group and rested before examination so the sample

ity or reduced seminiferous tubule output is a result

appears normal. As already indicated, treatment is

(Chandley, 1979). This does not appear to be as much

sexual rest since it takes nine weeks for development

of a problem in cattle as in man, though there is evi-

from the spermatogonia stage to ejaculation as a

dence of reduced fertility in cattle carrying a 1/29

mature spermatozoon. Hence ideally the bull should

Robertsonian translocation (Gustavsson, 1974; Logue

not serve for at least nine weeks before being re-exam-

& Harvey, 1978) and bulls with 61 XXY chromosomes

ined. There is little point in re-examining a bull after

are, as might be expected, completely sterile (Logue et

less than three weeks' rest. When this diagnosis is made

al. , 1979). However, the nature of the bovine karyotype the prognosis is good. However, one must always be

has meant that identification of reciprocal transloca-

aware that such a diagnosis may be complicated by

tions is not easy and it is likely that, with improved tech-

another underlying cause and so it is advisable to be

niques, some will come to light. These abnormalities are

'guarded but hopeful'.

more likely to be associated with infertility than the

Robertsonian translocations, which are not uncommon

in the cattle family.

Although testicular atrophy should be dealt with

Testicular hypoplasia (and testicular atrophy)

under degeneration from a clinical point of view it is

Testicular hypoplasia is defined as the congenital pres-

also being considered here because unless one has a

ence of either one or two small testes (i.e. bilateral or

firm history of the previous size of the testes it can be

unilateral). It has been closely studied in the Swedish

extremely difficult to differentiate between testicular

Highland breed of cattle, where it has been demon-

hypoplasia and testicular atrophy, especially in the

strated to be a heritable defect caused by a recessive

bilateral state. Both present as the 'small testes syn-

gene with incomplete penetrance (Fig. 38.16). In both

drome'(Fig. 38.19). Testes that have been affected by *unilaterally and bilaterally affected cases sexual behav-*

atrophy subsequent to a severe local infectious condi-

iour and secondary sexual characteristics are normal

tion or trauma may feel small, firm and nodular on pal-

(Lagerlöf, 1951). It is not known whether a similar

pation, while those affected by hypoplasia are usually

inheritance pattern applies to other breeds. It is theo-

less firm and more uniform. Frequently, one is left in

retically possible that toxic or infectious agents affect-

genuine doubt about the diagnosis.

ing the dam at a critical stage of organogenesis of the

Scrotal circumference measurement can be helpful in

testes could also cause hypoplasia, either bilateral or

giving an objective guide to testis size, as it is a simple,

unilateral. Mention should also be made of bilateral tes-

highly repeatable, measurement. In other species it has

ticular hypoplasia that is associated with the abnormal

been related to spermatozoa production and, intrigu-

sex chromosome constitution XXY, i.e. an 'extra' X

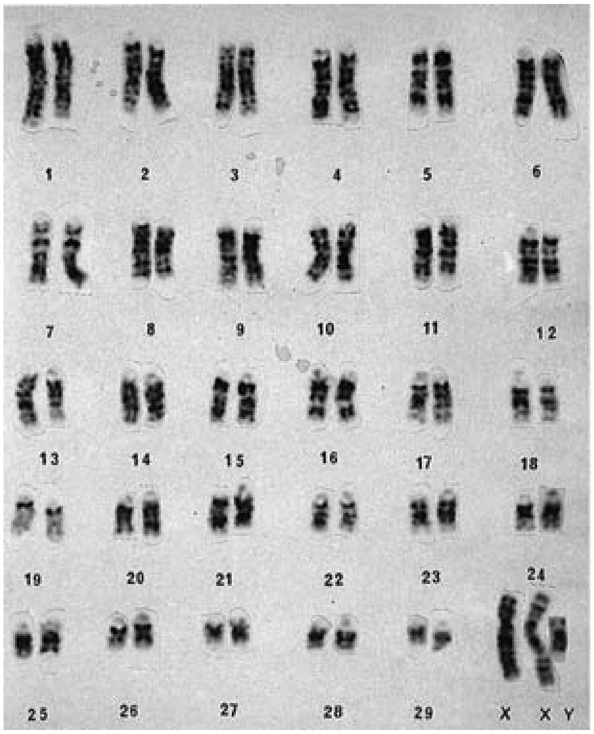
ingly, ovulation rate in the female offspring (Land,

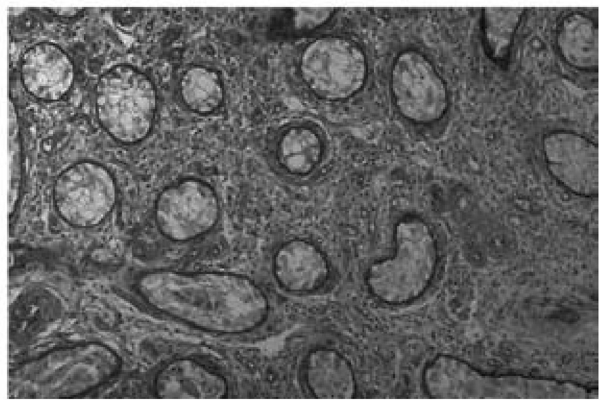
chromosome (Figs 38.17 and 38.18). Other cytogenetic

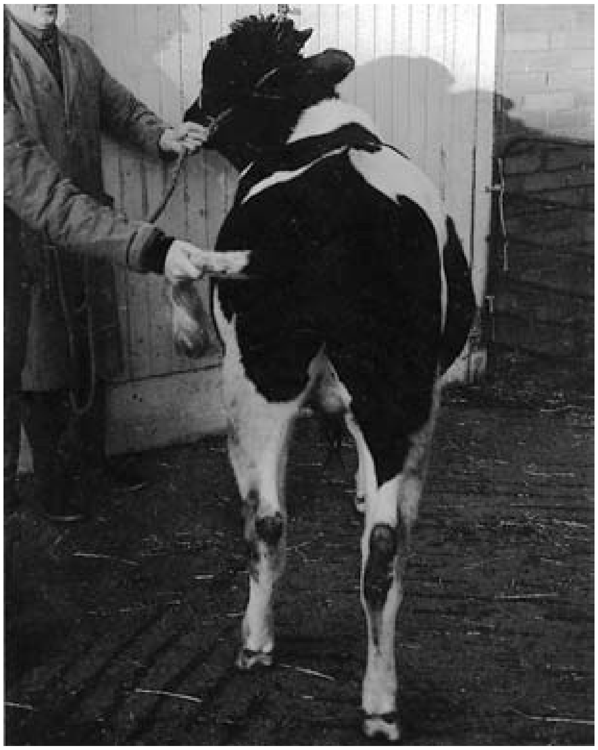
1978). However, from a practical point of view it is suf-

abnormalities may be associated with infertility. Thus it

ficient to note that those males with a below normal







(a)

(b)

Fig. 38.17

(a) G-band karyotype 61XXY. (b) XXY bull. Tubules lined by Sertoli cells only, Leydig cells moderately increased in proportion (Masson ¥195). (Courtesy of the Veterinary Record.) scrotal development have a greater likelihood of being

infertile. A further diagnostic aid that may prove of

value is the determination of the chromosomal consti-

tution of the animal.

As already mentioned, care must also be taken not

to jump to conclusions. Surprisingly good quality semen *has been collected from bulls with disappointingly small scrotal circumferences. However, such occasions are rare, so that in general the prognosis for the 'small testes syndrome' is poor. As far as the unilateral condition is concerned this is more problematical since the animal is often fertile. Here every attempt to obtain as reliable a history as possible should be made in order to differentiate between hypoplasia and atrophy because of the strong evidence of the heritable nature of hypoplasia. If the diagnosis is hypoplasia the owner should be advised that such stock are only fit for the production of 'slaughter generation' animals.*

Testicular degeneration and atrophy

In many infertile animals the main histological finding is the absence of dividing spermatogenic cells, the Sertoli cells and interstitial cells still being present. This ***Fig. 38.18***

A 61XXY bull with bilateral testicular hypoplasia.

is often the result of testicular degeneration. Evidently,

Fig. 38.19

'Small testes syndrome' (scrotal circumference 24

Fig. 38.20

Severe acquired testicular abnormalities in a Charo-

cm) in a Limousin bull aged 2 years with no previous history of lais bull aged 5 years. Chronic orchitis of the left testis mani-fertility. The bull also intermittently displayed spiral deviation of fested as atrophy, fibrosis and adhesions. The right testis whilst the penis. Semen density was very low (4.0 ¥ 106/ml).

of normal size was very soft in consistency. The bull showed a complete absence of libido.

however, histology does not show the defects of func-

Insults to spermatogenesis causing temporary or

tion, in particular the delicate interaction between the

permanent testicular degeneration can be categorized

cells of the testes and their hormonal influences from,

as either local or systemic.

and feedback to, other hormonal control centres. Sper-

Local:

matogenesis is a very sensitive process and can be easily

upset. Nevertheless, it can also recover, particularly if

***Scrotal sac disruption**: Obviously, severe trauma to*

the insult has been transient. Studies in the rat have

the scrotum can have a direct effect upon the testes and

shown firstly that Sertoli cell function was disrupted by

epididymes, but one of the main functions of the scrotum

a whole variety of noxious stimuli and that one side

is temperature control and any disruption of this can

effect of such damage was an increase in serum follicle

interfere with spermatogenesis. The first area of sper-

stimulating hormone (FSH) concentrations due to a

matogenesis affected is meiosis; the spermatogonia tend

decreased output of inhibin. Secondly, the Leydig cells

not to be affected and, after removal of the insult, regen-
were also affected since serum luteinizing hormone
eration within six weeks is to be expected providing the
(LH) concentrations were higher and testosterone
Sertoli or nurse cells are not damaged also. These are the
concentrations lower. Finally, there was evidence of a
most resistant to insult (Kumi-Diaka & Dennis, 1978).
reduced response to human chorionic gonadotrophin
While weather conditions are capable of insult and cause
(hCG) (de Kretser, 1979). The inference is that damage
variations in semen quality (Parkinson, 1987), it really
to the spermatogenic epithelium interferes with andro-
requires trauma, a severe skin infection, an allergic reac-
gen binding protein (ABP) and inhibin release leading
tion with scrotal oedema, a scrotal hernia or a deformity
to an increased FSH concentration, which in turn alters
of the pampiniform plexus (so-called varicocele) to
the balance of testosterone–oestradiol synthesis
produce serious infertility. Diagnosis should be deter-
towards the latter with a subsequent alteration in LH
mined by a clinical examination. The most obvious prob-

concentrations. Since there is evidence that LH can

lems are varicocele and inguinal herniation. Care needs

directly affect the Leydig cell, testosterone release and

to be taken when making the latter diagnosis as a pad of

so ABP release by the Sertoli cell, it can be hypothe-

fat can lie above the pampiniform plexus and feel very

sized that if events are prolonged or extreme these

like a hernia. The treatment and prognosis both depend

effects may accumulate and eventually result in a per-

on the cause. Thus for a simple skin infection one would

manent derangement. However, it is of considerable

be more hopeful of a return to normal fertility than for a

interest to veterinarians in the field that immunization

variococele or a hernia.

of bulls to gonadotrophin-releasing hormone (GnRH)

***Orchitis/epididymitis**: Inflammation of the testes is*

is generally reversible (Robertson et al. , 1982). This commonly a purely local problem and frequently it only

then implies that in many clinical cases where such a

involves one testicle. However, often the infection so

regeneration of the seminiferous epithelium does not *interferes with the temperature gradient of the scrotum*

occur the underlying aetiology is more than just a

that the remaining testicle is indirectly affected (Fig.

simple hormonal dysfunction.

38.20). A similar effect is seen with epididymitis,

although in this case there is the further problem of

infected with BVDV or to have high antibody titres to

obstruction of spermatozoa and testicular fluid on the

Leptospira hardjo. However, in some cases the animals

affected side. Often orchitis and epididymitis are

have subsequently proved fertile; this includes BVDV

concurrent. The causes of orchitis/epididymitis infec-

viraemic animals (Logue, D.N. & Cranshaw, N.M.C.,

tion are not well documented. In many cases

unpublished information). It should again be remem-

Arcanobacterium pyogenes can be isolated from the

bered that the bull might be presented some time after

affected testes, but whether this is the original pathogen

the incident when recovery is taking place. This can

is uncertain. Other bacteria, such as those of the

take a considerable time – at least some two to three
Haemophilus/Histophilus group, have been implicated
months. Finally one interesting condition, worthy of
in spermatogenic damage as have a number of viruses.
mention, is idiopathic angioneurotic oedema. This is
These conditions should also be relatively easily diag-
occasionally seen in young bulls, particularly of conti-
nosed by a clinical examination. Confirmation can be
nental breeds, and generally occurs soon after intro-
obtained from the semen findings. Generally, there will
duction to grazing. There is often tremendous oedema
be low concentration of spermatozoa, poor/marginal
of all the dependent areas, especially the scrotum, with
motility and poor spermatozoan morphology, especially
consequent azoospermia. The latter is presumably due
of the head. There will also be increased numbers of
to a temperature effect. In our limited experience
white blood cells and other cells indicative of damage
recovery is usually complete, however with other ill-
such as large multinucleate cells, so-called ‘giant cells’.
nesses this is not always the case, especially in older

Culture of semen may allow the identification of a

bulls. Treatment and prognosis are dependent on the

causative micro-organism. However, the findings will to

history, the origin of the insult and the age and type of

some degree depend on the time scale. Thus a bull with

the bull.

a spermatocele (see later) on the head of the epididymis

***Drugs**: Although therapeutic products are subject to*

could have been affected several years previously and

very stringent safety screening there are certain drugs

the effects of the lesion subsided, allowing the semen

that might affect male fertility. Anabolic steroids given

quality of the bull to return to normal.

to young growing bulls have been shown to have an

Treatment by antibiotics is usually ineffective and the

undoubted effect upon spermatogenesis, resulting in a

main aim should be to prevent testicular degeneration

reduced testicular size and delayed development of the

of the sound testis and epididymis. The strategy adopted

seminiferous tubules and interstitial cells (O'Lamhna &

depends on the severity of infection. Thus assuming the

Roche, 1983; Deschamps et al. , 1987a,b). Although it remaining testis is not affected the removal of a grossly

was suggested that these effects were temporary, in fact

infected testis is the most straightforward remedy.

there was a delay in puberty and the effect was more

Unfortunately, even then the local, and possibly sys-

severe in younger animals (these studies have only

temic, damage to the other testis may be sufficient to

involved animals of up to 15 months and may not truly

cause a permanent derangement of semen production.

reflect the field situation). In addition there was evi-

Thus the prognosis, even in animals that have recovered

dence of interference in the hypothalamic–pituitary

either after surgery or after conservative treatment,

axis and the size and structure of the testes and epi-

should be guarded. The owner should be reminded that

didymis. Finally, the fact that the studies were relatively

the daily sperm output may be affected in apparently

short term makes one very wary of such a claim. The

recovered animals and that they should carefully

only problem that might arise is with clandestine and *monitor the cows that have been served in the bull's*

improper administration of a drug, such as an anabolic

first series of matings to ensure that the proportion of

steroid or b agonist, with the intent of improving the

returns to service is acceptable.

appearance of the bull or even liveweight performance

test results. It is possible to test for residues. It is possible that a bull could suffer from an adverse reaction to

Systemic:

one of the common treatments, although such cases are

***Systemic illness**: Severe illness can disrupt sper-*

rare. The diagnosis is dependent on the history and the

matogenesis by one or all of three routes: firstly, by

treatment. Given the effect of anabolic steroids, by

interfering with the temperature gradient of the testes,

inference treatment with corticosteroids is also likely to

secondly as a consequence of toxaemic damage to the

affect semen quality (Li & Wagner, 1983), and indeed

spermatogenic epithelium and finally by interfering

some slight changes have been described short term.

with the complex hormonal secretions which control

However, administration to adult Holstein bulls did not
spermatogenesis and their interactions. The roles of
appear to cause any practical spermatogenic problems
bacteria and viruses in the aetiology of this condition
(O’Connor et al. , 1985). Nevertheless, there is more
are not well understood. For example, a few apparently
recent evidence that some non-steroidal anti-
infertile bulls have been found to be persistently
inflammatory drugs such as flunixin could have an

effect (Archibald et al. , 1990). Treatment of such
earlier have an effect solely upon the epididymes, since,
adverse reactions is symptomatic while the prognosis
as already mentioned, any disruption of testicular func-
depends on the exact form that the adverse reaction
tion frequently interferes with epididymal function.
takes. Field experience has also failed to show any
The epididymis, unlike the testis, develops from the
fertility effect associated with the administration of the
mesonephric (Wolffian) ducts and is prone to several
commonly used antibiotics. However, again the periods

congenital malformations (Blom & Christensen, 1960).

of administration were relatively short. Abbitt et al.

Aplasia of part of the epididymis, ductus deferens and

(1984) reported that neither dihydrostreptomycin sul-

seminal vesicles has been described as a congenital

phate nor oxytetracycline hydrochloride had any real

defect in the bull. The aplasia is usually unilateral and

effect upon reproductive function, even when given in

can be very specific. It is generally associated with

greater than normal therapeutic doses.

spermatocele formation (so-called sperm granulomas)

The diagnosis of testicular degeneration is dependent

proximal to the aplasia (Blom & Christensen 1960).

upon a history of fertility, followed by infertility with

These are swellings of the epididymis reflecting a

the latter being confirmed by the collection of a semen

rupture of the tubules and the consequent foreign body

sample of poor spermatozoa motility, concentration and

reaction to the escaped products of the testes and are

morphology. In addition there will sometimes also be

most commonly seen on the head of the epididymis.

small, darkly staining, degenerate spermatids, which in

While they have been described as being a result of seg-

some cases 'raft' together in clumps. In the extreme case

mental aplasia (see above), in some cases spermatoce-

the sample may be aspermic. In cases of testicular

les arise in this position apparently spontaneously.

degeneration the testes may be smaller than normal

Spermatocele formation has been diagnosed in the field

due to atrophy, but often they are within the norm.

following a sudden failure to mount and thus, by infer-

While collection of semen is the main diagnostic tool

ence, it is painful in the acute phase (Logue & Greig,

many workers have desired to examine the seminifer-

1986). Since this was the only behavioural demonstra-

ous tubules. A number of authors have attempted to use

tion of pain it could be that any discomfort is only

a testicular biopsy as a means of obtaining histological

appreciated during sexual arousal. The exact relation-

evidence of spermatogenic dysfunction (Galina, 1972).

ship of the spontaneous condition to segmental aplasia

This technique is hazardous even when one uses a *is uncertain but one cannot ignore the possibility of*

modern disposable biopsy needle due to haemorrhage

an infectious condition causing an epididymitis and

(the testis is very vascular), spermatogenic disruption

subsequent spermatocele.

However,

epididymitis

and adhesions. However, with time, good spermato-

resulting from infection by Brucella sp. and the

genic recovery can occur (Galina, 1972; Logue, 1975).

Haemophilus/Histophilus group appears to occur most

Because testicular degeneration can be either tem-

frequently in the tail of the epididymes. Mycoplasma

porary or permanent, it is impossible to be certain of

infections have also been implicated in epididymitis (La

the prognosis on the basis of a single semen examina-

Faunce & McEntee, 1982).

tion. However, some guidelines can be obtained by

Unilateral spermatoceles need not necessarily cause

looking at the length of infertility and the semen

sterility since once the inflammatory reaction has

picture. Should the time scale be relatively short, say
settled the remaining testicle can produce an
three months, and there is evidence of normal motile
apparently normal ejaculate. However, it is clearly not
spermatozoa, albeit at a low concentration, then it is
advisable to use such an animal with a large number of
worth waiting another three months for a re-examina-
females, as in two cases known to the authors, where the
tion. Where the degeneration of the seminiferous
bulls involved were at an AI centre and the concentra-
epithelium is permanent then this may result in a
tion of the ejaculate never returned to the level seen
gradual diminution in size of one or both testes, i.e. tes-
before the incident. In one of these bulls the epididymis
ticular atrophy. Unfortunately, unless one had prior
of the other testis also later suffered the same problem
knowledge that the affected bull had previously had
and the bull had to be destroyed. No significant micro-
normal-sized testes in the bilateral condition this small
organism could be found (Logue, D.N. & Hignett, P.G.,
size could quite easily be considered to be testicular

unpublished information). Ease of diagnosis depends

hypoplasia. Where there is good evidence of testicular

on the site and the extent of the problem. Should there

atrophy being present then the prognosis is very poor.

be a spermatocele then this is generally easily palpated

provided one is careful and palpates the entire epi-

didymis. However, some defects can be very small and

Interference with transport and storage

ultrasound may well prove a very useful diagnostic aid.

of spermatozoa

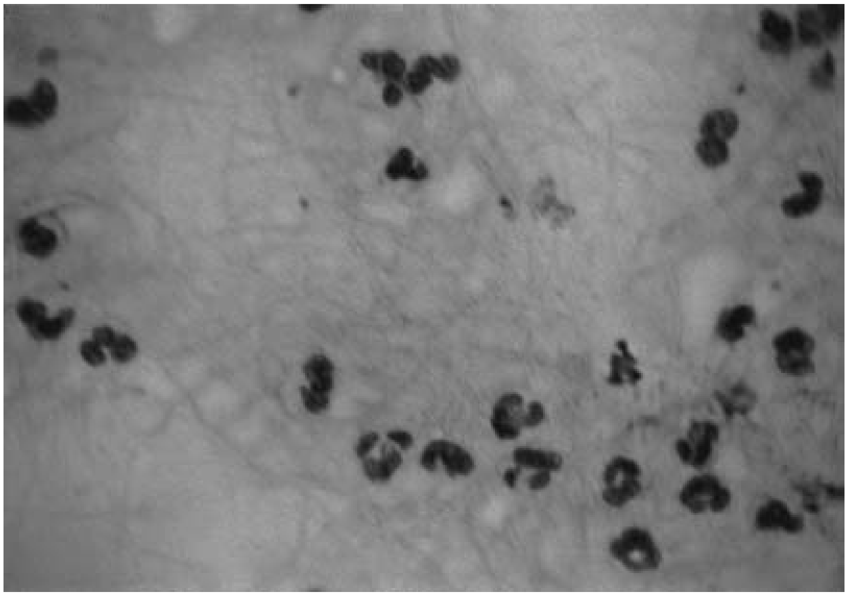
Treatment is usually symptomatic and certainly in the

It is generally impossible to differentiate clinically

early stages antibiotic administration is probably

which of the local and systemic effects mentioned

worthwhile.



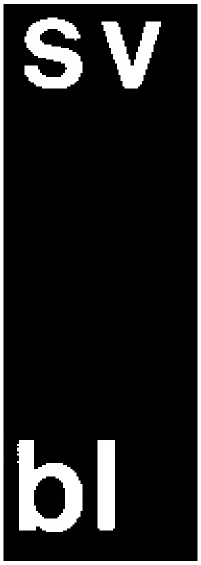


Fig. 38.21

White blood cells in semen (methylene blue) (¥700).

Abnormalities of the accessory sex glands

The accessory sex glands consist of the seminal vesicles, ampullae, prostate and bulbourethral glands.

As already mentioned, abnormalities of the seminal vesicles are the most commonly diagnosed condition. Segmental aplasia of the seminal vesicle occurs and often appears to be related to a congenital defect (Blom, 1979a,b). Numerous infectious agents have been isolated and implicated in the aetiology of seminal vesiculitis in the bull, such as members of the Chlamydia *group, Mycoplasma bovigenitalium and Mycoplasma bovis (La Faunce & McEntee, 1982). However, in severe clinically recognizable cases the most common organism isolated is Arcanobacterium pyogenes (Arthur, 1960; McCauley, 1980). Some authors believe that these infections of the seminal vesicles are secondary to congenital defects. Diagnosis of these abnormalities is firstly dependent upon rectal palpation (where enlargement, firmness, pain and adhesions may be detected in the case of seminal vesiculitis) and ultrasonic scanning; and secondly upon laboratory tests, particularly the examination of semen for white blood cells which indicate the presence of inflammation (Fig.*

Fig. 38.22

Real-time ultrasound of the seminal vesicle. sv,

38.21). Hopefully, ultrasound scanning will prove of

seminal vesicle; b, bladder.

value in the reliable diagnosis of severe seminal vesiculitis and also of segmental aplasia of the seminal vesicle (Fig. 38.22). However, as mentioned before, the application of the technique is still in its infancy (Little

In some cases small compact masses up to the size of

& Woods, 1987). Treatment of an infectious condition

a pea, so-called cysts, can be felt both on the epididymis

obviously requires antibiotic, preferably one with a

and on the spermatic cord itself. They are developmen-

broad spectrum, and given that there is no evidence of

tal in origin and of no consequence as long as they do

severe effects upon the structure of the seminal vesicles,

not interfere with sperm transport.

prognosis is good.

Conditions affecting the other smaller accessory

of the corpus cavernosum penis. Veterinary Record, ***104****, sex glands of the pelvis in the bull have rarely been*

423–8.

recognized clinically, but this may yet be possible using

Ashdown, R.R. & Glossop, C.E. (1983) Impotence in the bull: ultrasound.

(3) Rupture of the corpus cavernosum penis proximal to the

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Ashdown, R.R. & Majeed, Z.Z. (1978) Haemorrhage from the

Conclusion

bovine penis during erection and ejaculation: a possible

explanation of some cases. Veterinary Record, **103**, 12–13.

The investigation of infertility in the bull is one of the

Ashdown R.R. & Pearson, H. (1973a) Anatomical and exper-

imental studies on eversion of the sheath and protrusion of

most interesting examinations in farm animal practice.

the penis in the bull. Research in Veterinary Science, **15**, The approach is standard and success is dependent

13–24.

upon attention to detail in all the facets mentioned in

Ashdown, R.R. & Pearson, H. (1973b) Studies on ‘corkscrew’

this chapter. One of the main advantages the general

penis in the bull. Veterinary Record, **93**, 30–5.

practitioner has compared with the specialist is an

Bane, A. (1954) Sexual function of bulls in relation to

intimate knowledge of the farm, the ability of those

heredity rearing intensity and somatic conditions. Acta

involved as stockworkers and also a fair idea of the

Agricultura Scandinavica, **4**, 95–208.

reliability or otherwise of the history and records. On

Bane, A. & Hansen, H.-J. (1962) Spinal changes in the bull and the other hand, the major disadvantages are the small

*their significance in serving ability. Cornell Veterinarian, **52**, number of cases that the practitioner will see in a year,*

363–84.

so limiting the experience that can be built up, and the

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Clinical survey and radiologic interpretation. Journal of the standard of equipment,

particularly microscope,

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required. Finally the amount of time and flexibility of

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time that need to be devoted to such work must be

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balanced against other, possibly more remunerative,

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Chapter 39

Artificial Insemination and Diseases

Transmitted by Semen

G.H. Wentink

Introduction

627

the ejaculate. Extenders are applied to improve the

Semen processing

627

buffering action of the media surrounding the sperma-

Technique of artificial insemination

627

tozoa for protection against toxic metabolic substances

Disease transmissible by semen (and/or mentioned

(mainly lactic acid), and secondly to increase the

in trade certificates)

628

volume in order to serve as many cows as possible with

Semen safety

one ejaculate.

Between 300 and at least 1000 straws can be pro-

duced from one ejaculate, depending on the concentra-

Introduction

tion needed in one dose. Fertility after insemination is

often expressed as the non-return rate (NR): the per-

Large scale artificial insemination (AI) for cattle was

centage of cows that are not rebred within a certain

started in Russia at the beginning of the twentieth

period (usually 56 days). This information can be used

century (1909) by the stimulating impetus of Professor

to optimize the concentration of spermatozoa per dose.

Ivanovich Ivanov. Verbal history says that it was used

Each dose is delivered in a straw (0.25 ml in Europe,

for genetic improvement, but mainly to avoid transmis-

0.5 ml in the USA) containing on average 15 ¥ 106

sion of venereal diseases. These diseases were trans-

sperm cells. However, fertility results differ between

mitted from infected cows to cows on different farms

bulls. The average NR in the Netherlands is 68 per cent;

by travelling bulls used for natural service. Using

some bulls score above and others below the average.

extended (diluted) semen the great number of offspring

Thus the semen concentration of each bull is altered to

by one bull also produced more information on its

produce the average NR and thereby allow an optimal

breeding value. The main goal of AI is to improve the

number of cows to be served and become pregnant with

genetic potential of cattle, and considerable progress

each ejaculate. Fertility of bulls can only be judged after

has been made since its applications.

insemination based on NR. The criteria in the labora-

Semen is shipped all over the world, and conse-

tory do not have predictive value for fertility: very often

quently must be free from infectious diseases. Relevant

disappointing results are obtained with semen that was

regulations apply in all parts of the world, but may

considered of excellent quality in the laboratory, while

differ slightly between countries. The EU regulations

conversely excellent fertility has been obtained after

concerning semen production are laid down in Direc-

natural service with bulls that did not fulfil the stan-

tive 88/407; semen imported into the EU from other

dards for AI bull approval.

countries must also conform to this standard.

Semen is only safe beyond doubt if produced by bulls

that were proved to be free of infectious diseases 21

Technique of artificial insemination

days after its production. International regulations

current at the start of the twenty-first century do not

The technique in itself is easy to perform, cheap and

fulfil this requirement.

applied world-wide rather uniformly by technicians and

veterinarians. Insemination is routinely performed by

the recto-vaginal technique. One arm is introduced into

Semen processing

the rectum of the restrained cow in heat, grips the cervix

and stretches the vagina. After careful cleaning of the

After collection and application of extenders (specific

vulval area, the AI gun is inserted into the vagina and

diluents), semen must be cooled to 5°C over a period

through the cervix for the deposition of three quarters

of 2–5 hours before freezing in liquid nitrogen. During
of the semen into the corpus uteri (uterine horns are
this period metabolism of the spermatozoa continues
too deep) and, after limited withdrawal of the AI gun,
and metabolic products are excreted into the liquid of
the remaining quarter is deposited in the cervix at the

first insemination after parturition. At the second or
discharge and abortion in up to 30 per cent of pregnant
higher number of inseminations the semen must be
animals. The disease has a high morbidity but a low
deposited in the cervix only, because a limited number
mortality. However, the disease might follow a more
of cows show signs of heat in the presence of an embryo.
severe course if complicated by bacterial infections.
Introduction of the gun into the corpus uteri might
IPV is characterized by erosion in the vagina or on the
interrupt the integrity of the embryo and thus interfere
penis, leading to adhesions. The disease is caused by
with pregnancy.

bovine herpes virus type 1 (BHV1) which can be sub-
The proper time for insemination is in the last period
divided in strains with preference for the respiratory or
of the standing heat. Cows are selected for insemina-
genital tracts respectively. Diagnosis is made by demon-
tion by observation of the herd at least twice daily
stration of the virus in secreta from respiratory and/or
during moments of quiescence: observation during
genital tracts up to 14 days after infection, and by serol-
periods of even limited excitation (for example during
ogy. However, sensitivity and specificity of serological
collecting for milking) can lead to the insemination of
tests applied in various countries differ considerably.
cows not in heat and thus to disappointing fertility
The agent may survive in favourable conditions (high
results. Several aids have been applied to improve heat
relative humidity, low temperatures) for 30 days in the
detection such as electronic pedometers, heat mount
environment. BHV1 is easily transmitted by semen. AI
detector pads, spotter bulls, etc. However, careful
centres in the EU must be free of IBR: only serologi-

observation of the herd and proper records of heat

cally negative animals are allowed as BHV1 infections

periods undoubtedly form the backbone of good fertil-

lead usually to latency. Latently infected animals are

ity results (see Chapter 41b). Harmful side effects of

the source for new epidemics. Latently infected animals

improper insemination are infections and/or injuries of

are serologically positive for BHV1, but some seroneg-

the genital tract, which are dealt with in Chapter 36.

ative latently infected cows have also been reported.

However, the sensitivities of the tests applied in these

animals are doubtful. Straub (see Horzinek, 1990)

Diseases transmissible by semen

described seronegative latently infected animals after

(and/or mentioned in

the application of a one hour incubation serum neu-

tralization test with a limited sensitivity: the animals

trade certificates)

would probably have been positive with sensitive tests.

It is thought that seronegative latently infected animals

Table 39.1 summarizes the diseases in this category.

develop during the period of maternal immunity after
an infection with a very low dose of BHV1 and they
Foot-and-mouth disease (FMD) (see also p. 700)
should exist in very low prevalence in endemic areas.
However, Switzerland, Denmark and Austria became
This is a highly contagious disease of cloven-hoofed
free of IBR: these countries eliminated the virus from
animals characterized by high fever followed by vesi-
their cattle populations without unexpected disease
cles on the mucosa of mouth and tongue, the feet and
outbreaks caused by serologically negative latently
the udder. FMD is caused by a picornavirus comprising
infected animals. The straightforward isolation of posi-
seven serotypes; infection with one serotype does not
tive animals was successful. So the problem of serologi-
induce immunity to other serotypes. In order to prevent
cally negative latently infected animals is very limited
spread of the disease in a country immediate recogni-
or even non-existent.
tion of the clinical picture is essential. For a positive
diagnosis the demonstration of FMD viral antigen by

indirect sandwich ELISA techniques, preferably in the

Bovine virus diarrhoea (BVD) (see also pp. 578, 853)

epithelium of unruptured or freshly ruptured vesicles,

BVD is observed clinically as transient diarrhoea

is sufficient. The agent is very resistant to environmen-

during three to ten days after infection in at maximum

tal factors and may be spread over long distances by air

5 per cent of infected animals; in exceptional cases

and/or vehicles and/or man. FMD virus is easily trans-

severe diarrhoea, fever, ulceration of the buccal

mitted by semen.

mucosa, haemorrhages and death occur. The remaining

95 per cent of the infections pass unnoticed. When

infected in the first four months of pregnancy, cows may

Infectious bovine rhinotracheitis/infectious pustular

deliver persistently infected (pi) calves that shed the

vulvovaginitis (IBR/IPV) (see also pp. 289, 579)

virus during their lifetime. The disease is caused by the

This is a disease of the upper respiratory tract or of the

pestivirus bovine virus diarrhoea virus (BVDV).

genital tract, respectively. IBR is characterized by

Bovine virus diarrhoea is endemic world-wide. Diag-

clinical signs such as high fever, nasal discharge, ocular

nosis is by antigen ELISA or culture of the virus from

Table 39.1

The main characteristics of infectious diseases that could be transmitted by semen or artificial insemination.

Disease

Incubation

Reservoir

Excretion mainly

Period of

Transmission

period

by

transmission/

by semen/AIa

viraemia

FMD

2–8 days

Animals in the acute

Saliva

<14 days

++

phase

Other secreta

Carriers for

Chronic carriers

up to 2 years

(cattle)

IBR/IVP

2–5 days

Latently infected

Nasal discharge

2–20 days

++

animals

Rinderpest

4–15 days

Cattle in the acute

All secretions and

21 days or

++

phase

excretions

longer

BVD

2–15 days

Persistently infected

Saliva

Variable, usually

++

(pi) cattle

All secretions and

2–15 (but up to

Cattle up to 56 post

excretions of pi

56) days

infection

animals

MCF

From a few

Sheep during

Unknown

Unknown,

0

days to

lambing period

not cow to

year(s)

cow

Akabane virus

??

Biting insects

Viraemia

Viraemia

0

during

prolonged

periods

Bluetongue

3–6 days

Biting insects

Viraemia

Viraemia,

0

mostly <14

days

Enzootic

Up to 35 days

Chronically infected

Intact blood

During lifetime

0

bovine

cattle

Lymphocytes

after infection

leukosis

(EBL)

Genital

<3 days

Chronically infected

Copulation

During lifetime

++

campylobacteriosis

cattle: bulls without

after infection

symptoms

Bovine

14–120

Chronically (latently)

Vaginal discharge

Prolonged

+

brucellosis

days

infected animals

Fetal membranes

periods

Bovine

>3 weeks

Chronically infected

Nasal discharge

During lifetime

+

tuberculosis

cattle

after open

tuberculosis

Leptospira

<7 days

Chronically infected

Urine

Prolonged

+

hardjo

cattle

periods after

infection

Johne's

Occasionally Chronically

infected

Faeces

From

18

0

disease

12; usually 24

cattle

months before

months

overt clinical

disease

onwards

Mycoplasma

2–6 weeks

Chronically infected

Nasal discharge

During lifetime

+

mycoides

cattle

Urine

after infection

(contagious

bovine

pleuropneumonia:

CBPP)

Haemophilus

??

Harboured in genital

Nasal discharge

During lifetime

+

somnus

and respiratory tracts

Effluents from

after infection

in healthy animals

genital tract

Genital

<3 days

Chronically infected

Copulation

During lifetime

++

tritrichomoniasis

cattle: bulls without

after infection

symptoms

Query-fever

??

Ticks

Fetal membranes

Prolonged

0

(Q-fever)

Environment (dust)

Vaginal discharge

periods

Chronically infected

cattle (animals)

Bovine

4 years

CNS of

Contaminated food

No

0

spongiform

contaminated transmission

encephalopathy cattle

reported

(BSE)

a 0, unlikely; +, possible; ++, easily.

??, no experience and no information found in the literature.

the peripheral blood or organs after death, and by serol-

can occur via the semen. The virus survives in the

ogy. Persistently infected animals transmit the virus

environment for limited periods.

during their lifetime and infect sentinel animals easily.

Transiently viraemic animals, however, transmit the

Malignant catarrhal fever (MCF) (see also p. 935)

disease to a limited extent. These primary infections

might lead to prolonged periods of viraemia (up to 40

MCF is a sporadically, almost invariably fatal disease of

days), the presence of virus in bronchoalveolar wash-

cattle of all ages. The disease is characterized by high

ings (up to 56 days after infection) and in semen even

fever, bright red coloration of all mucous membranes, *after seroconversion has taken place. Therefore, the risk*

enlarged superficial lymph nodes and very often diar-

for transmission of BVDV by semen is substantial. One

rhoea. A herpes virus (BHV3) causes the disease.

exceptional bull has been described that shed BVDV

Diagnosis in live animals is by clinical signs, and by PCR

in the semen over prolonged periods (11 months),

on heparinized blood. Culture of the virus is not possi-

although the animal was serologically positive. This

ble, therefore information on the resistance of the virus

unusual pattern might be explained by a primary infec-

against environmental influences is not available. Cow

tion during puberty or an intrauterine infection around

to cow transmission has never been reported. Trans-

the time of maturation of the immune system. There is

mission by semen is therefore very unlikely.

information that this phenomenon might occur more

frequently. The agent survives for some days in the envi-

Bluetongue (BT) (see also p. 691)

ronment. Transmission by semen is easy. AI centres

only accept bulls that are not persistently infected.

BT occurs mainly in small ruminants but may occur in
However, because some infectious routes for the intro-
cattle as well. If clinically overt (many infections pass
duction of BVDV are not completely understood, in
unnoticed in cattle) the disease is characterized by
endemic areas BVDV might infect bulls in an AI
fever, facial oedema, haemorrhages and ulceration of
station. Where there is unintended infection of AI bulls
the mucous membranes. An orbivirus consisting of 24
the infection passes subclinically and, as this disease is
serogroups causes the disease. The virus is identified by
easily transmitted by semen, it is very important to test
culture and by PCR techniques on blood samples of
for BVDV. Monthly tests for serologically negative
febrile animals. The agent is transmitted by insects of
donor bulls and, in the case of seroconversion, ensur-
the genus Culicoides; transmission from cow to cow
ing the semen is free from BVDV might be the only
has not been reported. Transmission by semen is very
solution.
unlikely.

Enzootic bovine leukosis (EBL) (see also p. 693)

Akabane virus (see also p. 580)

EBL is found clinically by enlarged lymph nodes or

Infections of Akabane virus were shown to cause spo-

other lymphosarcomas, or by lymphocytosis in the

radic epizootics of premature births and developmen-

peripheral blood in the minority (some 30 per cent) of

tal deformities in the new born (arthrogryposis-

infected animals. Infections for the greater part pass

hydranencephaly) in cows, sheep and goats. The disease

completely unnoticed. The disease is caused by the

has been reported in Southeast Asia, the Arabian

retrovirus bovine leukemia virus (BLV), which may be

Peninsula and the Middle East and African countries.

demonstrated in the blood by PCR techniques. Routine

Diagnosis is done retrospectively by serology in adult

diagnosis is performed by serology (ELISA, AGID).

animals, and by culture techniques in abnormal fetuses

The agent does not survive in the environment. Only

and calves. Biting insects transmit the agent. After

intact lymphocytes are infective: the infection is trans-

experimental infection in bulls, Akabane virus was not

mitted by blood. Transmission by semen is very

demonstrated in the semen; transmission by this route

unlikely.

is therefore unlikely.

Rinderpest (see also p. 707)

Bovine genital campylobacteriosis (see pp. 568, 582)

This is a very contagious disease of mainly cattle and

This is a venereal disease characterized by infertility,

buffaloes. The disease is characterized by high fever,

early embryonic death and abortion. In bulls, infections

erosions on the gums, tongue and palate together with

are inapparent. The disease is caused by Campylobac-

nasal and ocular discharge, and diarrhoea. Rinderpest

ter fetus ssp. venerealis, which in bulls can be cultured is caused by a Morbelli virus that can be demonstrated

from preputial washings. Serological methods are unre-

in blood or lymph nodes and spleen, mainly by culture.

liable. The organisms survive in the environment for

Transmission is mainly directly by infected animals and

limited periods (hours). Mating and/or semen mainly *cause transmission. Virgin bulls are absolutely free of*

and may survive for several months and transmission

this agent. This agent was the impetus for the world-

by semen is possible. Tuberculosis is a zoonosis.

wide application of AI techniques and for the obliga-

tory addition of antibiotics to the semen. If this

Leptospirosis (see also p. 735)

procedure is properly executed, semen is free from this

bacterial agent. Bull stations should be free of this

Leptospirosis is a contagious disease of animals and

agent, but the low transmission rate makes testing more

humans. Many Leptospira species exist, each with their often than once a year useless. However, when a posi-specific carrier host (reservoir) in which infection leads

tive result is obtained, all semen batches after the last

to diseases of limited severity and prolonged excretion.

negative result should be checked for the presence of

Infection in other animal species (end hosts) leads to

the agent and positive ejaculates destroyed.

very severe, life threatening disease symptoms. Clini-

A very similar agent, Campylobacter fetus ssp. fetus, cally, infections in *susceptible end hosts are characteris associated with abortion storms in sheep. In cattle,*

ized by fever, icterus, haemorrhages, uraemia and blood

after oral uptake, this agent infects the gastrointestinal

tinged urine. After recovery, the Leptospira are com-

tract and is shed by the faeces. In exceptional cases, oral

pletely eliminated from the end host's body and trans-

infections in adult pregnant cattle may lead to bacter-

mission by semen is very unlikely. Infections in the

aemia and in limited numbers to infection and expul-

carrier hosts pass with minor clinical problems and may

sion of the fetus. This agent is not transmitted

even pass unnoticed.

by mating or semen. Giacoboni et al. (1993) isolated

Cattle are carriers for Leptospira hardjo, but end

Campylobacter fetus ssp. fetus from the faeces in 26.5

hosts for other Leptospira species. Infection with L.

per cent of young calves, and in 15 per cent of older

hardjo in cattle leads to prolonged or intermittent

cattle. Excretion by the faeces leads inevitably to con-

excretion with urine (and semen) and therefore may be *tamination of the environment and thus to the risk of*

transmitted by semen. Leptospira may survive in the

contamination of the prepuce. In The Netherlands,

environment in humid and warm conditions (summer)

Campylobacter fetus ssp. fetus was isolated from the for longer periods. Attention in AI stations should be

prepuce of AI bulls ranging in age from 10 months to

concentrated on Leptospira hardjo infections. L. hardjo 5 years that had never served naturally.

is a zoonosis and causes milker's fever in man.

Brucellosis (see also p. 580)

Contagious bovine pleuropneumonia (CBPP)

(see also Chapter 49b)

This is manifested by abortions in the last third of

pregnancy. The causative organisms are excreted in

CBPP is characterized by fever, dyspnoea, coughing,

abundance with uterine discharges and with milk. The

nasal discharges and anorexia. It is caused by

disease, which is a zoonosis, is caused by Brucella (B.)

Mycoplasma mycoides ssp. mycoides, which can be abortus, occasionally by B. melitensis (lower numbers of demonstrated in nasal secreta and bronchoalveolar

aborting cows in the herd) and exceptionally by B. suis.

washings or in pleural fluids collected after puncture

The disease is diagnosed by culture of the causative

by culture in appropriate media. The agent is vulnera-

organism from uterine discharge and milk, by serology

ble for environmental influences and is transmitted by

(CFT, BUA, ELISA) or by a specific skin test. The

infective animals over limited distances. Transmission

organisms survive in the environment in favourable

by semen is possible.

circumstances for prolonged periods. Transmission by

semen is possible.

Johne's disease (paratuberculosis) (see also p. 857)

This disease is chronic enteritis of ruminants, charac-

Bovine tuberculosis (see also p. 862)

terized in cows by severe diarrhoea, emaciation and

This passes unnoticed in the early phases after infec-

submandibular oedema. It is caused by Mycobacterium

tion, but in advanced cases emaciation, coughing and

(M.) avium paratuberculosis, which only leads to clini-enlargement of the lymph nodes develop. It is caused

cal disease and excretion after infection at a very young by Mycobacterium (M.) bovis and occasionally by M.

age. Infection leads to progressive thickening of the gut

tuberculosis (the human tuberculosis strain) when an

wall, causing a protein losing enteropathy with diar-

infective human source is present. Tuberculosis in live

rhoea in the final stages after 24 months or longer. M.

animals is diagnosed by a specific skin test, gamma-

paratuberculosis was found in the semen of bulls that interferon assay using peripheral blood lymphocytes,

suffered from severe clinical disease.

serology (ELISA) and by culture from nasal secretions.

In the clinical stages, the agent can be demonstrated

The organism is resistant to environmental influences

in faeces and exceptionally in milk and the fetus by

culture and/or PCR techniques. The use of PCR on the

diagnosed, no treatment is available and the bull and its

faeces lacks sensitivity. For the detection of subclini-

semen must be destroyed.

cally infected animals a skin test, ELISA and CFT are

applied. Each method has the disadvantage of limited

Bovine spongiform encephalopathy (BSE)

specificity and sensitivity.

(see also p. 909)

Transmission by contaminated semen or semen from

contaminated bulls has never been demonstrated.

BSE is a fatal neurological disease of cattle with a long

Johne's disease is endemic in most countries of the

incubation period. Clinically, behavioural changes and

world. The prolonged incubation period and test

locomotion disturbances such as ataxia manifest the

systems with low sensitivity lead inevitably to the intro-

disease. Feed is generally regarded as the most likely

duction of infected calves into the AI centres. However,

source of infection. After (oral) uptake of abnormal

excretion by semen does occur only after prolonged

protein some of the body protein is stereometrically

excretion by the faeces, and shedders can be traced by

altered, making the protein invulnerable to proteases

the application of annual faecal culture tests from the

and thus leading to intracellular accumulation of prions.

age of two years. Furthermore, there is no evidence that

This stereometrical change leads to death of brain cells,

contaminated semen infects cows after insemination.

resulting in the aforementioned. No diagnostic tests for

Johne's disease might be a zoonosis (Crohn's disease in

live animals are available, although some promising

man).

results have been reported. The prions are extremely

resistant to environmental factors. BSE prions have

never been demonstrated in the genital organs of dis-

Haemorrhagic septicaemia (HS) (see also p. 728)

eased bulls or in the semen and experimental insemi-

HS is a highly fatal disease characterized by initial

nation of susceptible cows with semen from

fever, respiratory signs and terminal septicaemia

BSE-contaminated bulls has not been shown to induce

leading to recumbence. It has been reported from Asia

BSE in the cows or progeny. There is no proof that

and Africa, and is caused by certain strains of Pas-

prions might be present in the semen. At present the

teurella multocida. The agent can be cultured from

risk of BSE transmission by semen is thought to be neg-

blood and from internal organs. P. multocida is moder-ligible and so restrictions on semen trade due to BSE

ately resistant to environmental influences. Transmis-

should be minimal or none. BSE is considered to be a

sion by semen is very unlikely.

zoonosis (new variant CJD).

Query fever (Q-fever) (see also p. 586)

Other infectious agents

In cattle, Q-fever is characterized by abortion, retained

Ubiquitous agents that might be or are present in

placenta, metritis and infertility. The disease is caused

semen, e.g. E. coli, Proteus spp., Pseudomonas spp., by Coxiella (C.) burnetti. Diagnosis is established by Haemophilus spp., Campylobacter spp. except C. fetus microscopy of fetal membranes or aborted fetuses, or

ssp. venerealis, Mycoplasma spp., and Ureaplasma spp., by culture of this agent in embryonated eggs from

should not hinder the semen trade: the addition of

uterine effluents. Routine diagnostic tests are made by

appropriate antibiotics after proper procedures is a suf-

serology (CFT, ELISA). The agent is extremely resist-

ficient guarantee for safety.

ant to environmental influences. Transmission is caused

by biting insects or by inhalation of contaminated dust.

Transmission by semen is limited or unlikely. Q-fever is

Semen safety

a zoonosis.

For safety testing of semen, two approaches can be

applied: examination of the end product or continuous

Bovine genital tritrichomoniasis (see also p. 584)

surveillance of the bulls before and after semen pro-

This is characterized by infertility and abortion. Bulls

duction. The tests for the presence of infectious agents

may be infected without clinical signs. The disease is

in the semen completely depend on one single investi-

caused by the protozoan Tritrichomonas fetus, which

gation and therefore rely on the sensitivity of the test

comprises three serotypes of equal pathogenity. The

methods only. The continuous surveillance of the semen

agent can be cultured from uterine discharges and

donors for infectious diseases before and after semen

preputial washings. Tritrichomonas is rather resistant to collection is based on sequential investigations, increas-environmental influences. Mating and/or semen mainly

ing the reliability by the application of multiple tests. In

cause transmission. Virgin bulls are free of this agent.

terms of semen safety, testing the donor for the absence

However, if an infection with tritrichomoniasis is

of infectious diseases 21 days after semen collection is

beyond doubt the best method. Therefore the bulls in

period is short. For diseases with high transmission

AI centres must be negative for the diseases mentioned

rates (e.g. IBR) monthly checks of 20 per cent of the

above. The very first step is to accept only virgin bull

donor bulls give a certainty of 99.9 per cent for semen

calves negative for these diseases. Most AI centres in

safety. This method is applied in one centre in The

Europe that release semen for the EU market collect

Netherlands.

their bull calves before the age of six months. There are

no concerns about diseases from which the area is offi-

cially declared free. An annual check on the health

References and further reading

status will suffice if the country in which the AI centre

is situated remains negative. However, if diseases are

Berchovich, Z. (1998) Maintenance of Brucella abortus free endemic, theoretical

risks exist for the introduction of

herds: a review with emphasis on the epidemiology and the

disease agents into AI studs. Preventive measures

problems in diagnosing Brucellosis in areas of low preva-

should concentrate on optimal hygiene for humans

*lence. Veterinary Quarterly, **20**, 81–8.*

entering the premises (showering and changing

Bruschke, C.J.M. (1998) Pathogenesis and vaccinology of

clothes), on 48-hour storage periods (including forage)

bovine virus diarrhoea virus infections. Thesis, Utrecht.

or on disinfection of materials before admittance into

Chen, S.S., Redwood, D.W. & Ellis, B. (1990) Control of

the station, the use of mains water, and on the eradica-

Campylobacter fetus in artificially contaminated bovine semen by incubation with antibiotics before freezing.

tion of vermin. One risk factor remains, however infec-

*British Veterinary Journal, **146**, 68–74.*

tious particles transported by air and/or birds. Only

Council Directive (88/407/EEC) (1993).

large distances (more than 1 kilometre) between the AI

Den Daas, J.H.G. (1997) Prediction of bovine male fertility.

station and other cattle in the area will suffice.

Thesis, Wageningen.

The next step is to minimize the consequences of the

Eaglesome, M.D. & Garcia, M.M. (1997) Disease risks to

unintentional introduction of agents into AI centres.

animal health from artificial insemination with bovine

Regular checks must be performed for the presence of

semen. Revue Scientifique Office International des Epi-

disease agents that might be transmitted by semen:

*zooties, **16**, 215–25.*

animals found positive must be separated or destroyed

Giacoboni, G.I., Itoh, K., Hirayama, K., Takahashi, E. &

immediately. The system for checking the disease-free

Mitsuoka, T. (1993) Comparison of fecal Campylobacter in status of the bulls depends on the transmission routes

calves and cattle of different ages and areas in Japan.

*Journal of Veterinary Medical Science, **55**, 555–9.*

and transmission rate. Highly contagious diseases with

Herman, H.A., Mitchel, J.R. & Doak, G.A. (1994) The

a high risk for transmission by semen should be checked

Artificial Insemination and Embryo Transfer of Dairy and *regularly (monthly). The rates at which diseases are*

Beef Cattle, 8th edn. Interstate Publishers, Danville.

transmitted to other animals depend on a number of

Horzinek M.C. (1990) Virus Infections in Vertebrates. In Viral characteristics of the pathogen, the host and of the

Infections in Ruminants. (ed. by Z. Dinter & B. Morein) contact structure between animals. An important

Elsevier; Amsterdam, Oxford, New York, Tokyo.

parameter related to transmission is the basic repro-

Merkal, R.S., Miller, J.M., Hintz, A.M. & Bryner, J.H. (1982) duction ratio, i.e. the number of animals that are

Intrauterine inoculation of Mycobacterium paratuberculosis infected by one typical infectious animal during its

into guinea pigs and cattle. American Journal of Veterinary entire infectious period. This number depends greatly

*Research, **43**, 676–8.*

on the number of effective contacts between animals. A

OIE (1996) OIE Manual of Standards for Diagnostic Tests and Vaccines, 3rd edition. Office International des Epizooties, contact is effective when the pathogen is transmitted

1997. ISBN 92-9044-423-1.

from one infected animal to another (excretion titre

Thrusfield, M. (1995) Veterinary Epidemiology, (2th edn).

above the minimal effective dose). These contacts

Blackwell Science, Oxford.

might be either direct (animal–animal) or indirect (by

Wentink, G.H., Frankena, K., Bosch, J.C., Vandehoek, J.E.D.

air, people, equipment, etc.). High transmission rates in

& van den Berg, Th. (2000) Prevention of disease transmis-

AI stations will be achieved when the number of effec-

sion by semen in cattle. Livestock Production Science, ***62****, tive contacts is high and the length of the incubation*

207–20.

Chapter 40

Embryo Transfer

A.K. Smith

Introduction

634

• Increased numbers of progeny from genetically

The principles of embryo transfer

634

superior dams.

Results

637

• The possibility of progeny of the other sex from

Donors

637

dams that previously may have only produced

Recipients

637

calves of one sex.

Embryo collection: practicalities

638

• Increased diversity for marketing herd genetics

Donor selection criteria

638

including international trade.

Nutrition

638

Superovulation

638

• Banking of frozen embryos to accommodate sea-

Insemination

639

sonal breeding or longer term breeding strategies.

Embryo collection

641

• As a diagnostic technique for infertility cases,

Embryo processing

642

especially in diagnosing blocked oviducts.

Embryo freezing

642

• As a method of continuing breeding from animals

Embryo thawing

643

unable to do so naturally.

Embryo transfers: practicalities

643

• Improved disease control applicable to high health

Recipient selection criteria

644

status herds and international trade by reducing the

Nutrition and management

644

number of individual animal movements.

Disease control

644

Oestrous synchronization

644

Transferring the embryo

644

Hormone supplementation

645

Record keeping

645

The principles of embryo transfer

Legislation

645

Troubleshooting

646

As previously described (see Chapter 33), follicular

Advanced technologies

646

dynamics result in either two or three waves of follicle

Embryo splitting

646

development during the oestrous cycle. In each wave a

In-vitro fertilization (IVF)

647

dominant follicle suppresses the development of sub-

Ovum pick-up (OPU)

647

ordinate follicles until at the end of the cycle the corpus

Embryo sexing

648

luteum (CL) is lysed, allowing the dominant follicle of

Cloning

648

the last wave to become the ovulatory follicle.

Superovulation utilizes commercially prepared folli-

Introduction

cle stimulating hormone (FSH) to encourage a group

of developing follicles to overcome the dominant folli-

Although considered a recent technology, Walter Heap

cle suppression and continue developing to ovulation

performed the first successful embryo transfer (ET) in

with concomitant maturation of the oocytes. The FSH

rabbits over a hundred years ago. A further six decades *is commonly administered as a twice-daily injection*

elapsed before the first embryo transfer calf was pro-

regime over four days, commencing mid-cycle (days

duced in 1951, in the USA, by Willet and his colleagues.

9–14). Incorporated in this regime is a prostaglandin F2a

The first commercially acceptable results were recorded

(PGF2a) injection, usually given alongside the fifth FSH

in cattle in 1969 by Rowson and his colleagues. In 1973

injection, to return the donor cow to oestrus. The onset

Wilmut and Rowson produced the first calf born from

of oestrus and subsequent ovulation are accelerated in

a frozen-thawed embryo and five years later Willadsen

superovulated animals and oestrus occurs usually 48–56

succeeded in producing commercially acceptable

hours after the PGF2a treatment, with ovulation occur-

results for cattle embryo freezing.

ring as early as the onset of oestrus (cf 12–18 hours post

Now ET technology is widely used in pedigree cattle

oestrus in non-superovulated cows). Accordingly it is

breeding offering breeders a number of opportunities:

usual to inseminate the donor cow soon after the onset of oestrus (e.g. the afternoon of the day of oestrus, with

Box 40.1

Description of embryo grading. Source: IETS

a second insemination the following morning).

Manual, 3rd edn (Stringfellow & Seidel, 1998).

Embryo collection is performed on day 7 of the

oestrous cycle (day 0 = day of oestrus). Embryos enter

Grade 1: Symmetrical and spherical embryo mass with indi-

the uterine lumen from the oviduct at approximately

vidual blastomeres (cells) that are uniform in size,

colour and density. The embryo is consistent with

day 4 of the oestrous cycle and, although embryos can

its expected stage of development. Irregularities

be collected successfully from the uterus between days

should be relatively minor and at least 85 per cent

5 and 9, a day 7 collection allows recovery of the most

of the cellular material should be an intact, viable

flexible stages of the embryo for both freezing and fresh

embryonic mass. This judgement should be based *transfer. Collection (flushing) is a non-surgical proce-*

on the percentage of embryonic cells represented

dure requiring catheterization of the uterine horns.

by the extruded material in the perivitelline space.

Two types of embryo collection catheter exist:

The zona pellucida should be smooth and have no

concave or flat surfaces that might cause the

• Two-way, which has two tubes within it. One allows

embryo to adhere to a petri dish or a straw.

inflation of a latex cuff near the tip of the catheter,

Grade 2: Moderate irregularities in overall shape of the

whilst the other enables the flushing media to enter

embryonic mass or in size, colour and density of

and leave the uterine horn. Greater volumes of

individual cells. At least 50 per cent of the cellular

media are required as a larger segment of the

material should be an intact, viable embryonic

uterine horn is flushed (Fig. 40.2).

mass.

• Three-way,which consists of three tubes. One allows

Grade 3: Major irregularities in shape of the embryonic mass *or in size, colour and density of individual cells. At*

inflation of the cuff situated 10 cm behind the tip.

least 25 per cent of the cellular material should be

Another tube allows media to enter the uterine

an intact, viable embryonic mass.

lumen from the tip of the catheter and a one-way flow

is created by the media returning down the third tube

via its entry hole at the level of the cuff (Fig. 40.3).

injury, particularly when cooling is slower than

The flushing media, Dulbecco's phosphate buffered

optimum.

saline (PBS), is infused into the uterine lumen to allow

• *Intracellular ice: this results in physical damage*

slight distension before drainage by gravity flow along

when cooling is faster than optimal.

with the embryos and ova into a collection filter. The

filter contains a metal or plastic micromesh with a pore

Cooling rates of 0.3°C/min to 0.6°C/min are considered

diameter approximately half that of an embryo

rapid whereas 0.1°C/min is considered slow. The cryo-

(embryo diameter 140–170 mm), allowing excess media

protectants lower the temperature at which intracellu-

to run through whilst retaining the embryos.

lar ice forms, reduce the amount of ice present in

Embryo searching is performed once both uterine

extracellular fluid, moderate the solute effect and help

horns have been flushed. The contents of the filter are

stabilize the cell membrane. Some cryoprotectants

emptied into a petri dish and examined under a stereo-

themselves may cause osmotic injury to cells and need

scopic microscope at between ¥6 and ¥10 magnification.

to be added or removed gradually. The cryoprotectants

Recovered embryos are placed in embryo holding

most commonly used commercially are 10 per cent

solution (Dulbecco's PBS with bovine serum albumin,

glycerol and 1.5 m ethylene glycol. Stepwise addition or

glucose and antibiotics), classified (Fig. 40.1; Plate 40.1)

removal is required for 10 per cent glycerol in increas-

and graded (Box 40.1). Embryo holding solution is also

ing or decreasing gradients of concentration respec-

known as ovum culture medium (OCM). Embryo eval-

tively, whereas one-step thawing of embryos frozen in *uation is by subjective visual assessment under ¥50*

ethylene glycol can be performed as it crosses cell

stereoscopic magnification. Embryos can survive on the

membranes more rapidly. Embryos are frozen in

bench at ambient temperature (20°C) for up to eight

0.25 ml plastic straws which must be identified with the

hours with little drop in pregnancy rate, but they are

donor name, sire name, collection team code, breed

best frozen or transferred within three hours of collec-

code and date code. The straws are sealed either by a

tion (Wright, 1985).

plastic plug or are heat-crimped.

Embryo freezing involves, initially, partial dehydra-

The cooling curve to be used is preprogrammed into

tion of the embryo in a cryoprotectant to prevent freez-

the freezing machine and the straws are subjected to a

ing damage. Two main factors influence the success or

controlled rate of freezing as this progresses to ensure

failure of freezing cells:

optimal survival of the embryo. A process called

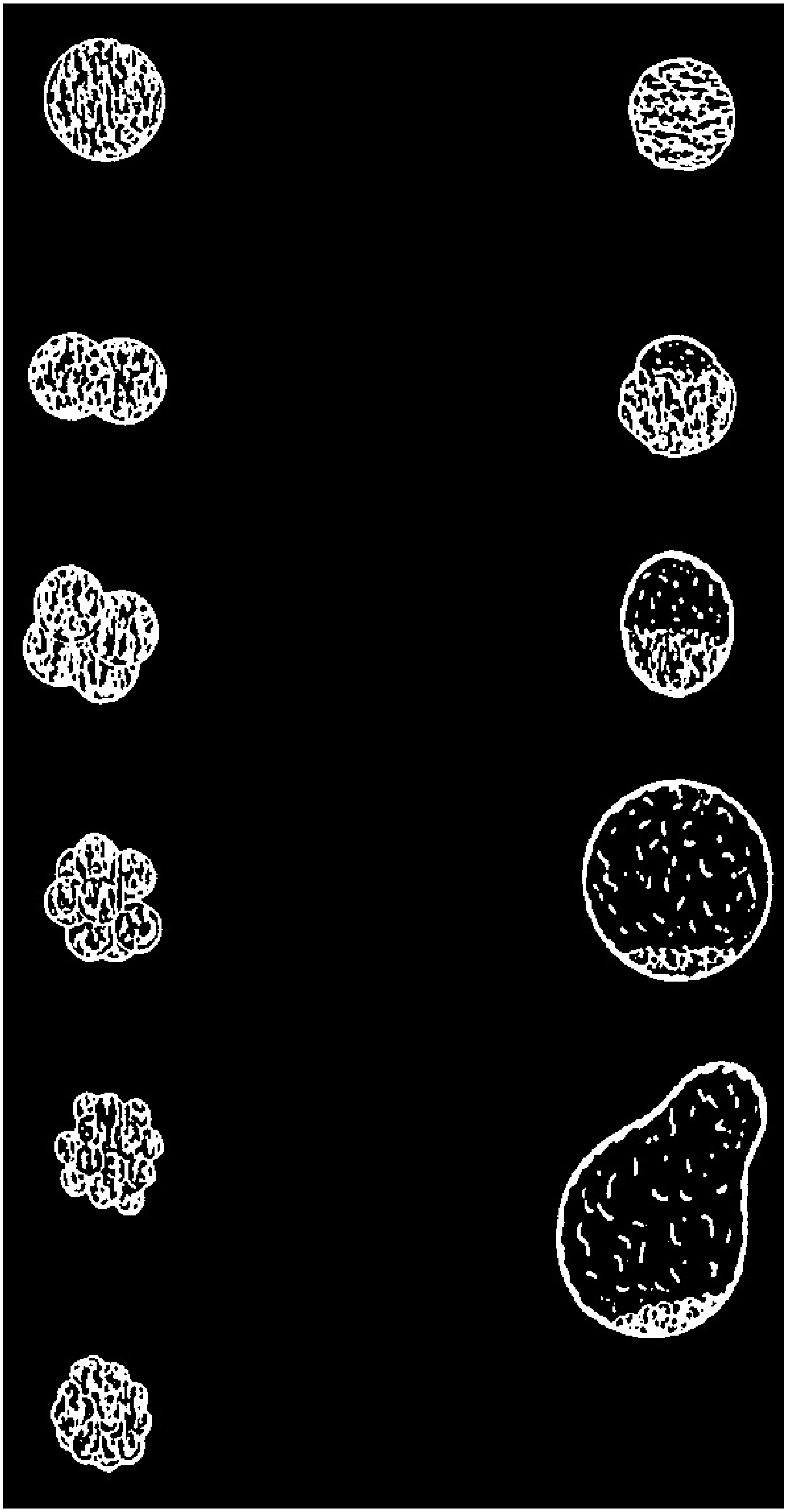
‘seeding’ is performed when the freezer chamber tem-

• *Solution effects: the solute concentration within a*

perature is at -6°C (some programmes -7°C). This

cell increases due to dehydration and causes cell

nucleates the freezing medium with an ice crystal when



(1) 1-cell

(4) Late morula

(day 1)

(day 6)

(2) 2-cell

(5) Early blastocyst

(day 2)

(day 7)

(2) 4-cell

(6) Blastocyst

(day 3)

(day 7–8)

(2) 8-cell

(7) Expanded blastocyst

(day 4)

(day 8–9)

(2) 16-cell

(8) Hatching blastocyst

Fig. 40.1

The code for stage of develop-

(day 5)

(day 9)

ment is numerical. Number 1 identifies an

unfertilized oocyte or a one-cell embryo.

Number 2 identifies embryos with 2 to 16

cells (approximately day 2 to day 5).

Number 3 identifies an early morula, and

numbers 4 to 8 (inclusive) identify post com-

paction stage embryos as illustrated above.

(3) Early morula

(day 5–6)

In commercial embryo transfer, embryos are

collected on days 6 to 8 of the oestrous

cycle (morula to blastocyst).

1 or 2°C below its freezing point, preventing super-

checked and then they are reloaded into straws for

cooling and excessive temperature rise from the release

transfer.

of latent heat in the cooling process. At the end of the

The embryo transfer procedure for the recipient is the freezing programme the *straws are plunged directly*

same for fresh or frozen embryos. Recipients need to

into liquid nitrogen before being placed in plastic

have been synchronized to display oestrus on the same

goblets and stored under liquid nitrogen in cryogenic

day as the donor cow or within a 24-hour period either

flasks.

side of that day. For frozen embryos the recipients are

Thawing of the straws is a reversal of the previous

synchronized to be in oestrus six, seven or eight days

procedures. The straws are thawed in a flask of warm

prior to the day of transfer. Before transfer of the

water and if frozen in 1.5 m ethylene glycol are then

embryo the recipient's ovaries are examined by manual

ready for immediate transfer. Those frozen in 10 per

rectal palpation or ultrasound scanner for the presence

cent glycerol must first have this extracted from the

of a CL. Note is also made of which ovary has the CL.

embryo. The embryos are removed from the straws they

Recipients receive an epidural anaesthetic and, after

are frozen in and passaged through decreasing concen-

the perineum has been cleaned, the transfer gun is

trations of glycerol until finally they are placed in

passed through the cervix and guided along the uterine

embryo holding solution, re-examined, their grades

horn ipsilateral to the corpus luteum before depositing

Table 40.1

Analysis of results achieved from 1110 commercial

Table 40.2

Analysis of pregnancy results for 3820 embryos

embryo collections. Source: Ovaflo Embryo Transfer.

transferred commercially. Source: Ovaflo Embryo Transfer.

Overall results per collection

By classification

Total ova (includes unfertilized ova,

10.08 (mean)

Blastocysts

62.3%

degenerate embryos and viable embryos)

(grade 1)

Total viable embryos

5.03 (mean)

Early blastocysts

62.4%

Fertilised ova

58.6%

(grade 1)

(includes viable and degenerate embryos)

Morulas

62.4%

(grade 1)

By classification

Blastocysts

11.3%

By procedure

Early blastocysts

15.2%

Fresh transfers

64.8%

Morulas

73.5%

(grade 1)

Frozen transfers

58.8%

By grades

(grade 1, 10% glycerol)

Grade 1 embryos

88.0%

Grade 2 embryos

11.7%

By freezing method (purchased embryos) *Grade 3 embryos*

0.3%

10% Glycerol

53.4%

1.5 M Ethylene glycol

55.4%

By embryo grade

the embryo. Historically embryos were transferred

Grade 1

62.4%

surgically, involving paravertebral anaesthesia and

Grade 2

44.5%

laparotomy of the sublumbar fossa, but for welfare

reasons surgical transfers have been superseded by the

By dam breed

non-surgical technique.

Beef

59.3%

(grade 1)

Dairy

64.5%

Results

(grade 1)

Donors

In superovulated animals an estimate can be made of

anomalies were found in day 7, 8 or 9 embryos, sug-

the likely number of ova by counting the corpora lutea

gesting embryos with abnormal karyotypes were non-

on the ovaries. Manual estimation is poor if there are

functional by that stage. Whilst embryos from donors

more than ten CLs on an ovary, but if there are

over 15 years old have shown lower pregnancy rates

fewer then estimates have a higher accuracy. Some dis-

(Hasler et al., 1987), the biggest single embryo factor crepancies can be accounted for by luteinized follicles

affecting pregnancy rates is embryo quality. Good

which histologically show an enclosed oocyte with the

quality embryos give better pregnancy rates

cumulus cells dispersed and luteinization in the granu-

(Donaldson, 1985). By day 16 well-developed embryos

losa cells (Monniaux et al., 1983). Heifers can exhibit produce significantly more interferon, thus fully inhibit-large responses to superovulation (based on palpated

ing luteolytic PGF2a, than do poorly developed embryos

CLs) with high fertilization rates of the recovered ova

at that stage.

but lower recovery rates than parous animals (Hasler et

al., 1983). Examples of results achieved commercially

Maternal factors

are given in Table 40.1.

The best pregnancy rates are achieved when the syn-

chrony is close (±24 hours) between the embryo's stage

Recipients

of development and the recipient's uterine environ-

Successful pregnancy rates are influenced by a number *ment (Donaldson, 1985; Newcomb & Rowson, 1975).*

of factors, both embryonic and maternal.

Transfer of the embryo to the uterine horn ipsilateral

to the corpus luteum with deep placement of the

embryo, rather than placement at the level of the

Embryonic factors

intercornual ligament, gives the best pregnancy rates

Although some young embryos (days 3–6) have been

(Christie et al., 1979). The CL ensures a source of prog-shown to have abnormal karyotypes (7 per cent) no

esterone but maternal progesterone concentrations can

show considerable diurnal fluctuations. Progesterone is

this relationship, but since diet supplementation can

required in the first half (approximately 12–14 days) of

raise insulin levels nutrition has an important role.

the oestrous cycle to suppress the oxytocin receptors.

Donors should be on a rising plane of nutrition for six

Inhibition of the oxytocin receptors is less effective in

to eight weeks before flushing. All adjustments must be

cows with a low progesterone concentration, meaning *gradual without any sudden changes. The timing of*

that the luteolytic mechanism develops earlier allowing

housing and turn-out needs to be planned carefully as

less time for the conceptus to produce sufficient tro-

either event occurring in the middle of a superovula-

phoblastic interferon to create an adequate block to

tion programme can have a disastrous effect on the

luteolysis. Remsen et al. (1982) and Northey et al.

success rate. Careful attention to mineral supplementa-

(1985) demonstrated maximal pregnancy rates (PR)

tion is also important. Apart from ensuring a balanced

when plasma progesterone concentrations were in the

level of minerals, consideration should be given to

ranges 2–5 ng/ml (PR 74 per cent) and 2–6 ng/ml (PR 68

molybdenum toxicity. Embryo donors on a high

per cent), respectively. However Hasler et al. (1980) and molybdenum diet (15–20 mg Mo/kg dietary DM)

Smith et al. (1996) found no correlation between preg-

produce greater numbers of abnormal embryos,

nancy rates and progesterone concentrations. A review

suggesting that elevated dietary molybdenum will *of mean pregnancy rates that can be achieved com-*

retard embryo development. In addition, diets contain-

mercially is given in Table 40.2.

ing 5 mg Mo/kg DM decrease conception rates and

cause anovulation and anoestrus in cattle. Protection

against molybdenum toxicity is achieved by providing

Embryo collection: practicalities

adequate supplies of copper. Although copper can be

supplied by injection or orally as powdered mineral,

Forward planning is the key. Careful animal prepara-

drenches and capsules it seems, from some studies, that

tion and attention to detail will improve success.

the use of intraruminal boluses is more efficacious

(p. 298).

Donor selection criteria

Donor heifers:

Superovulation

• Body condition score approximately 21/2 (assessed

Gonadotrophins such as equine chorionic gona-

over the range 1–5; Lowman et al., 1976; see also

dotrophin (eCG) and human menopausal gonadotro-

Chapter 2);

phin (hMG) have been used in the past to superovulate

• Regular oestrous cycles;

cows, but due to the undesirable effects from extended

• Age 15–18 months.

activity of the luteinizing hormone (LH) fraction they

Donor cows:

have been superseded by purified FSH. This is avail-

able as a freeze-dried product with diluent which,

• At least six weeks calved;

when mixed, produces a solution with controlled

• Clean uterus and returned to regular oestrous

amounts of LH activity. These commercial FSH prod-

cycles;

ucts are sourced principally from ovine and porcine

• Preferably two heats since calving;

pituitaries.

• Maintaining or increasing liveweight (body condi-

It is best to start superovulation from a known refer-

tion score 2–3).

ence heat so that the injections commence at a known *point in the oestrous cycle. A superovulated response*

can be achieved starting anywhere in the cycle, given

Nutrition

good control of the follicular wave, but the most repeat-

It is now recognized that the time required for a pri-

edly consistent results are achieved when the FSH

mordial follicle to develop to an ovulatory follicle is

injections commence between days 9 and 14 (Hasler et

60–90 days and the environment that the cow is in

al., 1983). This same review found no differences in the during that time can influence not only the vitality of

number of ova (11.6 versus 10.2) or viable embryos (6.2

that oocyte but also the subsequent embryo (Webb et

versus 6.4) recovered from donors superovulated fol-

al., 1999). In particular there is a correlation between lowing prostaglandin-induced reference heats versus

follicular development and plasma levels of insulin and

natural reference heats, respectively. The use of intra-

peripheral levels of insulin-like growth factor-1 (IGF-

vaginal devices to mimic the hormone levels found mid

1), with elevated levels of insulin being associated with

cycle can supply an exogenous source of progesterone.

enhanced ovulation rates. Research continues into

Although less consistent than starting from a known

identifying the mechanisms and pathways involved in

reference heat, the results from this method are satis-

Table 40.3

Examples of commercial superovulation regime for cattle.

Maiden heifer

Mature cow

day 12

am

2.25 ml FSH solution

3.0 ml FSH solution

pm

2.25 ml

3.0 ml

day 13

am

1.75 ml

2.5 ml

pm

1.75 ml

2.5 ml

day 14

am

1.25 ml + double dose of PGF2a

2.0 ml + double dose of PGF2a

pm

1.25 ml

2.0 ml

day 15

am

0.75 ml

1.5 ml

pm

0.75 ml

1.5 ml

Total dose

12 ml

18 ml

Note:

At the time of publication there is one licensed FSH product in U.K. This is an *ovine FSH (Ovagen, ICP, NZ) containing 0.88 mg/ml NIADDK-oFSH-17 ovine pituitary FSH.*

PGF2a = Prostaglandin F2a

These protocols are included as examples of regimes used in commercial embryo transfer practice. Alternative protocols do exist with variations in total volume, volume of individual injections and rate of decline of dosage regime.

factory even if few or no behavioural signs are seen at

is to improve the superovulatory response without

the time of the reference heat.

creating an over-response, because as the number of

When a twice-daily injection regime is used the injec-

follicles stimulated increases there is a negative effect

tion interval is ideally 12 hours, but as long as the inter-

on the viable percentage of the recovered ova. Gener-

val is no less than eight hours satisfactory results will

ally this happens once the total CL count rises above

still be achieved. Product manufacturers advocate that

20. As numbers increase above this level there is a ten-

the total dose be split into eight equal injections, but the

dency for a rise in numbers of unfertilized and degen-

use of a declining regime with higher dose volumes at

erate embryos and a decline in viable embryos, often to

the start gives superior results. Responses to the same
zero. However, some donors can still perform success-
superovulation regime will vary from donor to donor
fully with CL counts in the range of 20–30. It is,
and there are also breed differences in sensitivity to the
however, the author's opinion that a preferred target is
treatment with the Simmental breed being particularly
a superovulatory response yielding a total ova count in
sensitive. In addition, body condition, nutrition and
the mid teens, which can result in 8 to 12 viable embryos
environmental factors will all influence the response to
(fertilization rate 50–60 per cent). As Table 40.1 demon-
treatment. A generalization can be made that maiden
strates real results are lower than this. This can be partly
heifers will respond satisfactorily to a lower total
attributed to some donors being consistently successful,
dosage of FSH than that required for a mature cow.
but others being consistently poorer performers.
Although aged cows can be successfully superovulated
Studies of donor populations corroborate this, but such
the oocyte quality may be compromised in these cows,

profiles can only be built up over time and on the

especially if over 15 years old, so that fertilization rates

strength of a single flush a donor cannot be categorized

of these ova or pregnancy rates of subsequent embryos

simply as good or bad other than for that single event.

may be poorer. An example of a standard commercial

Cleanliness at the time of injection is important as

programme used for maiden heifers and mature cows

contamination of the stock solution can result in loss of

is shown in Table 40.3.

potency of the FSH. New sterile syringes and needles

Between animals there can be a substantial variation

should be used for each injection. In animals that have

in their superovulatory response to a given dose of

high body condition scores the superovulatory response

FSH. What can be an effective dose in one animal may

is improved if the injections are given into the neck

result in either too low or too high a response in

muscle.

another. Animals which fail to respond sufficiently

(fewer than two ova is a non-response and fewer than

Insemination *(see also Chapter 39)*

five ova is a low response) can usually be improved by

increasing the dose on a subsequent occasion. Increas-

The number of straws of semen recommended can vary

ing the total dose in 2 ml increments (0.25 ml per injec-

from operator to operator, but given good quality

tion) is usually an acceptable approach. The objective

semen three straws given in two insemination periods

Balloon cuff

Uterine horn

Oviduct

Superovulated ovary

Cervix

Vagina

Flexible PVC catheter

(catheter stiffened with steel stylet for insertion)

Cuff

Inflation

Fluid outlet

3 way

Tap

Embryo collection

Fluid inlet

filter

Fig. 40.2

Two-way embryo collection

catheter.

are usually adequate, firstly the afternoon of the day the

previous experience, the semen is known to be of poor

donor is in oestrus and again the following morning.

quality then extra straws may be used (e.g. three

The precise timing of this action can be dependent on

sessions utilizing two, two and one straws of semen).

the time of onset of oestrus. If the donor is in standing

A mix of semen from two different bulls can also be

oestrus in the morning then artificial insemination (AI)

used when quality is questionable. It should be con-

at mid afternoon that day with two straws and again the

firmed that the Breed Society rules permit this practice

following morning with one straw is sufficient. If the

and all progeny produced will need to be either blood-

donor only comes into standing oestrus later in the day

typed or DNA tested to confirm parentage. Equivocal

then the first AI can be delayed. This is easily done if

evidence exists as to whether heterospermic interac-

DIY AI is used, but may be awkward with a technician

tion in this scenario will synergistically enhance fertil-

service. The time of onset of heat is usually directly

ization rates. Published data suggest enhancement in

proportional to the size of the superovulatory res-

a range of 2 to 10 per cent, dependent on whether

ponse. If a cow is in standing oestrus the night before

two bulls (same breed) or three bulls (different

she is expected then a large superovulatory response

breeds) were used respectively. Natural service can also

can be assumed and an extra AI session using an

be used and the bull should be allowed to serve the

additional two straws of semen should be planned

donor as soon as she comes into oestrus. Consideration

for the morning of the first day of AI. If, through

must be given to the health status of bulls used

Uterine horn

Oviduct

Balloon cuff

Drainage holes

Cervix

Superovulated ovary

in catheter

Flexible PVC

catheter

Vagina

Stainless steel

intraducer

Embryo

Fluid inlet

collection

filter

Cuff inflation

Fig. 40.3

Three-way embryo collection

catheter.

for natural service to avoid transmission of venereal

A successful recovery rate requires good catheter

and other diseases.

position and good media flow. These conditions are

most easily met if the epidural completely abolishes

rectal peristalsis. The ideal position for a two-way

Embryo collection

catheter is to have the cuff inflated at least 5 cm past the

Cleanliness of the epidural site and the perineum is

level of the intercornual ligament (ICL) (Fig. 40.2). In

important and cotton wool swabs dampened with sur-

the three-way system the stainless steel cannula, down

gical spirit are ideal for this. All instruments, catheters,

which the catheter passes, is inserted to the level of the

tubing and filters must be sterile. Metal instruments,

ICL. Upon removal of the centre, the catheter is passed

silicone tubing and glass tubing can be autoclaved,

down the cannula and along the uterine horn until the

whereas catheters and filters are usually gas sterilized

tip is about 10–15 cm from the end of the horn (Fig.

with ethylene oxide. No disinfectants or harsh cleans-

40.3). Inflation of the cuff should be enough to anchor *ing solutions that may persist on surfaces and be*

it in position without damaging the endometrium;

harmful to the embryos should be used. All equipment

usually 2 ml of air and 4 ml of sterile water will be suf-

sterilized by ethylene oxide must be aired for a

ficient in most donors. The two-way system will use

minimum of seven days before use.

more media than the three-way because a larger

(a) 10% Glycerol

Seeding Point

Embryo

Seal

Plug

Air

Air

Air

10% Glycerol

10% Glycerol

10% Glycerol

(b) 1.5 M ethylene glycol

Seeding Point

Embryo

Seal

Plug

Air

Air

Air

Air

Air

OCM

EG

EG

EG

OCM

OCM = Ovum culture media

Fig. 40.4

Methods of loading straws for

EG = 1.5 M ethylene glycol

freezing.

volume of uterine horn is being flushed. Generally the

Embryo processing

two-way system will require about 350–500 ml per horn Examination of the embryos requires a good quality compared to the three-way system using 180–200 ml per stereoscopic dissecting microscope with at least ¥10, ¥25 horn. Care must be taken not to overdistend the horn and ¥50 magnification. Disposable plastic Petri dishes and aliquots of approximately 30 ml in a three-way should be used. Once retrieved from the flushing solu- system would be sufficient. To aid successful drainage tion, embryos should be kept in embryo holding solution of the media down the catheter it is important to lift the at a constant ambient temperature (approximately 20°C) tip of the uterine horn gently so that it is not curled and out of strong light until the next procedure. Ideally, under the body of the uterus. The bovine uterus is a embryos should be frozen or transferred within three fragile organ and rough handling or excessively force- hours of collection. Although the law requires embryos ful actions can result in damage to the endometrium or to be washed ten times prior to freezing it is good prac- perforation of the wall.

tice to wash all embryos whether destined for freezing or

Best practice is to return the donor animals to normal

fresh transfer. An outline of this procedure is given in

cycles after the flush. This ensures termination of

Box 40.2 and a more detailed account can be found in

skulking embryos and reduces opportunities for

the Manual of the International Embryo Transfer Society

development of cystic ovarian disease after superovu-

(IETS) (Stringfellow & Seidel, 1998). The ten-times

lation. This can be done by injection of PGF2a or by

washing regime will remove a number of viruses from the

using a combined progesterone releasing intravaginal

zona pellucida whilst other more persistent ones can be

device with PGF2a. When using PGF2a alone a higher

removed by including a wash with trypsin in the proce-

dose than normal is required to lyse the luteal tissue

dure. Box 40.3 lists viruses and bacteria which can be suc-

present on superovulated ovaries. Consequently a

cessfully removed by standard washing procedures and

one-and-a half times or double normal dose of PGF2a

trypsin washing.

is used. If donors are to be repeat flushed they should

be allowed two oestrus events between flushes to opti-

Embryo freezing

mize the repeat results (Hasler et al., 1983). In practice this translates to an eight-week interval between

Prior to freezing the embryos are partially dehydrated

flushes.

in cryoprotectant. Ready-to-use 10 per cent glycerol

Embryo

Plug

Air

Air

Air

OCM

OCM

OCM

OCM

Fig. 40.5

Method of loading straws for

OCM = Ovum culture media

transfer.

Box 40.2

Embryo washing procedure. Source: IETS

Box 40.3

Pathogens not found after washing of embryos

Manual, 3rd edn (Stringfellow & Seidel, 1998).

previously exposed to these agents. Source: IETS Manual, 3rd edn (Stringfellow & Seidel, 1998).

•

Only embryos from a single donor should be washed

together

Normal ten-times washing:

Akabane virus

•

Ten or fewer embryos should be washed at one time

Bovine leukaemia virus

•

Only zona pellucida intact embryos should be washed

Bluetongue virus

•

Only embryos free of adherent material should be washed

Bovine viral diarrhoea virus

•

A minimum of ten washes is necessary, ensuring gentle

Foot-and-mouth disease virus

agitation in each wash

Brucella abortus

•

Use a new sterile micropipette each time embryos are

Trypsin washing:

Bovine herpes virus 4

moved from one wash to the next

Infectious bovine rhinotracheitis

•

Regulate volumes so that each wash is at least a 100-fold

virus

dilution of the previous wash, achieved by using 1 ml

Vesicular stomatitis virus

droplets of Dulbecco's PBS and a 10 ml micropipette to

move embryos

and 1.5 m ethylene glycol are available commercially,

straws are still submerged. If long-term storage is envis-

which have the benefit of being quality controlled and

aged, separate into two groups and store in different

screened for viruses. Prior to freezing the embryos need

cryogenic flasks.

to be allowed time to equilibrate in the cryoprotectant.

This state is achieved after 5 to 10 minutes immersion

Embryo thawing

in 1.5 m ethylene glycol, but with the 10 per cent glyc-

erol the embryo needs to be passaged step-wise through

Thawing of the straws is a reversal of the previous proce-

increasing concentrations of the solution. A common

dures. Once the straws have been removed from the

method is to allow 5 minutes in 5 per cent glycerol

liquid nitrogen they are placed in a flask of warm water.

(10 per cent glycerol diluted with an equal volume of

Some protocols require a short period of air thawing

embryo holding solution) followed by 15 minutes in

prior to entering the water. The water temperature

10 per cent glycerol. After the required equilibration

(22–37°C), the duration of submersion (7–30 seconds)

time in the cryoprotectant the embryos are loaded into

and the inclusion of air thawing (none–10 seconds) are all
straws (Fig. 40.4), sealed and labelled before being put
dependent on the method and programme protocol used
in the freezing machine. It is important not to greatly
for freezing. Most embryo transfer companies provide
overextend the equilibration time as the cryoprotec-
recommended thawing protocols along with the
tants themselves are embryo-toxic if overexposure is
embryos. Labels must be checked and the details
allowed. At the appropriate time in the freezing proto-
recorded. Straws with embryos frozen in 1.5 m ethylene
col the cooling process is paused to allow seeding.
glycol can be loaded into the transfer gun for immediate
Seeding is easily performed using a metal rod, e.g.
transfer. Embryos frozen in 10 per cent glycerol must be
brass; the rod is supercooled in liquid nitrogen then
removed from the straws they were frozen in and pas-
gently and briefly touched against the straw (Fig. 40.4).
saged through decreasing concentrations of glycerol;
The seeded medium immediately becomes opaque as it
they are then placed in embryo holding solution, re-

nucleates. Embryo damage can occur if too long a examined and their grades checked before they are period of time elapses at seeding (overseeding) or if too reloaded into straws for transfer (Fig. 40.5). This step-large an area is seeded. The use of a brass rod is there-wise removal of the 10 per cent glycerol is aided by the fore preferable to tweezers for this reason. Once all inclusion of sucrose in the solutions to prevent too rapid straws are seeded the cooling process continues and at an ingress of water to the cells. One brand of ready-to-use the end the straws are swiftly plunged into liquid nitro-solutions passages the embryo from 10 per cent glycerol gen (-196°C). Straws containing embryos (especially through 5 per cent glycerol, 0.5 m sucrose (5 minutes) the column of medium in the straw in which the embryo then 2.5 per cent glycerol, 0.5 m sucrose (5 minutes) and lies) should be kept submerged in liquid nitrogen and finally 0.6 m sucrose (5 minutes) before immersion in should not be exposed to air until thawing. The straws embryo holding solution/OCM prior to reloading. should be handled with tweezers, not fingers. The *easiest method to check identities on the straw labels*

is to place the whole goblet containing the straws in

Embryo transfers: practicalities

a wide-mouthed insulated flask containing liquid

nitrogen. Thus the labels/plugs can be read while the

For successful results forward planning is essential.

Recipient selection criteria

ence of virus from the live IBR vaccines which may cause

problems for ET progeny destined for export (including

Recipient heifers should be:

Northern Ireland) or for entry to semen collection

• At least 15 months old;

centres. IBR marker vaccines (p. 1010) may alter the

• At least 370kg (dairy heifers);

situation but this will depend on recognition by the

• At least 400kg (beef heifers);

importing country and importer. If BVDV is known to be

• Of a suitable frame size to carry to term and to

a problem on a farm then screening of the recipients prior

calve naturally an embryo calf of the breed to be *to vaccination may be desirable to identify and remove*

transferred;

any persistently infected animals. When leptospirosis is a

• Body condition score 2–21/

known problem on a farm then treatment of the recipients

2; (assessed over the

range 1–5; Lowman et al., 1976; see also Chapter 2);

with 25 mg/kg of dihydrostreptomycin (British Cattle

• Displaying regular oestrous cycles.

Veterinary Association (BCVA), 1992) at the time of first

vaccination may be required to reduce the infective load

Recipient cows should be:

of this bacterium. As the epidemiology of Neospora

• No more than a fourth calver;

caninum becomes better understood (see Chapters 19,

• Of a good breeding history;

37) it may be prudent to screen potential recipients for

• At least six weeks calved;

this agent, especially if vertical transmission of this proto-

• Clean and returned to regular oestrous cycles post

zoan from recipient to fetus could affect the reproductive *calving;*

performance of any resulting ET heifers.

• *Maintaining or increasing liveweight;*

• *Body condition score 21/2–3;*

Oestrous synchronization

• *Of a suitable frame size to carry to term and to*

(see also Chapter 42)

calve naturally an embryo calf of the breed to be

transferred.

For successful pregnancy to be achieved the recipients

need to be tightly synchronized to come into oestrus one

week before the embryo is transferred. Therefore a tight

Nutrition and management

synchrony period is required. A good method is to use a

It is important that recipients are on a rising plane of

progesterone releasing intravaginal device or progestage

nutrition for six to eight weeks before transfer and that

implant in combination with a prostaglandin injection.

this continues for at least another six weeks post trans-

The device chosen can be inserted for 9, 10 or 11 days and

fer. This is of particular relevance around the time of

the prostaglandin injection given 24, 48 or 72 hours
housing and turn-out and ideally these two events
before removal. This gives a tight synchrony with the
should not occur in the middle of a programme but
peak of activity 28–56 hours after device removal. In the
should be completed either two months before the
author's opinion a double prostaglandin injection proto-
transfer date or delayed until at least six weeks post
col will not provide a tight enough synchrony to maxi-
transfer. The ration should be checked to confirm that
mize recipient usage. The stockperson should observe
it is providing an acceptable balance of energy and
recipients for oestrus the week before transfer. Observa-
protein with sufficient levels of roughage. As with the
tion should be performed at least three times a day for a
donors, a suitable supply of minerals is important. If
minimum duration of 20 minutes per observation period.
molybdenum toxicity is likely to be a problem then a
Observations should occur for the three days following
suitable supply of protective copper should be made
the day the synchrony devices are removed.

available (e.g. intraruminal boluses) (see pp. 254, 298).

Purchasing recipients, mixing groups and routine

Transferring the embryo

procedures, such as worming, bolussing, vaccination,

freeze-branding and foot-trimming, should all be com-

Having checked for the presence of a CL, and recorded

pleted at least six to eight weeks before the transfer

which ovary it is on, the recipient is prepared for the

date to minimize stress.

embryo transfer. Cleanliness of the epidural site and

the perineum is important and cotton wool swabs

dampened with surgical spirit are ideal for this. After

Disease control

traversing the cervix the transfer gun is guided along

A number of infective agents can severely affect the

the uterine horn ipsilateral to the corpus luteum. Preg-

success of an ET programme. The principal culprits are

nancies can be achieved if the embryo is placed at the

bovine viral diarrhoea virus (BVDV), leptospirosis and

level of the ICL, but results improve if the site of trans-

infectious bovine rhinotracheitis (IBR). Vaccination is *fer is further up the horn. Ideally a position of 10 cm or*

possible for all three agents but there is a risk of persist-

more past the ICL is desirable. It is important to be as

gentle as possible and avoid manoeuvres which result

suppression was transient. Thus if the GnRH analogue is

in endometrial damage. Sometimes in fatter animals

given too soon the luteolytic mechanism may have time

with large dependent tracts it is necessary to accept that

to recover, resulting in a temporary benefit, but with

the site of placement is not ideal in preference to over-

some pregnancies being lost at a later date.

handling the tract, resulting in inflammation or physical

These observations indicate that although hormonal

injury to the endometrium.

supplementation has a tendency to improve pregnancy

rates, the concept of a blanket treatment for groups of

cattle needs to be considered carefully as inappropriate

Hormone supplementation

or mistimed treatments may at best have no benefit but

Exogenous hormonal supplementation has taken three *at worst could be detrimental to pregnancy results.*

main forms in an effort to provide support to the preg-

nancy. Firstly, exogenous progesterone or progestagen

has been used. Progesterone injections have improved

Record keeping

pregnancy rates in asynchronous recipients. However,

the use of progesterone releasing intravaginal devices

Box 40.4 lists the important records that should be kept

produced non-significant negative effects on pregnancy

for donors, recipients and embryos. Legislation requires

rates when these devices were in situ from day 7 to 19

that records are maintained for 12 months.

and had direct deleterious effects on embryo develop-

ment when two devices (double dose) were used from

day 7 to day 21. The use of exogenous progestagen

Legislation

treatments (Norgestomet), inserted on day 7, increased

pregnancy rates (57.3 per cent control vs 67.8 per cent

Trade in embryos between member states of the Euro-

treated). Norgestomet treatment in acyclic cows did

pean Union (EU) and importation of embryos from *support pregnancies, but by day 38 of pregnancy in*

approved third countries, including the associated col-

cyclic animals there were no significant differences

lection, processing, production and storage, is governed

between treated and control groups. It has been

observed that too much exogenous progesterone can

Box 40.4

List of necessary records to be maintained by

depress the secretion of LH and result in a reduction in

licensed ET teams for 12 months after collection/production

luteal mass. This depresses the luteotrophic support

of an embryo. Source: Ministry of Agriculture, Fisheries and

of the endogenous CL, leaving it unable to produce

Food (1995).

sufficient progesterone for continued support of the

pregnancy when the devices are removed. The conclu-

Donor

sion is that only discrete (as yet unidentifiable) cate-

Breed, pedigree name, ID no., herdbook no. and date of birth

Superovulation drug, dosage regime, dose, batch no.

gories of animal may benefit from this treatment and

Date of collection, place of collection

careful consideration will need to be given to the

Superovulatory response, number and category of embryos

dosage levels and timing of progesterone supplementa-

recovered, number and grades of viable embryos

tion before applying it as a blanket treatment.

Details of processing procedures for embryos (including

The second form of hormonal supplementation

freezing, transfer, micromanipulation and in-vitro fertiliza-has been the administration of human chorionic

tion and culture as appropriate)

gonadotrophin (hCG) given at various times and for

Recipient

varying durations. Christie et al. (1979) used multiple Breed, age and ID no. of recipient

injections between days 13 and 35 of pregnancy,

Date and place of transfer

whereas others used a single injection given on either

Identification of embryo transferred and its source (if known) the day of transfer, day 14 or day 15. All showed a non-Storage

significant improvement in pregnancy rates in the

Identification of every embryo stored

treated animals over controls.

Date of entry/departure of every embryo

The third method of supplementation has been the use

Place of origin of embryo prior to arrival

of a GnRH analogue (buserelin) given between days 11

Destination of embryo on departure

and 13. This has been shown to increase pregnancy rates

significantly (MacMillan et al., 1986). In cyclic cows IVF storage

In addition to above:

treated with buserelin on days 11 and 13 of the cycle the

IVF embryos can be identified on a batch basis

plasma oestradiol concentrations were significantly

Must contain details of the date and place of collection of

reduced, suggesting that the mode of action is to reduce

the ovaries/oocytes

the strength of the luteolytic mechanisms, so improving

Must identify the herd of origin of donor animals

the embryo's chance of inhibiting luteolysis;however,the

Box 40.5

Troubleshooting: in the event of poor superovulatory responses or embryo *recovery.*

Problem

Issues to consider

Solution options

No reference heat

Poor heat detection

Abandon programme and restart

Poor behavioural signs

Provide artificial CL through exogenous

progesterone supplementation

Poor synchrony

Re-attempt

Poor superovulatory response

Nutrition

Check ration and adjust nutrition

Mineral status

Check mineral status and adjust supplementation

Type of FSH

Try alternative type of FSH

Drug dose/regime

Increase drug dose or alter regime

Unfertilized ova

Semen quality

Check bull history/try different sire

Insemination technique

Check technique

Semen handling/thawing

Check technique

Donor/bull interaction

Try different sire

Insemination timing

Add additional AI session and extra straws

Poor ovum quality

Check nutrition/mineral status/body condition loss

Overstimulation

Reduce FSH dose

Defective uterine environment

Infection – antibiotic therapy and/or return to oestrus

Hormonal – difficult to identify/resolve

Superovulation drug

Try alternative product

Poor recovery

Catheter position

Check technique

(normal breeding history)

Leakage past cuff

Check cuff inflation/integrity of cuff

Inadequate flow

Raise tip of uterine horn higher than cuff position

If above fails reposition catheter

(Note: risk of embryo loss in this procedure)

Luteinized follicles

Poor recovery

As above plus

('problem breeder' history)

Blocked oviducts

Defective gamete transport

Ovarian/bursal adhesions

by EU Council Directive 89/556 of 25 September 1989,

should be considered in assessing poor results in super-

amended as appropriate by the relevant Council Direc-

ovulation of donor cows or pregnancy rates in embryo

tives and Commission Decisions. Within most member *recipients.*

states this European legislation is supported by domes-

tic legislation.

In the UK the statutory instrument is the Bovine

Advanced technologies

Embryo (Collection, Production and Transfer) Regula-

tions 1995. This covers the licensing of ET teams and

Embryo splitting

premises, legislation relating to disease control

This technology was promoted in the early 1990s as a

and welfare and also record keeping. The above EU

commercial application. Its appeal was that it could give

and UK legislation along with the Manual of the Inter-

proportionately more pregnancies from a collection

national Embryo Transfer Society (a procedural guide

of embryos than could be achieved by simply transfer-

and general information for the use of embryo transfer

ring the embryos whole. It involved bisecting the

technology emphasizing sanitary procedures) are

embryo with a microblade or a specially designed glass

essential reading for anyone planning to become *microneedle. These instruments were operated via a*

involved in practical embryo transfer.

micromanipulator which converts gross movements by

the operator at the controls to very fine micromove-

Troubleshooting

ments at the level of the embryo. One disadvantage

is that this is a relatively expensive piece of equip-

Embryo collection results will vary between donors and

ment. Inevitably the production of these demi-embryos

pregnancy results can fluctuate between batches of

resulted in some blastomere damage of the embryo so

recipients. Boxes 40.5 and 40.6 summarize factors that

that split embryos tended to have lower pregnancy rates

Box 40.6

Troubleshooting: in the event of poor pregnancy rates.

Recipients

Check:

Nutrition

Mineral status

Body condition gain/loss

Health

Risk of disease challenge

Vaccination status

Management

Check:

Correct completion of synchrony programme

Heat detection

Recipient handling/stress

Embryos

Check:

Grades used

Freezing protocol

Thawing protocol

Quality control of procedures at each step

Miscellaneous

Consider donor effects:

- *oocyte quality*
- *donor/bull interaction (genetic effect)*
- *donor uterine environment*
- *a percentage of donors are consistently poor candidates*

Consider operator technique/experience *than contemporary whole embryos (split embryos 57*

able variation between laboratories, but the incidence

per cent versus whole embryos 65 per cent). Even

in some cases was up to 20 per cent. The syndrome man-

though an increased number of calves could be pro-

ifested itself as giving large calves at birth (up to 75 kg)

duced (an increase of the order of 13 per cent) the tech-

with increased birthweights greater than could be

nique was never really accepted commercially by either

accounted for by extended gestation length alone. This

the ET operators or the cattle breeders.

was associated with an increased incidence of dysto-

cia and a higher mortality rate. Another feature was

enlarged placentae in some of these pregnancies, on

In-vitro fertilization (IVF)

occasion with a mean weight 25 per cent greater than

This technology involves the creation of embryos in the

those of untreated contemporaries. Additionally, in

laboratory. A source of immature oocytes is required.

some cases, there were congenital malformations and

These can be harvested from ovaries removed from a

problems with altered allometric coefficients for the
slaughtered animal as long as the ovaries are submitted
liver, kidney and heart which eventually left these
to the laboratory within four to six hours. Alternatively
calves unable to survive. Interestingly, despite differ-
oocytes can be collected from the live animal by ultra-
ences in birthweight, the mean liveweight at one year
sound-guided ovum pick-up (see later). The immature
for these animals can be similar to controls. The effects
oocytes must first be matured, which takes approxi-
on the pregnancies did vary depending on the labora-
mately 18 hours. After this fertilization takes place
tories from which the embryos came. Therefore it
by mixing capacitated sperm with the embryo. Follow-
was deduced that a factor in the maturation or culture
ing fertilization the embryos are cultured to a stage
method was significant. The resultant worldwide
of development equivalent to day 7 in-vivo embryos,
research effort is helping to elucidate the mechanisms
when they can then be transferred fresh or frozen. Preg-
involved. To date, one widely observed finding is that

nancy results with IVF embryos tend to be lower

the use of synthetic oviduct fluid (SOF) in the system

than from those originated in vivo (IVF 40–50 per cent as opposed to serum reduces, or eliminates, the inci-versus in vivo 50–60 per cent). Another potential

dence of large calves.

problem linked to IVF is that of the 'large calf syn-

drome'. Although it can also be associated with asyn-

Ovum pick-up (OPU)

chronous timing of embryo transfer and progesterone

supplementation early in the oestrous cycle of the dam,

This is the technique that allows the collection of

it was documented in the early 1990s as being associ-

oocytes for IVF from the ovaries of live donor animals.

ated with IVF calves. The results of various IVF labo-

It utilizes an ultrasound-guided transvaginal needle.

ratories worldwide showed that a significant number of

The operator places one hand in the rectum to allow

ET pregnancies could be affected. There was consider-

manual manipulation of the ovaries. The ultrasound

probe is placed in the vagina so that the ovary can be *cytometer/cell sorter utilizing a laser can then sort the*

visualized with only the vaginal wall between the ovary

sperm on the basis of their DNA content (Cran

and the head of the probe. Usually a 7.5 MHz curvilin-

et al., 1993). At present the technique is 90 per cent accu-ear probe is used. On visualization of a follicle on the

rate, but only small quantities of sperm can be processed

ovary a 60 cm needle (18–21 gauge) is passed down a

at a time and the resulting sexed semen is more success-

special channel in the probe. It punctures the vaginal

ful in fertilizing ova if used for deep uterine AI (Seidel et wall and enters the follicle on the ovary. A dotted line

al., 1998). New freezing protocol advances for sexed

on the scanner screen indicates the line down which the

semen may obviate the need for deep uterine AI.

needle will transect the ovary, allowing the operator to

line up the follicle with the intended path of the needle.

Cloning

At the point of entry the operator uses a foot-pedal to

apply a vacuum pressure to the collection line attached

Cloning results in the production of genetically identi-

to the needle. Too high a pressure results in stripping *cal offspring. The simplest form of cloning is twinning*

of the cumulus cells from the oocyte and these de-

(bisecting an embryo). Further advances in the tech-

nuded oocytes are less developmentally competent. On

nology resulted in the technique of nuclear transplan-

average, ten oocytes can be collected from both ovaries

tation. This involves several procedures including

per session and it is possible to perform a collection

enucleation of ova and the electrofusion of blastomeres

session weekly or twice weekly (van der Schans et al., from donor embryos. In essence, unfertilized ova are

1991). This usually translates, after developmental

used as recipients for new genetic material. The new

losses and fertilization failures, to two transferable

genetic material is supplied, in the case of embryos,

embryos per collection session. On average, 70–80

from a donor embryo which is between the 16 and 64

per cent of oocytes recovered are suitable for further

cell stage (32 blastomere stage at approximately day 5).

processing. Of these, 70 per cent will be successfully

These blastomeres are disassociated and an individual *fertilized and start to cleave and ultimately 40 per cent*

blastomere (genetically identical to the other 31 blas-

of the cleaved embryos will blastulate to become trans-

tomeres) is introduced into the enucleated recipient

ferable embryos. With an average pregnancy rate of 50

ovum. This new blastomere nucleus is then electrofused

per cent this means that approximately one pregnancy

to the recipient ovum's cytoplasm and the resultant

will result from each OPU session.

embryo is cultured to day 7 prior to transfer to a recip-

ient animal. Alternatively, at day 5 the whole procedure

can be repeated using blastomeres from the cloned

embryo to create another generation. There are reports

Embryo sexing

of this recloning process being used to produce second

Many methods have been tried over the years to find a

and third generation embryos. The difference between

simple, easy-to-use way of sexing embryos. The most

this procedure and that used to produce the late Dolly

widely used technique in the UK was developed in

the sheep is that, for Dolly, the donated nuclear mate-

Finland (Bredbacka et al., 1995). It involves taking a rial was recovered from an adult somatic cell which was

biopsy of a few cells from the embryo and lysing them

then 'reprogrammed' to be capable of differentiation

to release the DNA content. This DNA material is then

and subsequent organogenesis.

mixed with enzymes and multiplied using a polymerase

Currently, however, these procedures are too ineffi-

chain reaction (PCR). A stain is included in the solu-

cient for commercial production of large numbers of

tions which binds to the Y chromosomes, making them

cloned animals and are only justified for biomedical

fluoresce under UV light. On completion of the PCR

applications. This has resulted in some commercial

cycle the tubes containing the biopsies from male

companies utilizing the technology to produce cloned

embryos are identified by this fluorescence. Non-fluo-

animals for production of specific proteins for biomed-

rescing samples are deemed to be female. This tech-

ical purposes.

nique is 95 per cent successful in identifying females *and 100 per cent in identifying males. The discrepancy*

is due to errors when biopsies are not placed correctly

Acknowledgement

in the sample tubes.

New technology allows the production of correctly

The author would like to thank all who assisted with

sexed embryos through the use of sexed semen. X chro-

research for this chapter and particularly David McNee

mosomes contain more DNA than Y chromosomes. The

for the illustrations, George Seidel Jnr and Richard

semen is mixed with a stain which is taken up by DNA

Bowen of Colorado State University for the pictures

and fluoresces in a laser beam. X chromosomes with

and Seonaid Grimmer, Mike Kerby and Arthur

higher DNA content will fluoresce more brightly. A flow

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Chapter 41

Herd Fertility Management

(a) Beef herds

input and low output enterprises. In the UK, consumer

concerns about food safety and the BSE crisis mean

S. Borsberry

that cull cows are of relatively low value and so the

main income derives from the progeny, from either sale

as store or finished cattle (see Chapter 3). Calving inter-

Introduction

652

val is thus one of the most important measures of repro-

Determinants of reproductive performance

652

ductive performance. One of the main effects on

Factors affecting reproductive performance

654

reproductive performance in beef cows is the adverse

Infectious disease

654

effect of marginal nutrition. Inefficient suckler herds

Nutritional management

655

are unlikely to survive in the present economic climate

Controlling the length of the calving season

656

and, in Britain, marketing of progeny may become

Feeding policy

656

increasingly difficult following the 2001 foot-and-mouth

Culling policy

656

Post partum onset of ovarian cycles

656

disease (FMD) outbreak. There is likely to be increased

Factors affecting the post partum acyclic period

656

legislation concerning the movement of FMD suscepti-

Suckling

656

ble stock which may well affect public auction at live-

Nutrition, body weight and condition and the

stock markets, thereby reducing the potential number *post partum period*

657

of outlets for farm animals.

Season

657

In some beef herds cows and bulls are together all

Induction of ovulation in beef cows

657

the year round and there is little attempt to control

Gonadotrophin-releasing hormone

658

fertility or the season of calving. In better-managed

Oestrus synchronization and AI in beef cattle

658

herds a seasonal calving pattern is adopted and the

Methods

659

calving pattern itself becomes an important assessment

Management of heifers

661

of reproductive performance. An excellent review of *suckler cow management in the UK has been published*

(Lowman, 1988) and this paper is recommended if the

reader requires further detail after reading this chapter.

Introduction

Beef cattle fertility must be considered as a separate

Determinants of reproductive

entity from dairy cattle as they are managed under

performance

entirely different circumstances. Usually they are

managed as a herd or group and so do not receive the

In the UK, beef cows traditionally calve either in spring

same individual attention as do dairy cows. In general,

or autumn. The trend in gross margins has decreased

clinical infertility problems do not appear to occur to

over recent years (1995 to 1999); although there has

the same extent. However, with the dairy herd supply-

been a marginal increase in stocking rate, sale price has *ing fewer cross-bred female replacements and the ever*

reduced significantly (see Table 41.2).

increasing importance of biosecurity, many herds are

Autumn-calving herds tend to produce higher gross

breeding their own replacements. This results in a need

margins than spring-calving herds under UK conditions

for careful planning of breeding in order not to lose

(see Table 41.3). Spring-calving herds tend to be

fertility and longevity that is achieved with heterosis

stocked more heavily, but there is greater financial

(Table 41.1).

output from autumn-calving herds.

Veterinary involvement in most commercial suckler

The calf is essentially the sole product of the beef

herds is often limited, as these herds are run as low

herd, therefore the rate of calf production (calves born

Table 41.1

Traits affected by hybrid vigour (Reproduced with

Table 41.3

Gross margins and performance for upland

permission from Meat and Livestock Commission, 2000).

sucklers (1999) (Reproduced with permission from Meat and

Livestock Commission, 2000).

Trait

Predicted hybrid

vigour effect

Spring Autumn

calving

calving

Conformation

Skeletal size

0–5%

Low

}

Number of herds

43

43

Mature weight

Gross margin (£)

Per cow

208

227

Growth rate

Per hectare

355

404

Weaning weight

5–10%

Medium

}

Calf age at sale (days)

212

314

Milk production

Calf weight at sale (kg)

268

335

Fertility

Stocking rate (cows/ha)

1.7

1.5

Health

10–30%

High

}

Longevity

Table 41.4

Performance of upland suckler herds (1999)

(Reproduced with permission from Meat and Livestock Com-

mission, 2000).

Table 41.2

Trends in gross margin results for upland suckler

herds, 1995–99 (Reproduced with permission from Meat and

Bottom Top

Livestock Commission, 2000).

third

third

Sale price

Stocking rate

Gross margin

Gross margin (£)

(p/kg lw)

(cows/ha)

Per cow

151

278

(£/head)

(£/ha)

Per hectare

253

493

Cow performance (per 100 mated)

1995

124

1.4

313

438

Calving period (weeks)a

12

10

1996

112

1.5

295

445

Number barren

6

6

1997

107

1.7

308

505

Calves born alive

91

92

1998

87

1.5

214

316

Calf mortality

3

2

1999

95

1.5

217

380

Calves purchased

1

2

Calves reared

89

92

lw, liveweight.

Calf performance

Age at sale/transfer (days)

238

287

Weight at sale/transfer (kg)

276

329

Daily gain (kg)

alive and reared) is even more critical than it is in the

Male

1.0

1.1

dairy herd. In order to illustrate this a comparison

Female

0.9

1.0

between the worst and best performing (in terms of

Stocking rate (cows/ha)

1.5

1.6

gross margin/cow) suckler herds recorded by the Meat

and Livestock Commission (MLC) (2000) is shown in

a For 90 per cent of calvings.

Table 41.4. The most important factors causing the

differences were

Also, the gestation period and hence the calving

(1)

The number of calves reared/100 cows and

interval can be influenced, to a limited extent, by the

(2)

The calf weight at sale/transfer.

breed of sire.

Put more simply, the most successful herds sold more

When breeding replacements for the suckler herd,

heavier calves than the worst.

two aspects must be considered: mature body size and

Calf weight and age at sale/transfer are reflections of

breed composition. Mature body size must be matched

health and growth rate; obviously, calf weight is further

by feed resources. The larger the cow, the more difficult

dependent, to a major extent, on the breed of the sire

it is to maintain good body condition and this will

and breeding programme used. The heavier breeds

reduce fertility. In order to maximize hybrid vigour the

such as Charolais and Simmental produce calves with

cross breeding system can be worth up to 23 per cent

a high weight. However, this has to be balanced

more weight of weaned calf per cow put to the bull

against a higher risk of dystokia and possible calf

(Meat and Livestock Commission, 2000).

mortality (see Table 41.5), but it must be remembered

An important index of reproductive performance in

that there is considerable variation within a breed.

the suckler herd is the length of calving season. A 365-

Table 41.5

Pure bred results (Reproduced with permission from Meat and Livestock Commission, 2000).

Birth

200 day

400 day

Easy

weight

average

average

calvings

average

(kg)

(kg)

(%)

(kg)

M

F

M

F

M

F

M

F

Aberdeen Angus

37

35

267

238

516

398

92

95

Blonde Aquitaine

41

39

274

238

548

421

80

88

Belgian Blue

45

41

269

245

494

404

17

32

Charolais

44

41

325

281

652

466

70

80

Hereford

41

39

248

223

447

362

87

92

Limousin

39

36

274

242

545

405

89

94

South Devon

46

42

271

245

499

389

73

86

Simmental

42

38

321

278

628

449

81

89

Sussex

39

36

232

214

411

331

94

94

Welsh Black

38

36

227

215

376

329

81

89

M = male, F = Female.

Table 41.6

Theoretical relationship between conception rate and the calving period in a 100 cow herd (adapted from ICI computer simulation by Allen & Kilkenny, 1980).

Herd conception

Service period for

Length of

No. of cows

rate (%)

90% of cows to be

calving period

calving in

pregnant (days)

(days)

first month

30

245

260

12

40

140

155

28

50

100

110

41

60

70

85

54

day calving interval is optimal, but a compact calving

theoretical relationship between the conception rate,

season is also desirable because:

the service period and the calving period was calculated

by ICI and is shown in Table 41.6.

• More cows calve early in the period, therefore the

age and weight of calves are higher at the time of

weaning and sale.

• The impact of calf disease and mortality may be

Factors affecting reproductive

reduced if there is little variation in calf ages.

performance

• Cows are all at a similar stage in the production

cycle, therefore feed can be rationed more precisely

Infectious disease

and the cows managed more conveniently.

In some cases of low herd reproductive performance

• When cattle are sold they can be batched to

there may be an underlying infectious disease.

produce groups of similar size, weight and

Although the UK is officially brucellosis-free there is

condition.

always the potential for its re-introduction; indeed, this

The calving season is almost directly dependent on the

has happened. Following the use of artificial insemina-

pregnancy rate to service and the length of the breed-

tion (AI), campylobacteriosis and Tritrichomonas fetus

ing or service period. Obviously, the higher the preg-

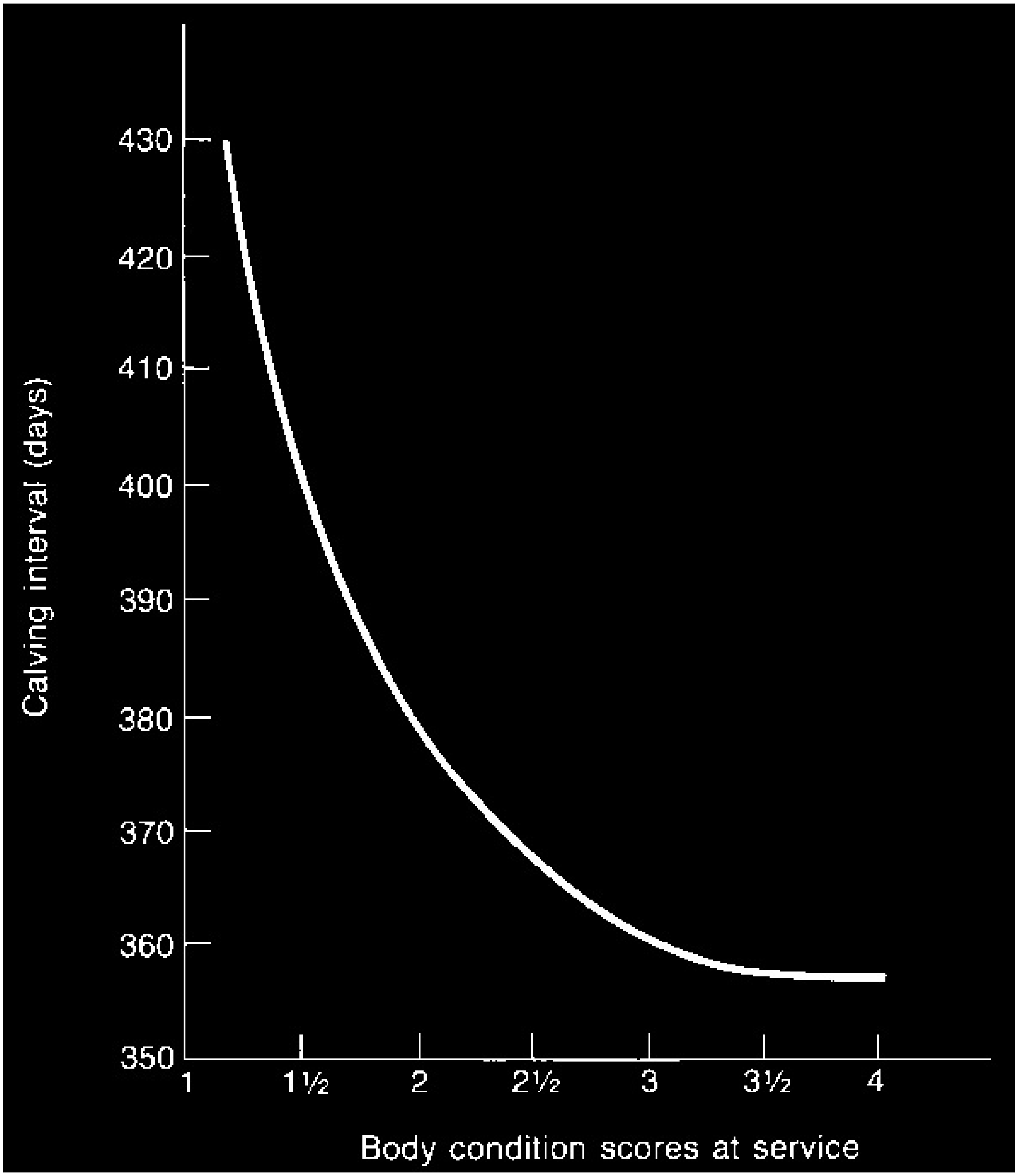
have almost been eliminated, but Campylobacter may

nancy rate, the shorter the service period required to

be a problem in some suckler herds where a bull is used

ensure pregnancy of all or the majority of the cows. A

(Caldow & Taylor, 1997). Additionally, some viral dis-



Herd Fertility Management • 655

Table 41.7(a)

Recommended target body condition scores of

Table 41.7(b)

Relationship between body condition and repro-

beef cows at various stages of the reproductive cycle (Lowman, ductive performance (Kilkenny, 1978).

1988).

Herd average

Calving interval

Calves weaned per

Calving

Mating

Weaning

mating scores

(days)

100 cows bulled

Autumn-calving

3.0

2.5

2.5

1–2

418

78

suckler cows

2

382

85

Spring-calving

2.5

2.0

3.0

2–3

364

95

suckler cows

3+

358

93

eases may result in poor reproductive performance, for example bovine herpes I (BHVI) infection (see pp. 289, 579) and bovine viral diarrhoea (BVD) (see pp. 578, 853).

Obviously, it is essential to rectify any infectious problem before attempting to improve herd reproductive performance by other means.

Nutritional management

Nutritional status is of major importance in the maintenance of a high rate of reproductive performance. The nutrition of cattle is covered more comprehensively in specialized texts and only the basic principles are described here.

Whilst specific deficiencies of micronutrients are common under particular circumstances and can affect fertility, under normal conditions dietary energy appears to be the main factor limiting reproductive performance. However, other nutritional deficiencies occur but are usually confined to localities or even individual herds. These include problems with manganese, selenium and cobalt (see Chapter 18) and some vitamins,

Fig. 41.1

The relationship between calving interval and body

particularly A and E. For a fuller account of this

condition score at service in beef cows (Kilkenny, 1978).

problem the reader is referred to Chapters 9 and 21.

The technique of body condition scoring has been developed as a simple semi-objective monitor of cows' *energy status. The principle depends on the manual*

operator can assess the body condition of cows to

palpation of the thickness of subcutaneous fat cover on

within one half-unit. Optimum body condition scores

various parts of the body (see p. 10).

for beef cows have been worked out for the various

Methods have been developed for both dairy

stages of the reproductive cycle and these are shown in

(Mulvaney, 1978) and beef cows (Lowman et al., 1976)

Table 41.7a. The target body condition score at service

and although the finer details vary slightly the overall

is the most critical as this is very closely related to

principle is the same. The thickness of fat cover over

overall reproductive performance. The calving interval

the lumbar and tailhead area is estimated and assigned

has been shown to be negatively correlated with body

a score, usually from 0 (emaciated) to 5 (very fat),

condition at the time of mating in beef cows, although

although different scales are sometimes used. Descrip-

the true relationship is probably curvilinear (see Fig.

tions of the various categories on the 0–5 scale are given

41.1) and affects the number of calves weaned (Table

on p. 10.

41.7b). This target score is also most difficult to achieve

An additional guide to body condition can be

in autumn-calving cows as they are mated during mid-

obtained by palpating over the hip bones, ribs and

winter when they are lactating and when good quality

either side of the tailhead. With a little experience an

feed is expensive. In a survey, approximately half of the

Table 41.8

Financial effects of a high culling rate (after Allen & Kilkenny, 1980).

Normal

High culling rate

culling

policy

Year 1

Year 2

Year 3

No. of cows

90

78

86

88

No. of replacements

13

36

20

16

Calving spread (days)

150

100

100

100

Average calf sale

Weight (kg)

285

285

305

315

Gross margin/ha (£)

219

174

233

257

autumn-calving beef cows failed to reach the target

necessitate the achievement of calving intervals in late-

condition score at mating (Kilkenny, 1978). In contrast,

calving cows of well below 365 days. However, it is

the nutritional drain of lactation is offset in spring

important to remember that proper nutritional man-

calvers by the plentiful supply of grazing.

agement is vital for the maintenance of a compact

Cows should be fed to calve at a condition score of

seasonal calving pattern.

2.5–3 and should lose minimum condition until con-

ception (see Table 41.7a). Cows calving in fatter condi-

Culling policy

tion may have calving difficulties, which in turn may

lead to delayed involution, reproductive tract damage,

This is the most extreme but probably the most effec-

susceptibility to infection of the tract or a combination

tive method of modifying a herd's calving pattern. As

of these problems. Also, cows with a score of 4 or more
discussed above, the length of the calving period is
are likely to mobilize their fat reserves excessively
highly dependent on the herd pregnancy rate. For
during the early postpartum period.
example, a five-month calving period is approximately
Beef cows calving in a low condition are also likely
equivalent to a pregnancy rate of 40 per cent. In this
to undergo a prolonged period before the re-
situation approximately 70 per cent of cows will calve
establishment of ovarian cycles, undernutrition being
in the first two months and 30 per cent in the next three
one of the major causes of failure to ovulate after
months. Therefore, the 30 per cent late calvers should
calving. Consequently, pregnancy is likely to be consid-
be culled and replaced. Many producers are reluctant
erably delayed in such cows.
to adopt such a high culling rate due to the high cost of
As pregnancy progresses the lactational demand for
purchasing or rearing replacement heifers, particularly
a high level of dietary energy decreases. This enables

during the first year or so. However, such a policy can

the cow to replace body energy reserves that were lost

be of eventual financial advantage due to a decrease in

during early lactation. Thus the cow can be brought

the spread of calving and the consequent management

back towards the target body condition for the next

economics as discussed above (see Table 41.8).

calving and subsequent mating.

Post partum onset of ovarian cycles

Controlling the length of the

A delay in the onset of ovarian cycles can lead to

calving season

extended calving intervals and possibly increased vari-

ation in calving intervals between cows within a herd.

There are a number of ways in which a compact sea-

This will result in increases in the length of the calving

sonal calving pattern may be established and main-

season.

tained in a healthy seasonally calving beef herd. These

include feeding policy, culling policy and postpartum

induction of ovulation.

Factors affecting the post partum

acyclic period

Feeding policy

Suckling

It is very difficult to restore compact seasonal calving

patterns by nutritional management in herds that have

Many studies have shown that the onset of ovulation

a grossly extended calving season, since this would

and/or oestrous behaviour is delayed in either dairy or

beef-type cows that suckle calves, relative to milked

suggested that photoperiod might play some role in

animals, particularly where more than one calf is

seasonality of reproductive activity in the cow and a

suckled per cow. In suckling beef cows kept under UK

negative correlation between daily photoperiod during

conditions the average time to resumption of ovarian

pregnancy and the onset of ovarian cycles after calving

cycles has been reported as 59.9 ± 2.5 days after calving

has been demonstrated (Peters & Riley, 1982b). It is

(Peters & Riley, 1982a), but there was considerable

possible that a vestigial sensitivity to photoperiod may

variation both within and between herds. Weaning of

be present in the domestic cow and that in feral cattle

calves, either temporary or permanent, or at least the

this pattern would predispose towards calving during

prevention of suckling has been reported to shorten the

the late spring to early summer, the optimal time for

acyclic period.

food supply.

In summary, a variety of factors affect the onset of

ovarian cycle in the post partum beef cow. The order of

Nutrition, body weight and condition

importance is probably nutrition, suckling and season.

and the post partum period

However, it is normally impossible in the practical

Long post partum acyclic periods in suckling cows may

situation to quantify these effects so that the time to

be reduced by the provision of increased dietary energy

first ovulation can be predicted.

(e.g. Dunn et al., 1969). Energy intake appears to be more critical than protein intake in the maintenance of

Induction of ovulation in beef cows

reproductive function as positive relationships between

energy intake and reproductive performance have been

Most evidence to date suggests that delay in ovulation

demonstrated in several studies. Low energy intake in

during the postpartum period is mediated by a low rate

prepartum and post partum cows increases the length

of gonadotrophin release; most work has been done on

of the anoestrous period and in heifers it has been

luteinizing hormone (LH), but follicle stimulating

shown to result in fewer ovarian follicles, lower pro-

hormone (FSH) is probably equally important. Such

gesterone levels and lower conception rates (Hill et al., endocrine changes occur as a result of external factors

1970).

(some discussed above) acting via the hypothalamus

Nutritional status at and before calving appears to be

to suppress the release of gonadotrophin-releasing

more important than that during the post partum

hormone (GnRH).

period, since Peters and Riley (1982a), using body

A reliable hormonal method of inducing ovulation in

weight as an index of nutritional status, found a sig-

acyclic cows would obviously be advantageous but it is

nificant negative correlation between body weight at

probably true to say that an ideal treatment has not yet

calving and the length of the acyclic period in beef cows,

been devised.

whilst body weight change after calving had no effect.

Gonadotrophins of non-bovine origin in the form of

Also, an increase in energy supply to pregnant beef

either pregnant mare's serum gonadotrophin (PMSG)

cows has been shown to accelerate the return of ovarian

and human chorionic gonadotrophin (hCG) have been

cycles after calving. Target body condition scores are

extensively used for this purpose in the past but results

given in Table 41.7a.

have been variable; hCG has largely LH-like activity

whereas PMSG has mainly FSH-like activity and may

result in the development of multiple follicles.

Season

However, Penny (1998) suggests a dosage of PMSG

In the temperate latitudes seasonal variations in con-

which in one study did not produce multiple ovulations

ception rates and a longer interval between parturition

(see Table 41.9).

and first oestrus in the winter and early spring have

The injection of oestrogens in cows results in pre-

been reported (e.g. Thibault et al., 1966). Furthermore, ovulation surges of gonadotrophin release (depending

spring-calving beef and dairy cows have been reported

on dosage) and oestrous behaviour. However, ovula-

to undergo longer periods between calving and first

tion may or may not follow such treatment. The

ovulation than autumn calvers (Bulman & Lamming,

response is generally too unpredictable for this to be a

1978; Peters & Riley, 1982a). Most authors have sug-

useful method of inducing ovulation.

gested that such seasonal effects are related purely to

Progestagens have been used extensively to synchro-

nutritional management; however, strong effects of

nize ovulation in cyclic cows, but may also be used

season have been demonstrated after adjusting statisti-

to induce ovulation after calving. Roche et al. (1981) cally for the effects of body weight at calving (Peters &

reported that 10-day treatment of beef cows with the

Riley, 1982b). Evidence for seasonality in cattle has

progesterone-releasing intravaginal device (PRID)

now been accumulated from Europe, North America,

resulted in ovulation in about half the cows treated,

Canada and New Zealand. Thibault et al. (1966) have

whereas Bulman and Lamming (1978) reported a 75

Table 41.9

Dose of PMSG at implant removal (Penny, 1998). Reproduced with permission of The British Cattle Veterinary Association.

Type of animal	***Conditions***	***Dose of PMSG at progesterone withdrawal***
Beef suckler cow	*Calved <55 days*	*400 iu*
	Calved >55 days	

Poor body condition score

(<2) 400 iu

Good body condition

score (>2) 250 iu

Beef heifer

None required under

normal conditions

PMSG, pregnant mare's serum gonadotrophin.

per cent success rate with a 12-day PRID treatment in

this treatment regime has been particularly successful

dairy cows. However, in the latter study the conception

in large-scale field trials with beef cattle (Mawhinney

rate in the responding cows was only 50 per cent and

et al., 1979). A short-lived rise in progesterone concen-treatment did not affect the mean calving-to-

trations following GnRH injection has been reported

conception interval. Other workers (Ball, 1982; Drew et

by several authors and may be compared to that occur-

al., 1982) have reported a reduction in the calving-toring naturally in some cows prior to the onset of normal

conception interval of up to 14 days following the use

ovarian cycles. There has also been interest in longer-

of PRID; however, the calving-to-conception interval of

acting administration of GnRH, but no product is yet

PRID treated beef cows was reduced only if used

commercially available.

before day 30 after calving (Peters, 1982).

Mulvehill and Sreenan (1977) have reported the best

success in induction of ovulation in beef cows by inject-

ing 750 iu PMSG at the time of progesterone with-

Oestrous synchronization and AI in

drawal. However, as a small number of twin and triple

***beef cattle** (see also p. 678)*

ovulations did occur, Penny (1998) suggests a lower

dose and a maximum of 400 iu (Table 41.9).

The full exploitation of genetic progress cannot be

made in beef cattle without the use of AI. AI is not very

widely used in beef cattle, but as oestrus synchroniza-

Gonadotrophin-releasing hormone

tion techniques have improved the number being

The injection of GnRH in cattle induces release of both

artificially inseminated has steadily increased. There are

LH and FSH. There have been many attempts to induce *several advantages of fixed-time AI (Penny, 1998) in*

ovulation in post partum cows by single intramuscular

that it:

injections of 100–500 mg GnRH and these have given

• Eliminates the practical problems of heat detection

variable results. In order to apply these treatments in

in beef cattle;

practice, more consistent responses would be necessary.

• Allows the use of superior sires with estimated

At the above dose levels, LH release of pre-ovulatory

breeding values (EBVs) (see p. 71) for important

surge magnitude usually occurs, depending on the

traits to improve the quality of the calf crop;

responsiveness of the pituitary. However, ovarian folli-

• Allows the use of tested sires to breed replacement

cles appear to require a two to three day period of rising

heifers;

plasma LH concentrations in order to mature fully

• Allows the use of sires selected on ease of calving,

prior to ovulation. Therefore, a pre-ovulatory LH surge

thus reducing the likelihood of dystokia;

will induce ovulation only if a follicle at the appropri-

• Helps to create a compact calving pattern;

ate stage of development is already present. Alterna-

• Can be used to eliminate venereal disease.

tively, the induced LH release might cause premature

luteinization of an unovulated follicle and transient

Anecdotal evidence suggests that AI pregnancy rate

secretion of progesterone sufficient to initiate ovarian

results on farm have been poorer than expected. Beef

cycles.

cattle tend to be less handled than their dairy counter-

Two injections of 500 mg GnRH at an interval of 10

parts. Mann (2001) suggests poor pregnancy rates in

days were advocated by Webb et al. (1977). Moreover,

dairy cattle were in part due to impaired ovulation as a

Table 41.10

Pregnancy rates after various treatments and

Table 41.11

Summary of oestrous synchronization and breed-

insemination regimens (after Smith et al., 1984, with permission ing protocol

(Penny et al. , 1997).

from the American Society of Animal Science).

Day

Procedure

Treatment

Timing of AI

Percentage

after last

pregnant

-12

Insert crestar implants

treatment

-4

Inject prostaglandin

-2

Remove Crestar implant ± PMSG

Control

Observed heat

72

0

First AI

6 day PRID plus PG day 6

Observed heat

82

12

Insert crestar implants

7 day PRID, PG day 6

Observed heat

73

21

Remove Crestar implants, take milk samples

2 ¥ PG

80 hours

52

23

Second AI if milk progesterone <3–5 ng/ml

7 day PRID, PG day 6

84 hours

66

35

Insert Crestar implants

44

Remove Crestar implants, take milk samples

PRID, progesterone-releasing intravaginal device; PG, prostaglandin.

48

Third AI if milk progesterone <3–5 ng/ml

PMSG,

pregnant mare's serum gonadotrophin; AI,

artificial

result of 'stress'. In order to maximize the success of

insemination; Crestar, 3 mg norgestomet implant.

synchronized AI, Penny (1998) advises the following:

• Ensure that the animals are handled and that the

handling facilities are safe and efficient.

Table 41.12

Results of the triple synchrony breeding pro-

• As nutrition has probably the greatest influence on

gramme over two years (Penny et al. , 1997).

the success or failure of oestrous synchrony, ensure

that target calving condition scores are achieved

Year 1

Year 2

and minimize body condition score loss between *calving and first service. This will result in the*

Pregnancy rate 1st AI

56% (27/48)

58% (40/69)

majority of cows cycling prior to the synchrony pro-

Pregnancy rate 2nd AI

69% (11/16)

48% (11/23)

gramme. Sudden changes in the plane of nutrition

Pregnancy rate 3rd AI

40% (2/5)

33% (4/12)

Pregnancy rate to all

58% (40/69)

53% (55/104)

may reduce pregnancy rates due to nutritional

services

'stress'.

Calving rate to all services

58% (40/69)

53% (55/104)

• Avoid major management changes during the pro-

Barren rate

17% (8/48)

20% (14/69)

gramme, e.g. turning out, housing, mixing groups

and treatments such as vaccination.

AI, artificial insemination.

• Ensure that adequate bull power is available for

repeats and, to reduce the risk of introducing vene-

really transmitted diseases, avoid hired or shared

bulls.

inations 56 hours post progestagen removal were to

cows which had a milk progesterone concentration of

<3.5ng/ml. Overall pregnancy rates, for the two years,

Methods

were 58 per cent and 53 per cent. However, the barren

Both prostaglandins and progestagens may be used in

rate was 17 per cent and 20 per cent (Table 41.12).

beef cows (Peters, 1986). Fixed time AI is not generally

Stevenson et al. (2000) compared combinations of

recommended, however. Programmes which have pro-

GnRH, Norgestomet and prostaglandin F2a. Fig. 41.2

duced acceptable pregnancy rates utilize a combination

shows the experimental procedure for oestrous syn-

of progesterone and prostaglandin (Table 41.10).

chronization. They found that prior to 60 days post

Prostaglandin administered 24 hours prior to progesta-

partum, programmes involving GnRH produced a

gen removal has the effect of synchronizing the decline

higher percentage of cows in oestrus and higher con-

in progesterone concentrations from endogenous and

ception rates compared to the programme involving

exogenous sources. Progestagen may either be in the

only two prostaglandin injections (Table 41.13).

form of a synthetic progestagen implant,

e.g.

Martinez et al. (2000) compared oestrous synchro-

Norgestomet, or a progesterone intravaginal release

nization and pregnancy rates in beef cattle given prog-

device.

esterone in the form of a controlled internal drug

Penny et al. (1997) described a triple synchrony pro-

release device (CIDR-B), prostaglandin F2a and oestra-

tocol (Table 41.11) in a spring-calving, single-suckled

diol or GnRH. Two experiments were conducted to

beef herd used over a two year period. Natural service

determine oestrous response and pregnancy rate in beef

was not used and AI was at fixed times. Repeat insem-

cattle given a CIDR-B device plus prostaglandin F2a

(PGF) at CIDR-B removal, and oestradiol or

100 mg GnRH, 54 hours after PGF, and concurrently

gonadotrophin releasing hormone (GnRH). In experi-

inseminated. Control heifers were inseminated 12 hours

ment 1, cross-bred beef heifers received a CIDR-B

after onset of oestrus. The oestrus rate was lower ($p <$ device and 1 mg
oestradiol benzoate (EB), plus 100 mg

0.01) in the GnRH group (55 per cent) than in either the

progesterone (E + P group; $n = 41$), 100 mg gonado-

E + P (100 per cent) or control (83 per cent) groups.

trophin releasing hormone (GnRH group; $n = 42$), or no

The mean interval from CIDR-B removal to oestrus was

further treatment (control group; $n = 42$), on day 0. On shorter ($p < 0.01$) and
less variable ($p < 0.01$) in the day 7, CIDR-B devices were removed and heifers

were

E + P group than in the GnRH or control groups. Preg-

treated with PGF. Heifers in the E + P group were given

nancy rate in the E + P group (76 per cent) was higher

1 mg EB, 24 hours after PGF, and then inseminated 30

($p < 0.01$) than in the GnRH (48 per cent) or control hours later. Heifers in the GnRH group were given

(38 per cent) groups. In experiment 2, 84 cows were

treated similarly to the E + P group in experiment I.

Cows received 100 mg progesterone and either 1 mg EB

Select Synch

or 5 mg oestradiol-17b (E-17) on day 0 and either 1 mg

GnRH

PGF

Detection of oestrus

2a

of EB or 1 mg of E-17b on day 8 (24 hours after CIDR-

and AI

B removal), in a 2 ¥ 2 factorial design, and were insemi-

nated 30 hours later. There were no differences among

–14

–7

0

1

2

3

4

5

6

groups for oestrus rates or conception rates. The mean

interval from CIDR-B removal to oestrus was 44.2

Select Synch = NORG

hours, sd = 11.2. Conception rates were 67 per cent, 62

GnRH

PGF

Detection of oestrus

2a

per cent, 52 per cent, and 71 per cent in groups E-17b/E-

and AI

17b, E-17b/EB, EB/E-17b and EB/EB, respectively. In

cattle given a CIDR-B device and estradiol plus pro-

–14

–7

0

1

2

3

4

5

6

gesterone, treatment with either EB or E-17b effec-

tively synchronized oestrus and resulted in acceptable

2 ¥ PGF2**a **(Control)

conception rates to fixed-time AI (Table 41.14).

GnRH

PGF

Detection of oestrus

2a

Penny and Lowman (2002) have designed a triple

and AI

synchrony system for beef cows which relies on fixed-

timed AI and not on natural service. The programme

–14

–7

0

1

2

3

4

5

6

allows cows up to three service opportunities over a

Days from PGF2a

46 day period (Table 41.14). Double insemination

improves pregnancy rate by 10 per cent compared to a

PGF2a: 25 mg Lutalyse (Pharmacia and Upjohn)

single insemination. GnRH (10 mg Buserelin) at the

GnRH: 100 mg Factrel (Fort Dodge) or Cystorelin (Merial Animal Health)

time of CIDR insertion gave an improvement in preg-

NORG (indicated by the shaded box): 6 mg Norgestomet

nancy rate of 12 per cent in treated cows. Cows which

– Syncro-Mate-B (Merial Animal Health)

were in a body condition score <2 (1–5 scale) or calved

<

Fig. 41.2

Experimental protocol for oestrous synchronization

55 days at first AI were injected with 400 iu PMSG.

(Reproduced from Stevenson et al. , 2000 with permission from PMSG was administered to maiden heifers and pro-the American Society of Animal Science).

duced a first service pregnancy rate of 74 per cent,

Table 41.13

The effect of oestrous synchronization treatment and number of days post partum on the percentage of cows detected in oestrus and conception rate (Reproduced from Stevenson et al. , 2000 with permission from the American Society of Animal Science).

Days post partum

Treatment

***Select Synch** +*

Select Synch

Norgestomet

***2 ¥ PGF2**a*

% Oestrus

% CR

% Oestrus

% CR

% Oestrus

% CR

£60

44.2

50.0

44.1

45.8

25.0

8.3

61–70

62.7

74.4

72.4

60.5

50.6

65.8

71–80

65.1

60.3

84.1

58.9

56.6

61.7

>80

60.0

73.8

72.4

64.0

46.0

72.4

Table 41.14

Triple synchronization programme for beef cows (Penny & Lowman, 2002).

Day

Day

Action

0

Thursday

Insert progesterone + GnRH

7

Thursday

Inject prostaglandin PGF2a

9

Saturday

Progesterone outa (am) + PMSGb

11

Monday

1st AI (am)

12

Tuesday

1st AI (am)

22

Friday

Insert progesterone in late calversc + GnRH

27

Wednesday

Insert progesterone

29

Friday

Inject prostaglandin PGF2a (late calvers)

32

Monday

Progesterone out (am) and tail paint (± PMSG late calvers)

33

Tuesday

Heat detect carefully

34

Wednesday

2nd AI (am) any cows seen bulling + late calvers

35

Thursday

2nd AI (am) any cows seen bulling + late calvers

46

Monday

Scan cows assumed pregnant and insert new progesterone in any non-pregnant + GnRH

50

Friday

Insert progesterone in 2nd AI group

53

Monday

Inject Prostaglandin PGF2a (scanned empty cows)

55

Wednesday

Progesterone out and tail paint

56

Thursday

Heat detect 2nd AI group

57

Friday

3rd AI (am) any cows seen bulling + non-pregnant group

58

Saturday

3rd AI (am) any cows seen bulling + non-pregnant group

a Rinse briefly in dilute antiseptic then dry with paper towels and store in cool dark conditions; wear disposable gloves when handling progesterone.

b 400 iu PMSG given to thin cows CS < 2 or calved >55 days.

c Late calving cows enter the programme for the second AI and therefore only have 2 opportunities for AI. Progesterone CIDR InterAgART.

GnRH 10 mg Buserelin Receptal Intervet.

which was better than untreated heifers (pregnancy

advantage in heifers along with fixed-time insemination

rate not published). The authors postulate that

if required, although a bull would still be necessary to

anoestrus may be a real problem in 15 month-old

serve non-pregnant animals subsequently.

heifers of later maturing beef breed crosses. They con-

clude that a target of 90 per cent calving rate is achiev-

able and repeatable in a 46 day breeding period and

Monitoring reproductive

leads to a sustainable compact calving period.

performance in the beef herd

As beef cattle are less used to being handled they can

become fractious when being confined and restrained.

This is very much more difficult in beef cattle than in

At times of hormonal treatments it is essential to

dairy cows because of the nature of the management

provide suitable handling facilities and sufficient expe-

systems.

rienced labour. If these are not provided there is con-

Even in the best-managed units, records of repro-

siderable danger to both animals and humans. Where

ductive events may be quite rudimentary, possibly

programmes involve progestogen implants, either as ear

including only date of calving. Since bulls are widely

implants or intravaginal devices, it must be remem-

used few records of service may be kept. The bull would

bered that these may be lost prior to their planned *normally be left with the cows for a length of time that*

removal. There are also welfare considerations and

corresponds to the aimed length of the calving season.

consumer concerns when subjecting animals to injec-

Whilst it is advantageous to identify barren cows at the

tions and implants.

end of the bulling period, in many cases it is not desir-

able to cull those animals because they are still suckling

calves. However, methods of early pregnancy diagnosis

Management of heifers *(see Chapter 5)*

are highly advantageous in the beef herd so that non-

pregnant cows may be identified quickly and appro-

Heifers should be bred to calve three to four weeks

priate action taken. It is unlikely that the milk

before the adult herd. Heavy breeds of bull likely to

progesterone test will become popular in beef herds,

cause dystokia, e.g. Charolais and Simmental, should be

even though a ‘cow-side’ test is available, because of

avoided. Oestrous synchronization may be used to

potential difficulties in sample collection. However, the *use of real-time ultrasound where embryos/fetuses can*

• An assessment of bull capacity including their ages

be detected by day 30 (White et al., 1985) or earlier

and clinical histories;

offers very exciting possibilities.

• Evaluation of the other farm enterprises so that the

It would be desirable for the practitioner to design a

best calving season can be chosen.

'herd plan' to monitor reproductive performance in

Beef cow stockworkers are capable of achieving rates

beef herds. The following could be used as a guide.

of heat detection equal to those of dairy stockworkers.

(1)

Condition-score cows at least two months before

If reproductive performance is to be optimized then the

the start of the calving season, e.g. at weaning.

stockworker must be prepared to observe and record

Those below target (Table 41.7a) should receive

the herd. For those who do so, techniques such as AI,

supplementary rations to bring them up to target.

oestrous synchronization/induction and induction of

Any cows above target should have their condi-

parturition will be much more successful.

tion reduced.

The veterinarian should be able to assess the potential

(2)

Condition-score cows at calving; those below

of a farmer and to educate and advise accordingly. This

target should receive supplementary rations.

should be on a long-term basis, i.e. five years, by which

(3)

Special attention should be paid to first and

time optimal targets should have been reached and

second calvers since these are most likely to be

advisory input can be reduced to a surveillance role.

vulnerable to problems, particularly extended

Where herds have an extended calving pattern it may

periods of anoestrus after calving.

take several years of planning and reproductive mani-

(4)

The producer should begin to observe and record

pulation before a herd achieves a two month calving *oestrus three weeks before the bull is introduced.*

period:

(5)

Oestrus periods and services should be recorded

• Calve heifers to an easy-calving bull one month

throughout the breeding season. Particular atten-

before the adult herd calve.

tion should be paid to the dates when cows are

• Body condition-score cows regularly; if they are too

expected to return to oestrus. The use of chinball

thin increase feed and/or wean calves early.

markers may assist oestrous observation with

• For late calving cows, manipulate oestrus and use

cows at grass.

AI soon after calving.

(6)

Pregnancy diagnosis should be carried out six

weeks after the bulls are removed. Barren cows

can then be culled when weaned. The findings at

pregnancy diagnosis in conjunction with the

(b) Dairy Herds

service records will enable the farmer/veterinarian

to estimate the likely calving dates and to plan the

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nutritional management.

Fertility problems arising in beef herds are likely to

Introduction

662

result from causes similar to those in the dairy herd.

Reproductive performance in the UK national dairy herd

663

However, investigation is often hampered by the lack

Components of a fertility control programme

664

of adequate records. Clinical problems such as retained

Identifying herd-specific goals

664

placenta, cystic ovaries and metabolic disease are much

Planning and setting targets

664

less likely to occur, but otherwise the more common

Cow identification, records, data analysis and

problems are similar to those in dairy herds. Similarly,

interpretation

667

when problems occur they are likely to reflect herd

Regular veterinary visits

668

status rather than just involving individual cows.

Periodic review and regular evaluation of performance

669

Maintaining motivation

672

Advice for veterinarians who wish to start herd fertility

control programmes

672

Reproductive record keeping and analysis

672

Analysing herd problems

If the client is aiming for a 12-month calving interval

673

If the client is aiming for a tight calving season

673

The following information is likely to be of value in

understanding and rectifying problems.

• *Cumulative frequency curve of calvings;*

Introduction

• *The age distribution of cows;*

• *The calving dates of first-calving heifers;*

A fertility control programme is a system to monitor

• *The culling rate and reason for culling;*

and manage reproduction, and is a well-established

element of preventive medicine in dairy herd manage-

Reproductive performance in the UK

ment that is successfully practised in many parts of the

national dairy herd

world. In a successful programme the farmer gains an

improved income more than the cost of implementing

There has been a general decline in fertility in the UK

the programme (Esslemont et al. , 1985). For the veterinational dairy herd over recent years, emphasizing the

narian, a well-managed fertility control programme
growing need for cost-effective veterinary intervention
should represent a profitable outlet for specialist pro-
in the form of well-managed fertility control pro-
fessional skills. In addition, regular farm visits to carry
grammes on dairy farms.
out fertility related work allow the veterinarian the
Analysis of approximately 9000 herds (National Milk
opportunity to promote other aspects of preventive
Records (NMR)) representing data on around 1 million
medicine, both within the dairy herd and also to other
cows, between January 1997 and September 2000, shows
livestock enterprises on the farm.
that the average herd size has risen from 97 to 112 cows,
Reproduction is particularly suitable for a preventive
and that the herd average yield has risen from below
medicine approach because if intervention is delayed
5500 kg to approach 7000 kg per annum. Over the same
too long there will be an irretrievable loss of produc-
period the mean calving to first service interval has
tion time and thus a financial loss to the producer.

risen from 84 to 88 days, the mean calving to concep-

Success depends on cooperation between the farmer

tion interval from 113 to 121 days (Fig. 41.3) and the

and the veterinarian, and is based on good husbandry

mean calving interval from 391 to 399 days (Fig. 41.4).

and consistently efficient work by the veterinarian.

There also seems to be a downward trend in first service

Because of the effect of husbandry (feeding, housing

pregnancy rate of approximately 3 per cent over the

and breeding management) and general health on

same period (Barrett, 2001). Royal et al. (2000) and

reproduction, a fertility control programme should also

Esslemont and Kossaibati (2000a) have also reported

incorporate other aspects of preventive medicine and

similar trends of falling fertility performance in the

encourage the practice of good husbandry. The devel-

UK and O'Farrell and Crilly (1999) have documented

opment of herd health plans such as the British Cattle

Veterinary Association (BCVA) Herd Health Plan over

recent years (Anon, 1999) has been a significant step

forward in this regard. The instigation of a herd health

Box 41.1

The main components of a successful fertility

plan allows the veterinarian to influence all aspects of

control programme.

husbandry and preventive medicine within the herd.

Furthermore, as most aspects of husbandry and health

Identifying herd specific goals

care will impact in some way on fertility and reproduc-

Planning and setting targets

tion, this holistic approach to preventive medicine

Cow identification, records, data analysis and interpretation

will aid and support the fertility control programme.

Regular veterinary visits

Periodic review and regular evaluation of performance

Box 41.1 lists the main components of a fertility control

Maintaining motivation

programme.

124

122

120

118

116

interval (days)

114

Mean calving to conception

Fig. 41.3

NMR data from approximately

112

9000 UK dairy herds showing the trend in

mean calving to conception interval

110

between January 1997 and September

Jan-97

Jul-97

Jan-98

Jul-98

Jan-99

Jul-99

Jan-00

Jul-00

Jan-01

2000.

Date

400

398

396

394

Mean calving interval (days) 392

Fig. 41.4

NMR data from appoximately

390

9000 UK dairy herds showing the trend in

Jan-97

Jul-97

Jan-98

Jul-98

Jan-99

Jul-99

Jan-00

Jul-00

Jan-01

mean calving interval between January

Date

1997 and September 2000.

lowered fertility in Irish dairy herds. This declining fer-

gramme for the herd to ensure milk is produced at the

tility may be due to a number of factors such as high

most profitable time, maximizing financial margins

levels of peri-parturient disease (Peeler et al. , 1994a, b), per litre as well as ensuring an optimal culling rate

inadequate nutrition (Webb et al. , 1997, 1999; Wathes with minimum involuntary culls and the production of

et al. , 1998), increasing genetic merit for milk produc-sufficient replacement heifers.

tion (Nebel & McGilliard, 1993, Lamming et al. , 1997; Given that producers will sell their milk to different

Lucy & Crooker, 1999), infectious diseases or numer-

milk purchasers who have different price structures, it

ous other independent or inter-related factors. Specific

is important to ascertain by discussion with the farmer

breeding management changes such as the increase in

and his other advisors what reproductive pattern will

the use of do-it-yourself artificial insemination (AI),

deliver the best overall profitability. For example, a low

with variable amounts of training of personnel, may *input, low to moderate yielding herd of 5000 to 6000*

also be significant (Howells et al. , 1999). Increasing milk l/cow per year looking to maximize the utilization of

yields and increasing herd sizes are almost certainly

grazed grass may be looking for a tight seasonal calving

contributing to the problem. It is also highly likely that

pattern with a calving index (mean calving interval) of

the decreasing availability of labour on farms is result-

365 days. In contrast, a farmer attempting to produce a

ing in reduced labour hours per cow per year. The

uniform supply of milk each month, purchasing a large

overall effect is greater difficulty in getting cows in calf

proportion of the feed used and running an intensive,

and increased costs of trying to do so.

high yielding herd of 10 000 l/cow per year may desire a

year-round calving pattern and a calving index of 420

days. On the other hand a pedigree breeder producing

embryos for sale may have general goals for the major-

Components of a fertility

ity of his herd, but very specific reproductive objectives

control programme

for his embryo donor cows. Having agreed the overall

reproductive strategy that suits a given herd, herd

Identifying herd specific goals

specific reproductive targets can then be set.

It is no longer possible to assume that every herd

owner's reproductive targets are the same. Targets will

Planning and setting targets

be determined by various factors fundamental to the

production system employed, for example contractual

A fertility control programme requires reproductive

agreement with milk purchaser, seasonal milk price,

targets. As outlined above, these are usually chosen for

milk constituent prices, feed costs, availability of labour,

economic reasons but are limited by what is physiolog-

other farm enterprises, etc. The ultimate aim of the milk

ically possible. It is the collective responsibility of the

producer will almost always be to maximize financial

farmer, his veterinarian and others in the farm advisory

return within the constraints of milk quota or produc-

team to choose the targets. However, the veterinarian

tion economics. Fundamental to achieving this is having

should ensure as far as possible that the targets are
a predetermined, and managed, reproductive pro-
realistic and achievable within an agreed time span.

There is no point producing targets that do not take into
Once the age of calving has been decided, other con-
account bovine reproductive physiology or that are
sequential targets have to be considered. If a heifer has
unduly optimistic concerning pregnancy rate, oestrous
to calve at 24 months old she must become pregnant at
detection rate or the standard of husbandry on the
15 months old. To do this she has to be cycling and well
farm. It is better to set a realistic target, achieve it and
grown (see p. 58). She also has to keep growing to be
then set a more demanding target than to begin with a
in a fit condition to calve down and be big enough to
target that is unrealistic and totally out of reach, as this
thrive in the dairy herd in competition with adult cows,
reduces stockman motivation. The farmer and his staff
or at least able to lactate, continue growing and get back
have to be in full agreement with the targets set, as only

in calf at the optimum time when managed in a group

if they really want to achieve the selected targets are

of first lactation cows. This means the farmer has to plan

they likely to be met. The veterinarian can only help

the growth rate from birth to meet the targets at these

and advise the stockmen on the farm, and cannot

critical times (see p. 56). The veterinarian has an impor-

achieve the aims of any fertility control programme

tant role in reducing calf and growing cattle diseases to

alone. A team spirit has to be engendered and each

allow planned growth rates to be achieved.

member of the team must play his or her part fully.

Other breeding targets have to be established, for

example an acceptable culling rate and the choice of

sires used. One aim is to avoid dystokia and this should

Heifers

be considered in choosing the breed of bull and

Dairy farmers often aim for seasonal calving for the

perhaps, more importantly, the individual bull to be

whole herd. To achieve this, it is essential that the

used for service. Under conventional breeding pro-

heifers calve early in the chosen season. As age at first

grammes the generation interval is one of the major

calving has a major effect on the proportion of a cow's constraints to genetic gain. There are advantages

life that is productive, there is an optimal age for first

in breeding replacement heifers out of heifers as this

calving and, for modern dairy breeds in Britain and

minimizes the generation interval and thus maximizes

elsewhere, this is usually put at 24 months old (see

genetic gain within the herd (see p. 59). If proven dairy

Chapter 5). However, farmers have to consider condi-

sires are used by artificial insemination (AI) they

tions in their own herds before they decide at which age

should be selected for ease of calving and be of higher

the heifers should calve. Seasonal calving herds may

genetic merit than the heifers being bred. At the

have to calve heifers at approximately 24 months of age,

present time health traits are gaining in importance

as the alternative of 36 months is usually not economi-

in the selection of dairy cattle, and in the future they

cally viable (see Chapter 5). However, year-round *may be seen as equally, or even more important, than*

calving herds or herds with two main calving periods

production traits, so in this context genetic merit

can be more flexible. For example, some may elect to

encompasses both health and production traits.

calve their heifers at 27 or 30 months of age.

It may also be a target to use beef sires on heifers, to

Having chosen the desired season of first calving and

allow the use of natural service or to avoid replacement

the desired age at first calving, various problems arise

dairy animals being produced from dams whose pro-

that have to be considered. If, for example, the calving

ductivity is unknown. This approach may also be used

season chosen is September, October and the beginning

to avoid too many dairy calves being born to the herd,

of November and the age at first calving is to be 24

particularly as pure bred dairy bull calves are of little

months, what is to be done with heifers that are born

or no value.

late in December, January or February? Will they be

left until the next calving season? Will they be sold

Cows

either as calves or perhaps later as in-calf heifers? Will

they be made to calve even younger than 24 months old

The most important targets are a controlled calving

or will they be allowed to calve in January or February

interval and season of calving, as these will impact

and extend the herd's agreed calving pattern outside

directly on profitability by influencing the mean yield

the optimum time period? These are important and dif-

per day of life of the cows and the margin per litre of

ficult decisions that have to be considered when the

milk produced. In addition, minimizing the involuntary

overall goals of the fertility control programme are

culling rate and allowing strategic voluntary culling are

agreed. Strategic decisions of this type have to be

necessary.

thought through, for example the above scenario can be

In fertility control work, the calving interval is the avoided completely if replacements are only bred from

number of days from the immediately past calving to

cows and heifers served during the agreed breeding *the next. Farmers are very conscious of the need to have*

season, and repeat breeders and late calving cows are

a controlled calving interval, but the ideal target varies

either culled or bred to a bull of a beef breed.

from country to country, from farm to farm and indeed

to derive the cost-benefit of any alterations in fertility

Box 41.2

Factors influencing the choice of calving interval.

parameters including an extended calving interval; the

Age and breed of the cow

principles behind this are discussed more fully by

Yield and shape of her lactation curve

Dijkhuizen et al. (1997).

Month of the year

Once the target calving pattern and target mean

Feeding

calving interval (calving index) have been chosen a

Cost

series of consequential targets emerge. If the target

Availability

calving index is, for example, 365 days, then the target

Calving and milking facilities

for calving to conception must be 85 days, which is 365

Milk sale contract and differential pricing structures

Milk quota

days minus a mean gestation length of 280 days. It

Calf value

should be noted that if the most profitable calving inter-

val for an individual cow is 365 days, then the aim in

theory would be to have every cow calve with that inter-

val. In practice what happens is that a herd calving

from lactation to lactation. In Britain the normal target

index becomes the target. However, care should be

for average yielding herds is a 12-month calving inter-

taken to minimize the distribution around this 365-day

val although, as discussed above, this may on occasions

mean figure, as cows with both longer and shorter

be extended for strategic reasons. Box 41.2 lists factors

calving intervals will be performing below their

that influence the choice of calving interval.

optimum. As the calving index is the mean interval

There are two reasons why calving interval is

between two calvings it only relates to those cows that

important.

calve again. In a herd with a 25 per cent replacement

rate only 50 per cent of the herd will contribute to the

(1)

Typically, milk yield reaches a peak about five

calving index, as it takes no account of the fertility of

weeks after calving and starts to decline at about

heifers or cull cows, and can be manipulated greatly by

eight or nine weeks after calving. This is why the

culling. It is important therefore always to interpret the

first part of a lactation is more profitable than later

calving index alongside the culling rate for failure to

parts and the dry period. Short calving intervals

conceive. The calving index as a measure of fertility in

result in a greater proportion of a cow's produc-

a herd is also too historical to be of much use in moni-

tive life being spent in this early, more profitable

toring fertility, as it relates to the fertility of the herd

part of lactation.

over a year before. A better and more contemporary

(2)

Short intervals produce more calves over a given

measure is the calving to conception (more correctly

period of time than long intervals. In a 100-cow

termed calving to establishment of pregnancy) interval

herd with a 12-month calving index there will be

as it relates to the current year rather than the previous

(approximately) 100 calves born per year; in a

year.

similar herd with a 14-month calving index the

Account must be taken of the fact that many cows

number of calves per year will be about 86.

require more than one service per pregnancy when cal-

However, longer calving intervals should not necessar-

culating the target interval from calving to first service.

ily be considered a bad thing. If lifetime production

In an individual herd this depends on conception

could be maintained while reducing the frequency of

rate, oestrous detection rate and culling rate. In many

calving of dairy cows there may be benefits. As many of *herds a target for calving to first service of 65 days is*

the disease problems seen in dairy cows occur around

satisfactory.

the time of calving or in early lactation, having a system

It is clear that cows must be cycling by the target date

of extended lactation that reduces both disease in the

for first service. A target that is often taken for the start cows and the numbers of low value calves produced

of cyclicity based on the physiology of the dairy cow is

may bring significant welfare benefits to the dairy

42 days after calving.

industry (Knight & Sorensen, 1998).

It is quite obvious that a target of first service 65 days

It is tempting when marketing fertility control to put

after calving has to be modified to become the oestrous

a money value on the loss occasioned by every day the

cycle that straddles 65 days, often taken as 56–76 days

calving interval is extended beyond the target. A figure

inclusive (eight to eleven weeks) after calving. This

that has remained remarkably constant over the

modifies the target for calving to conception to the last decade (to 2002) is £2.50 to £3.00/day. It should be

three-week period around 85 days, i.e. up to 96 days

realized that this (or any other generalized figure) is

after calving. It follows therefore that cows should be

not necessarily applicable to any individual herd.

served to the first observed oestrus after 56 days post

Where possible, herd specific costings should be done

calving. In other words, the voluntary waiting period in

this example should be 55 days. Shortening this period

systems there is still the need for a stockman to be able

will allow cows to be served more quickly, but in general

to identify each animal readily and rapidly in the herd

it will result in poorer conception rates.

in all housing and pastures used without risk of error or

Many farmers have as their prime target the season

the need to resort to specialist equipment.

of calving, which tends to dictate a 365-day target

calving index within a predefined service and calving

Record systems

period. The emphasis tends to be different from farmers

aiming for a different calving index, although the
A great deal has been written about record systems,
method of calculation of target indices is in essence the
ranging from simple, individual cow card-based
same. The start and end of the service season is con-
systems, other paper-based systems and wall mounted
trolled by the targeted calving season. It is essential that
breeding boards (Anon, 1984) to detailed state of
as many cows as possible are served in the first three
the art computerized systems such as National Milk
weeks (i.e. one oestrous cycle) of the breeding season.
Records' 'InterHerd' software. Simple systems for
It is particularly important to have all the cows cycling
beginners are described at the end of this chapter
in time and therefore the target for cyclicity is the three
(see p. 673).
weeks before the start of the service period. Submission
rates (defined as the proportion of cows eligible for
Why are records needed?
service served in a defined time period, usually 21–23
days) during the breeding season of seasonal calving

(1)

Records are needed for efficient day-to-day

herds must be optimized, therefore oestrous detection

running of the herd, even in herds with no

is paramount and every effort has to be made to ensure

thought-out plans and targets. They tell the stock-

that cows are served.

worker whether a cow that is in oestrus is due for

service or should be left until the next oestrus;

they indicate when a cow is expected to come in

season from the recorded date of last oestrus or

Cow identification, records, data analysis

service and they allow the accurate selection of

and interpretation

cows for the veterinary visit or for sampling.

A clear, reliable cow identification system is needed to (2)

Records are needed to monitor progress. It is nec-

run a fertility control scheme. Good identification is

essary to keep an eye on herd progress as well as

needed for accurate records.

individual cow status. Monitoring will indicate

Without proper identification there will be no clear

how many cows have started cycling on time after

system to ensure that cows are served when planned,

calving, how many cows have been served on time

no way of knowing which animals fail to meet targets

and it will show the success rate of services and

and dangerous confusion when animals are presented

the incidence of long and short interservice inter-

for veterinary examination. As an example of the latter

vals. Regular monitoring of herd events gives the

point, consider a cow that has an unrecorded service, is

veterinarian the chance to deal with herd prob-

pregnant and is presented to the veterinarian as 'not yet

lems at an early stage.

seen in oestrus'. She will have a corpus luteum, and the

(3)

Accurate records analysed and interpreted cor-

usual treatment with prostaglandin or an analogue

rectly are an essential aid to the diagnosis of herd

would cause abortion. Similarly, if a cow that was pre-

fertility problems. Records may be analysed for *sented for pregnancy diagnosis on the basis of a known*

the whole herd, or if cows are grouped according

service date had an unrecorded service at a later date,

to factors that may be related to fertility it is some-

even the most experienced veterinarian could make an

times possible to pinpoint aetiological factors

erroneous diagnosis of 'not pregnant'.

which may have temporal or other links. Exam-

Although it is now compulsory within Europe that all

ples include where one bull has a poor pregnancy

cattle are tagged in both ears with a unique identifica-

rate, or the mean calving-to-first-service interval is

tion number, this may not allow rapid identification of

very long in first calvers or if a seasonal effect on

cattle at pasture or within a large group during routine

fertility is noted.

handling. The veterinarian should encourage the farmer

to choose an identification system suitable for the con-

What are records?

ditions in which the herd is kept. Under most situations

this will mean freeze branding, although other methods

Records consist of the following information written

such as numbered collars may be utilized in some

down by a farm worker: a cow number, a date and an

systems. Even with the advent of electronic tagging

event. Errors of two sorts occur: items are written down

Box 41.3

The main fertility/reproductive/production events

Box 41.4

Selection of cows for routine visit (the stage for

to record.

examination or intervention figures are in brackets).

Calving, oestrus, service, result of service, abortion

Cows with abnormalities at or after calving (21 days after

Veterinary reproductive findings and treatment

calving); some will examine all cows about 21 days after

Other diseases

calving, although this is probably unnecessary

Production information

Cows not seen in oestrus (≥42 days) after calving

Milk yield

Cows in target service period but not yet served (56–76 days

Feeding

after calving)

Cows overdue for service (≥77 days after calving)

Cows due for pregnancy diagnosis (≥42 days after last

service or earlier if ultrasound examination used)

incorrectly and events occur and are not recorded. The

Cows seen at the previous visit and not yet served

main events that are recorded in variable detail are

Other problem cows, e.g.

listed in Box 41.3. Even on farms with the poorest

Purulent vaginal discharge

records, many of the required data should be available.

Aberrant sexual behaviour

For example, the number of cows in the herd, culling

Repeat breeders

records and calving records have to be recorded for

statutory purposes (data required by the British Cattle

Movement Service). If AI is used the AI company can

provide data on service dates. This, along with a veteri-

Regular veterinary visits

nary examination of each cow to determine pregnancy

status, will provide enough information to calculate, or

At each farm visit, the owner will have selected animals

estimate, basic fertility parameters for the herd.

for examination based on an ‘action list’ generated

using a system agreed between the client and veteri-

Problems in record analysis: There are two intrinsic,

narian. Where a computerized data management

insurmountable problems in relation to data analysis.

system is in place the computer software may generate

an action list based on predetermined agreed criteria.

(1)

With very few exceptions the amount of data

The animals presented for examination will vary from

available, when taking into account the variability

herd to herd and between practices. The groups of cows

of all fertility measurements, is not enough to give

shown in Box 41.4 are examples of cows that may be

statistically valid information. This is particularly

presented at the regular visit.

the case when the records are subdivided into age *groups, seasonal groups and so on.*

have been discussed in Chapter 35. At each visit the

(2)

Information that is up-to-date is practically always

clinician should spend a few minutes looking over

incomplete (see below) and as a result may

the records with the client to pick up any problems at

produce incorrect conclusions; complete informa-

an early stage, to modify targets, to give information to

tion is nearly always out-of-date.

the farm staff and to give them the chance to discuss

Up-to-date, incomplete information will give a more

any veterinary problem that is worrying them.

favourable result than is true in the measurement of the

time from one reproductive event to another. Consider

Records kept at the visit

the calculation of the herd mean and spread of the

interval from calving to first service. If the figure is cal-

Apart from the breeding records the veterinarian

culated before all the cows in the calculation have been *should keep a simple record sheet that records every-*

served (or marked as 'not to be served') the result will

thing done and advised, an example is shown in

be biased because it will include only cows served soon

Fig. 41.5.

after calving and will exclude those problem cows that

Whatever method is used to transfer the veterinary

will eventually be served after a long calving to first

findings to the records, care should be taken with cows

service interval. Incomplete pregnancy data based on

that are found to be non-pregnant to make sure that it

non-return rates or on extremely early pregnancy diag-

is clear to which service 'non-pregnant' applies. Errors

nosis using progesterone assays may also distort the

arise when the cow is served later and the result 'non-

real picture.

pregnant' may be taken to apply to that subsequent

These errors matter because decisions can be based

service. Where a bull is present on the farm, a diagnosis

on false assumptions. The actual analysis of records is

of 'pregnancy not detected' is safer than non-pregnant.

further discussed in the section on periodic review and

The quality of the work done at the farm visit

the regular evaluation of performance.

together with the informal discussion of progress and

Farm		Date of visit	30.6.02
		minus 42 days*	19.5.02
		TSP 56 to 77 days**	14.4.02 to 5.5.02

Pregnancy diagnosis

Date of service	Result	Treatment

Anoestrus etc.

Cow	Calving date	Observation	Treatment

Date of last visit 16.6.02

List of all cows examined at last visit and recommendations (except positive pregnancy diagnosis)

(Check if served or not;
if not served should be in group of cows for the current veterinary examination)

*date for pregnancy diagnosis and oestrus due
**target period for first service

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Fig. 41.5

Record of veterinary visit.

problems is very important. It acts not only to detect

interest and with the apparent success rate as noted at

and treat problem cows and gather fertility and related

each visit. The basis of the periodic review is an analy-

data such as body condition scores, but also supports

sis of the herd breeding records and an assessment of

the advice given at the periodic review.

the effectiveness of all interventions. Cows in the

milking herd will be considered separately from heifers.

There are so many ways of recording and analysing

Periodic review and regular evaluation

herd breeding records that this simple exercise can be

of performance

unnecessarily confusing. There are two reasons for

Detailed descriptions of the many different ways of

analysing herd records in these periodic reviews:

gathering and analysing breeding records are easily

• *Assessment of current status to establish whether*

obtained in other publications (Anon, 1984; Esslemont

there is a problem that needs attention or whether

et al. , 1985; Brand & Varner, 1996a, b; Bailey et al. , 1999).

things are progressing satisfactorily.

Instead of repeating them here, attention is concen-

• Discovery of any particular areas of weakness.

trated on what the analysis is trying to achieve and on

some of the problems of interpreting records.

In the analysis of purely reproductive data (not

While at each visit an eye is kept on the progress of

factors which affect reproduction) there are five analy-

the herd's breeding pattern, periodically it is necessary

ses that can be carried out, as listed in Box 41.5. The

to look more thoroughly at the fertility of the whole

most important of these are marked with an asterisk.

herd. The intervals between periodic reviews will vary

Even in herds where overall performance is adequate

with the calving pattern, with the intensity of the client's

there may well be subsections of the herd where both

Box 41.5

Analysis of reproductive data.

Box 41.6

Measurement of success rate of service.

Intervals in days between calving and subsequent reproduc-

Percentage (pregnancy rate): 'successful services' of 'all

tive events

services', e.g. 55%

Calving to first observed oestrus

Ratio (services per pregnancy): 'all services' to 'successful

*Calving to first service**

services', e.g. 1.82

*Calving to conception**

Visually: as a cumulative sum (Anon, 1984) – visual and

Pregnancy (conception) rate or services per pregnancy

allows a degree of temporal analysis

*(conception)**

Intervals in days from service to service (interservice

intervals)

Involuntary culling rate (reasons for culling)

*Submission rate (in herds with short breeding season)**

The mean is of limited value because it may be made

up of a wide range of values. For example, a mean

** Most important reproductive data.*

calving to first service interval of 65 days may consist of *very short and very long intervals (unsatisfactory) or*

it may be the result of most intervals being close to

the target (satisfactory). If the mean is greater than

the farmer and the veterinarian should be concentrat-

the target, results are certainly not satisfactory and the

ing their efforts. Analysis of those data relating to herd

mean does give some idea of the seriousness of the

subsections may reveal these areas of weakness.

situation. However, calculation of a mean ± standard

However, beware of overinterpreting data from a small

deviation for each parameter would be better, with the

number of animals.

target standard deviation as small as possible.

The first step is to define clearly which cows are to be

Consequently, the concept of a 'target period' has

included in the analysis. The ideal baseline is all cows

been developed. For example, instead of a 65-day target

that calve in a specified period. This period has to end

for a mean interval from calving to first service, the

long enough before the day of analysis to allow every

target changes to having as many cows as possible *cow to have completed her reproductive cycle to the*

served in the oestrous cycle period around 65 days, i.e.

stage of pregnancy diagnosis or to the decision to cull.

from 56 to 76 days (8–11 weeks) after calving. The

Once the group to be analysed has been selected, it

target for conception is the period around 85 days, i.e.

is important that the analysis makes it clear what has

76–96 days (11–13 weeks) after calving. For first oestrus

happened to every cow in the group.

it is best to aim for as many cows as possible seen in

oestrus by 42 days.

Information about the number of animals that fall

Calving to subsequent reproductive events

into the target period, before the target period and after

(to first oestrus, to first service, to conception)

it can be presented in histogram form. This is very

It is simple to calculate the number of days from calving

clear, easily understood and puts the extent of the

to first observed oestrus, to first service and to concep-

problem into exact numbers. This is particularly easy

tion (the date of the service that resulted in a confirmed *with modern software spreadsheet programs such as*

pregnancy). It is more difficult to express this informa-

Microsoft (MS) Excel and some of the specialist soft-

tion in a clear way and to interpret the results correctly.

ware available for herd record analysis.

The first thing to note is how many cows actually had

a first observed oestrus, had a first service or became

Success rate of services

pregnant, in relation to the number of animals that

started in the group. Culling rates of about 25–30 per

The success rate of services is again quite simple to

cent are common in dairy herds. If the rate is much

work out, but to avoid misinterpretation it is essential

greater than this, the veterinarian should establish

to understand the different ways of doing this, as shown

whether something is going wrong in the herd or

in Box 41.6. The difficulty arises because of the differ-

whether the records are incomplete.

ent ways of defining 'all services' and 'successful serv-

The next thing to calculate is the mean number of

ices'. 'All services' can mean literally that; it can also *days from calving to oestrus (target: cycling by 42 days) mean all services up to a certain number of services, say*

to service (target: 65 days) and to conception (target:

five, or it can mean ‘all first services’ (first service is

85 days). Targets assume that the object is to have a

defined as the first service after calving or in a heifer’s

12-month calving interval. While the means are not

life). ‘Successful services’ can mean services that result

completely satisfactory numbers they are worth

in calving, or that result in positive pregnancy diagno-

knowing and comparing with targets.

sis by rectal palpation or ultrasound examination, or

positive pregnancy diagnosis by milk progesterone or

of 18–24-day returns is quite useful for assessing

by non-return to service at various intervals after

levels of oestrous detection.

calving.

• Observation of the incidence of irregular intervals,

Depending on the definitions used the success rate

such as <18 days and between 25 and 36 days, gives *calculated from the same group of animals can vary*

an indication of the frequency of inaccurate heat

enormously.

detection. However, it should be recognized that

In most herds that are under veterinary supervision

these irregular intervals may be brought about by

'success' will be defined as positive pregnancy diagno-

late embryonic death or may be artefacts due to

sis undertaken by the veterinarian using ultrasound

veterinary intervention to manipulate the oestrous

examination or rectal palpation. There are several

cycle.

points in favour of basing the success rate on first serv-

The proportion of cows presented for pregnancy

ices rather than on all services, in particular:

diagnosis that are not pregnant also gives an indication

• The result can be obtained earlier than if one has

of the number of missed oestrous periods because most

to wait for the result of the last repeat breeder in

non-pregnant cows have been in season once or twice

the group.

before examination and have not been observed in

• Each cow contributes the same weight to the

oestrus. Another indicator of oestrous detection effi-

calculation.

ciency is the submission rate, defined as the proportion

of cows eligible for service served in a defined time

Therefore, in herds controlled by a veterinarian, success

period, usually 21–23 days. This measure is particularly

rate is best defined as the first service pregnancy rate, useful in seasonal calving herds.

i.e. the percentage of cows that are pregnant to first

service. It should he borne in mind that an accurate

figure will not be obtained until the result of the last

Culling rate

first service is known, which may be about six weeks

after that last service.

The incidence of culling in relation to the total starting

Once the first service pregnancy rate has been

population and the stage at which the decision to cull

worked out it is compared with the target rate of

is taken is presented as a percentage and an actual *between 45 and 60 per cent, the target depending on a*

number. It is desirable to record the reason for culling.

variety of factors.

In addition to first service pregnancy rate, at the end

Effectiveness of treatment and accuracy of

of a breeding season it is valuable to calculate an all-

pregnancy diagnosis

service pregnancy rate as it is this that will dictate the number of straws of semen used and the total insemi-Treatment, including conservative treatment, takes

nation charges. The all-service pregnancy rate will give

place:

a measure of the overall fertility within the herd, but

• At and after calving

should be interpreted in light of other information such

• In the preservice period and

as the culling policy for failure to conceive.

• At and after service.

Lists should be prepared with appropriate dates, diag-

Interservice intervals

nosis, treatment and outcome following treatment.

Many veterinarians who have not previously

The number of days between services is worked out.

analysed their results will find the effectiveness of fer-

These data are presented as one or two normal cycle

tility treatment disappointing. Better results require

lengths (18–24 and 36–48 days), or less than one,

more accurate diagnosis, careful selection of cases for

between one and two or more than two cycles (<18,

treatment and improvement of the client's breeding

25–35 and >48 days). Alternatively, the figures are set

management, so that practically all cows in oestrus after

out as a histogram with each day represented sepa-

treatment are inseminated at the right time.

rately, which is satisfactory for visual presentation but

difficult to describe in a report. The object of doing this

is to assess the efficacy of heat detection.

Heifers

• The assumption is made that most cows that do not

Analysis of breeding records for heifers is often

become pregnant return to service at a normal cycle

restricted because of lack of information, particularly

length of 18–24 days and therefore that returns *where natural service is employed. Where AI is used*

longer than this represent a missed oestrus. While

analysis is to some extent as for adult cows. The aspects

this is not strictly correct in all cases the proportion

shown in Box 41.7 should be borne in mind.

Advice for veterinarians who

Box 41.7

Analysis of heifer breeding records.

wish to start herd fertility control

Starting population

Percentage cycling when put to bull

programmes

First service pregnancy rate

Percentage that become pregnant (in defined breeding

Problems on the dairy farm that limit herd productiv-

period)

ity and profitability such as suboptimal fertility usually

Length of calving period

have multiple causes and require an integrated, multi-

Range of ages at first calving (available from milk records)

disciplinary approach (de Kruif, 1998). The veterinary practitioner will be most effective when he or she is part of a dairy farm consultant team that includes, in addition to the veterinarian, personnel such as the nutri-
After the purely reproductive analysis the next stage
tionist, financial consultant and other agricultural
is to correlate the fertility results with factors that could
professionals who can contribute to a team approach
interfere with reproductive efficiency.
for problem solving. If all the key advisors meet regu-
At the periodic review a written report should be pre-
larly on the farm and collaborate with developing
sented to and discussed with the client and his other
solutions for farm problems, benefits will outweigh
advisors. Targets can then be reviewed and adjusted as
those seen if each advisor acts independently. This
considered appropriate.
team approach has been advocated for many years (O'Connor et al., 1985; Kelly & Whitaker, 1999), but has

Maintaining motivation

been slow to be recognized by some and barriers are *sometime found between the different professionals.*

It is essential if a breeding programme is to be success-

The veterinary surgeon should work to break down

ful for all interested parties to remain focused and moti-

these barriers for the benefit of his client.

vated at all times. This requires good communication

Many veterinarians who are not carrying out fertility

between all involved and regular review of the herd's

control work for any of their clients find it difficult to

fertility performance within an economic framework.

get started. One problem is lack of confidence as

There are considerable benefits to be gained from

regards skills in rectal palpation or ultrasound exami-

improvements in herd health; for example, a farmer

nation. If this is the case it has to be overcome by

with 77 cows, who adopted a planned approach to herd

self-education and by undertaking suitable continuing

management, saw his farm profits improve by £13 000

professional development (CPD) training.

in 2 years. It was estimated that £6000 of this came from

Marketing of the service is best done via practice *improved fertility management alone (Esslemont & newsletters and a special client meeting to explain to Kossaibati, 2000b). This in itself should be enough to clients all that is involved in control programmes, motivate farmers to undertake schemes of this type. preferably with the help of a client who is convinced of The economic appraisal of herd health schemes has the benefits talking to others who are more sceptical. been extensively reviewed elsewhere and will not be Help to arrange a meeting can be obtained from many discussed in depth here (Esslemont & Peeler, 1993; sources, such as other (specialist) practitioners who run Esslemont, 1995). However, it is important to realize fertility control schemes, commercial firms or col- that the financial benefits are often hidden and not leagues in the veterinary schools.*

immediately apparent to the farmer unless the herd Beginners often have difficulty in knowing what to do records are analysed regularly and benefits quantified on regular farm visits and particularly how to set up and in monetary units.

use a recording system.

Given the economic pressure on the dairy industry,

farmers cannot afford to pay for services that do not

bring financial benefits, nor can they afford to tolerate

Reproductive record keeping

less than optimum fertility within their herds. In the

and analysis

past the uptake of herd fertility programmes has been

poor in the UK (Wassell & Esslemont, 1992). If they are

The first decision to be made on reproductive record

to become a regular feature on the majority of dairy

keeping and analysis is who is to undertake this. Is it to be

farms then it is the responsibility of the veterinarian to

the farmer, the veterinarian (or his staff) or a third party?

ensure that they are cost-effective and to be able to

There are distinct advantages if the veterinarian offers

illustrate this fact to his client. The use of spreadsheet

a complete package to the farmer including record

programs containing herd specific economic parame-

keeping. This gives the veterinarian control over which

ters and easily interpreted graphics would make this *cows are presented at the regular farm visits. However, if*

task much easier.

the farmer already keeps adequate records this may result

in duplication of effort and the farmer may be unwilling

rate records for more than one or two months prior to

to pay for something he considers he already has. What-

starting (except those data which are required to be

ever system is agreed upon the farmer will be required to

recorded by law) so that recording should be started at

collect most of the data and will need some records on

the same time as the rest of the programme. The best

farm to make day-to-day management decisions.

recording is likely in herds where there is some other

It is essential that accurate herd records be maintained

recording system used, such as individual cow milk pro-

and that they are analysed and acted upon regularly

duction records. Data kept in this way will require

(Varner & Brand, 1996; Bailey et al., 1999). A computer-regular analysis which, if done by hand, will be time

based system of record keeping offers many advantages, *consuming and thus costly.*

including rapid data analysis and the rapid production of

Many farmers find that a circular breeding board is

action lists and high quality reports. Many dedicated

useful to supplement this sheet (Anon, 1984; Fig. 4.29).

herd fertility record software packages such as DAISY

Figure 41.6 could also be used as a template for the con-

(Agrisoft, NMR), InterHerd (Agrisoft, NMR), Dairy-

struction of a computer spreadsheet for data analysis.

WIN (Massey University) and DairyCHAMP (Univer-

sity of Minnesota) are now commercially available.

If the client is aiming for a 12-month

These offer distinct functions, which have been pro-

calving interval

duced specifically to handle herd fertility data. In

addition, software packages such as Herd Browser

Depending on the calving pattern and herd size,

(Livestock Services UK Ltd) and Herd Management

arrange to visit the herd say every 14 days and at each

(Sum-it Computer Systems) offer some fertility record-

visit examine all cows that:

ing and analysis functionality within more general soft-

• Are more than 56 days after calving and have not

ware packages that have wider usage to the farmer.

been served;

While computers are invaluable in data handling and

• Were served 42 days or more previously and have

analysis it is important to realize that specific software

not returned to service (if unsure of early preg-

is not essential. It is perfectly possible with limited com-

nancy diagnosis, start later);

puter skills to maintain and analyse herd reproductive

• Have had any problems.

data in a spreadsheet package such as MS Excel,

although it will not easily generate action lists and some

Keep a record of everything you do on the farm and

of the other output available from dedicated herd fer-

find out what has happened to all the cows you saw at

tility software. The interpretation and understanding of

the last visit (see Fig. 41.5).

herd records can be greatly enhanced by the use of

It takes a year before the records are complete *computer generated graphs and charts, such as those*

enough for sensible analysis. Make an initial analysis

quickly and easily produced by computer programs like

after six months, bearing in mind the problems dis-

MS Excel (Hendry, 1999).

cussed above (see p. 672 onwards). After that, analyse

Computerized recording will allow more in-depth

the records every six months, or other suitable interval,

and frequent analysis of data. However, it is vital that

to show the following as a minimum:

the veterinarian (and the farmer) understands fully the

(1)

The number of cows that calved.

output of these systems and recognizes that the output

(2)

Calving to service interval:

is only as good as the quality of those data being

(a)

The number that have been served since

entered into the system.

calving;

If for any reason the veterinarian is unwilling or

(b)

The number not served;

unable to use a computer-based system a written record

(c)

The mean calving-to-service interval;

system is perfectly adequate for small herds, although

(d)

A simple, small histogram of distribution of

it lacks the ability to rapidly produce regular record

calving-to-service intervals.

analysis, action lists and reports containing graphical

(3)

The same information for calving-to-conception

representation of data. The following simple, paper-

interval.

based system, which can be made up in the practice and

(4)

First service conception rate (and all service con-

photocopied, is suggested as a starting point. One sheet

ception rate).

of A4 paper is marked across the top with headings that

(5)

Culling rate (and reason for culling).

cover one reproductive cycle for each cow from calving

to confirmation of pregnancy or disposal/death. The

If the client is aiming for a tight

sheet is lined horizontally and each sheet will take

calving season

records from about 20 cows (see Fig. 41.6).

This sheet is filled in by the farmer in chronological

Use the same record system. Discuss oestrous detec-

order of calving. It is usually impossible to obtain accu-

tion. Make sure the farmer records all heats in the

Herd breeding record:

Farm:

Sheet no.:

Cow

Calving

Normal

Lactation

Pre-service heat

Target

Service dates/bull used

PD

Days from calving to:

date

no.

dates

1st

2nd

1st

2nd

3rd

4th

5th

1st heat

1st serve

Pregnancy

36

6-3-2001

Y

6

8-5-2001

1-5-2001

25-5-2001

P+

63

80

80

GS

20

7-3-2001

Dead calf

3

2-5-2001

12-5-2001

11-7-2001

P+

—

66

126

DH

Char

38

9-3-2001

Y

6

16-4-2001

4-5-2001

3-5-2001

P+

38

55

55

DH

186

10-3-2001

Y

4

5-5-2001

1-7-2001

¥

To be sold

P-

—

114

—

DH

148

8-7-2001

CS

1

2-9-2001

13-9-2001 —

67

DH

148

11-8-2001

Y

I

6-10-2001

219

12-8-2001

Y

2

15-9-2001

7-10-2001

34

Fig. 41.6

A simple herd fertility recording system. Y, yes; CS, Caesarean section.

three-week period before the first day of the service

Caldow, G.L. & Taylor, D.W. (1997) Experiences with vene-

period.

real Campylobacter infection in suckler herds. Cattle Prac-Examine, and treat where needed, all animals that

*tice, **5**, 327–34.*

have not been in season at the end of the three-week

Drew, S.B., Gould, C.M., Dawson, P.L.L. & Altman, J.F.B.

preservice period. Visit at weekly or fortnightly inter-

(1982) Effect of progesterone treatment on the calving-to-

conception interval of Friesian dairy cows. Veterinary

vals thereafter to examine all cows not yet seen in

Record, ***111***, *103–6.*

oestrus and to follow up treatments. Monitor the

Dunn, T.D., Ingalls, J.E., Zimmerman, D.R. & Wiltbank, J.N.

submission rate.

(1969) Reproductive performance of two year old Hereford

Carry out pregnancy diagnosis nine weeks after the

and Angus heifers as influenced by pre- and post-calving

first day of the service season. Remember this simpli-

energy intake. Journal of Animal Science, ***29***, *719–26.*

fied advice covers the first steps to help beginners to get

Hill, J.R., Lammond, D.R., Hendricks, D.M., Dickey, J.F. & started.

Niswender, G.D. (1970) The effects of undernutrition on

ovarian function and fertility in beef heifers. Biology of Reproduction, ***2***, *78–84.*

Future developments in herd

Kilkenny, J.B. (1978) Reproductive performance of beef cows.

fertility management

World Review of Animal Production, ***14***, *65–74.*

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The decreasing availability of staff on farms in the UK

Lowman, B.G., Scott, N.A. & Somerville, S.H. (1976) Condi-

is presenting a real challenge to many farmers and vet-

tion scoring of cattle. East of Scotland College of Agricul-erinarians as they attempt to maintain and improve

ture, Bulletin No. 6.

herd fertility. Over recent years there have been numer-

Mann, G.E. (2001) Pregnancy rates during experimentation in

ous technological developments that can help, particu-

*dairy cows. The Veterinary Journal, **161**, 301–5.*

larly aids to oestrous detection such as the KaMaR heat

Martinez, M.F., Kastelic, J.P., Adams, G.P., Janzen, E., McCart-mount detector, pedometers and milk progesterone

ney, D.H. & Mapletoft, R.J. (2000) Estrus synchronization

assays (Peters & Ball, 1995). It is probable that in the

and pregnancy rates in beef cattle given CIDR-B,

prostaglandin and estradiol or GnRH. Canadian Veterinary

future accurate and reliable automated systems to

*Journal, **41**, 786–90.*

assess the cow's physiological state using biosensors will

Mawhinney, S., Roche, J.F. & Gosling, J.P. (1979) The effects be developed (Koelsch et al., 1994; Frost et al., 1997; of oestradiol benzoate (OB) and gonadotrophin releasing

Mottram, 1997; Scully et al., 2000). New developments hormone (GnRH) on reproductive activity in beef cows at

in this area of technology may allow automatic milk *different intervals post partum. Annales de Biologie*

progesterone assays, and other assays, to be performed

Animale Biochimic et Biophysique, ***19****, 1575–87.*

while cows are being milked, allowing the timing of

Meat and Livestock Commission (1986) Beef Year Book, p. 55.

ovulation to be accurately predicted and removing the

MLC, Milton Keynes.

need for oestrous detection. In addition, technologies

Meat and Livestock Commission (2000) Beef Year Book pp.

such as automated milking may become more wide-

23–4, 31, 44–47. MLC, Milton Keynes.

spread, freeing stockmen from routine mundane tasks

Mulvaney, P. (1978) Dairy cow condition scoring. Paper

No. 4468. National Institute for Research in Dairying,

and allowing them to concentrate on improving cow

Reading.

care. New methods of data recording, such as the use of

Mulvehill, P. & Sreenan, J.M. (1977) Improvement of fertility palm held computers and mobile phones with internet

in post-partum beef cows by treatment with PMSG and

capability, will allow data collected on the farm to be

progestagen. Journal of Reproduction and Fertility, ***50***, *logged direct to remote computer databases in the farm*

323–5.

office or at distant sites.

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p. 183 , Granada, London.

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*Journal, **142**, 20–9.*

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Esslemont, R.J. & Kossaibati, M.A. (2000b) Dairy farming

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*Science, **58**, 792–800.*

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*British Veterinary Journal, **149**, 537–47.*

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Influence of the number of days spent training in an

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*Science, **48**, 209–17.*

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tional influences on subfertility in cattle. Cattle Practice, ***5****, matic interpretation of milk progesterone data: an aid to*

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dairy fertility management. Cattle Practice, ***8****, 407–10.*

Webb, R., Royal, M.D., Gong, J.G. & Garnsworthy, P.C. (1999) Varner, M. & Brand, A. (1996) Monitoring reproductive perThe influence of nutrition on fertility. Cattle Practice, ***7****, formance: decision making and follow-up. In Herd Health*

227–34.

Chapter 42

Pharmacological Manipulation of

Reproduction

J.G. Allcock and A.R. Peters

Introduction

678

(3)

By the simulation of corpus luteum function, by

Control of the oestrous cycle

678

administration of progesterone (or one of its syn-

Induction of luteolysis

678

thetic derivatives) for a number of days, followed

Trophic hormone and prostaglandin combinations

680

by abrupt withdrawal.

Use of progestagens

680

Factors affecting pregnancy rate after controlled

The three methods are discussed in greater detail below.

ovulation

682

Synchrony after prostaglandins

682

Synchrony after trophic hormone–prostaglandin

Induction of luteolysis

combination techniques

683

The most potent luteolytic agents available are deriva-

Synchrony after progestagens

683

tives of prostaglandin F2a (PGF2a). Injection of exoge-

Possible methods of overcoming problems of asynchrony 683

nous PGF

Field evaluation of oestrus synchronization techniques

684

2a or one of its analogues during the mid

luteal phase of the cycle results in premature luteolysis

Establishment of pregnancy

684

Pharmacological induction of parturition

686

and a consequential fall in peripheral progesterone

Methods of induction of parturition

concentrations. This is followed by a rise in the secre-

tion of pituitary gonadotrophins and eventual ovula-

tion. The fall in progesterone concentration is rapid,

Introduction

often reaching basal levels within 30 hours of injection.

There are now several commercial analogues of PGF2a.

Examples of those currently marketed in the UK and

This chapter aims to cover the manipulation of repro-

elsewhere are shown in Table 42.1.

duction in cattle where this is not covered in the chap-

Prostaglandins have been used to control the

ters on general fertility. The discussion includes control

oestrous cycle in several different ways. Some possible

of the oestrous cycle, the establishment and mainte-

methods are given below:

nance of pregnancy and induction and postponement of

parturition.

(1)

Following rectal examination, only those cows

with a corpus luteum are injected. These cows should

Control of the oestrous cycle

then show oestrus and ovulate three to five days later.

This method has the disadvantage that it is time-

The control of the oestrous cycle is dependent on

consuming and that rectal palpation involves added

manipulation of the hormonal events occurring during

expense. The results also depend on the accuracy of

the normal ovarian/oestrous cycle. The over-riding event

detection of corpora lutea by rectal palpation.

controlling the development of an ovarian follicle

(2)

All cattle are observed for oestrus over a seven-

to the point of ovulation in the cyclic cow is believed to

day period, serving any that show oestrus. The rest are

be the process of luteolysis or decrease in progesterone

injected with prostaglandin on the following day and

secretion occurring between days 17 and 18 of the

may be inseminated either once or twice at fixed

normal cycle (see Fig. 42.1). This fall in peripheral *times or at observed oestrus. The reason for the initial*

progesterone concentrations may be manipulated arti-

seven-day observation period is that there is a period

ficially in three ways:

of about seven days in the cycle (day 18 to day 0 and

(1)

By the artificial induction of premature luteolysis

day 1 to day 4) when the animal is unresponsive to

using luteolytic agents, e.g. the prostaglandins.

prostaglandin, i.e. when no corpus luteum is present.

(2)

By attempting to modify the timing of normal

After seven days, those originally between days 18 and

ovarian events through a combination of trophic

0 will have shown heat and been served, while those

hormones and luteolytic agents.

that were between days 1 and 4 will now be between

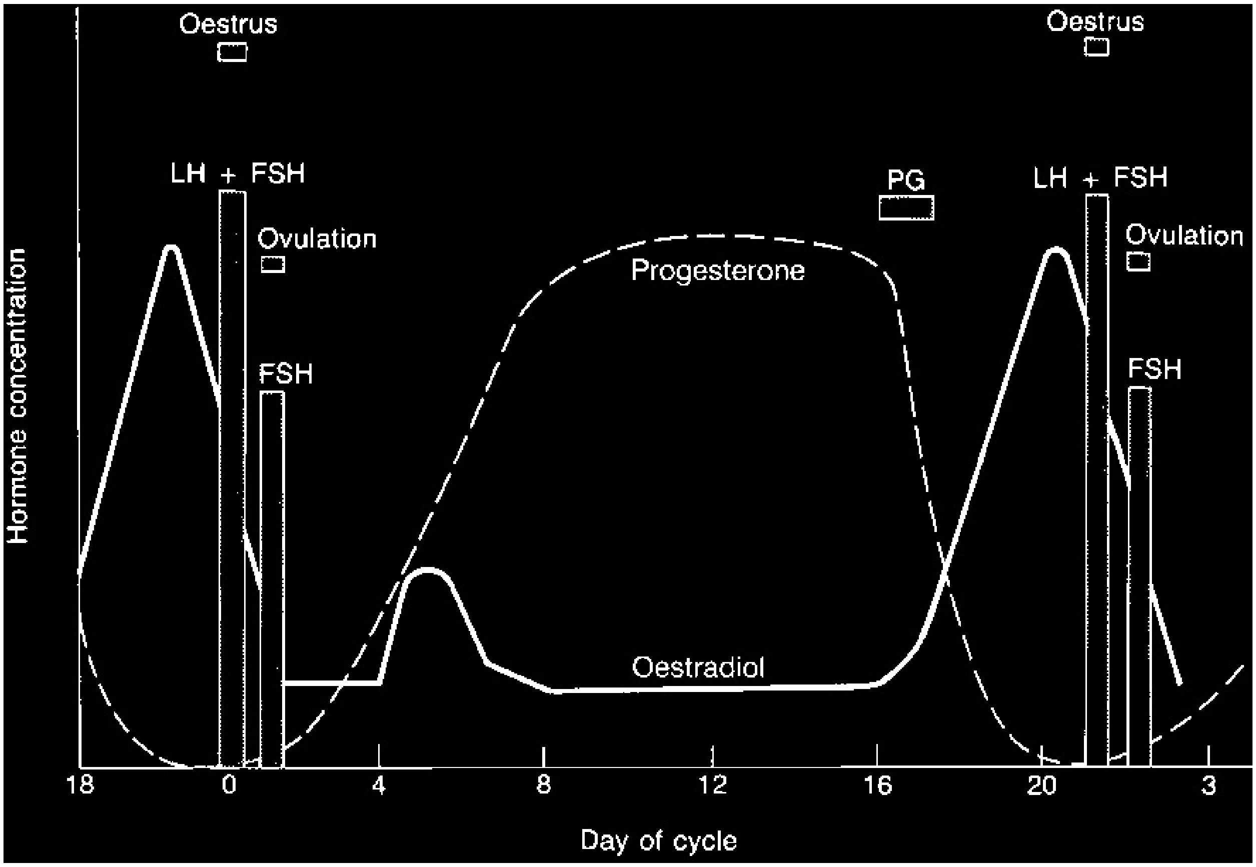

Fig. 42.1

Changes in blood plasma

concentrations during the bovine

oestrous cycle (schematic): — oestradiol;

--- progesterone.

Table 42.1

Examples of prostaglandin analogues available in the UK and elsewhere (2003).

Trade name

Active

Distributor

Route of

Dose rate

Insemination timing

component

injection

(mg)

recommendations (hours)

Double

Single

Estrumate

Cloprostenol

Schering-Plough

im

0.5

72, 96

72–84

Prosolvin

Luprostiol

Intervet

im

15.0

72, 96

72

Lutalyse

Dinoprost

Pharmacia &

im

25.0

72, 90

78

Upjohn

Enzaprost

Dinoprost

CEVA

im

25.0

72, 96

No recommendation

Noroprost

Dinoprost

Norbrook

im

25.0

72, 96

No recommendation

Prostavet

Etiproston

Bimeda

im

5.0

72, 96

No recommendation

tromethamine

days 8 and 11, i.e. in the mid luteal phase, and therefore

sis in response to the injection and will ovulate some

responsive to prostaglandin.

four days or so later. At the time of the second injec-

tion (10 or 11 days later) these cows will be on about

(3)

The two injections plus two inseminations

days 8 and 15 of the next cycle (Fig. 42.2). The cows that

method. The so-called 'two plus two' technique was *were not responsive to the first injection, i.e. those designed to synchronize groups of animals cycling at between days 18 and 4 of the cycle, would now be random without prior knowledge of their precise between days 8 and 15 at the time of the second injec- ovarian status. All cattle are injected on day 1 of tion. Therefore all animals are theoretically in the treatment and the injection is repeated 10 or 11 days responsive mid luteal phase at the time of the second later. Artificial insemination (AI) is then carried out injection. The technique is popular and quite successful usually three and four days later (72 and 96 hours after in synchronizing cycles in heifers (Cooper, 1974) and the second prostaglandin injection).*

has resulted in pregnancy rates equivalent to control The principle of this regimen is illustrated in animals. However, pregnancy rates achieved with this Fig. 42.2. At the time of the first injection some animals technique in adult cows have not always been will be responsive to the prostaglandin, i.e. between consistent and some of the reasons for this are discussed *days 5 and 17 of the cycle. These will undergo luteoly-*

later.

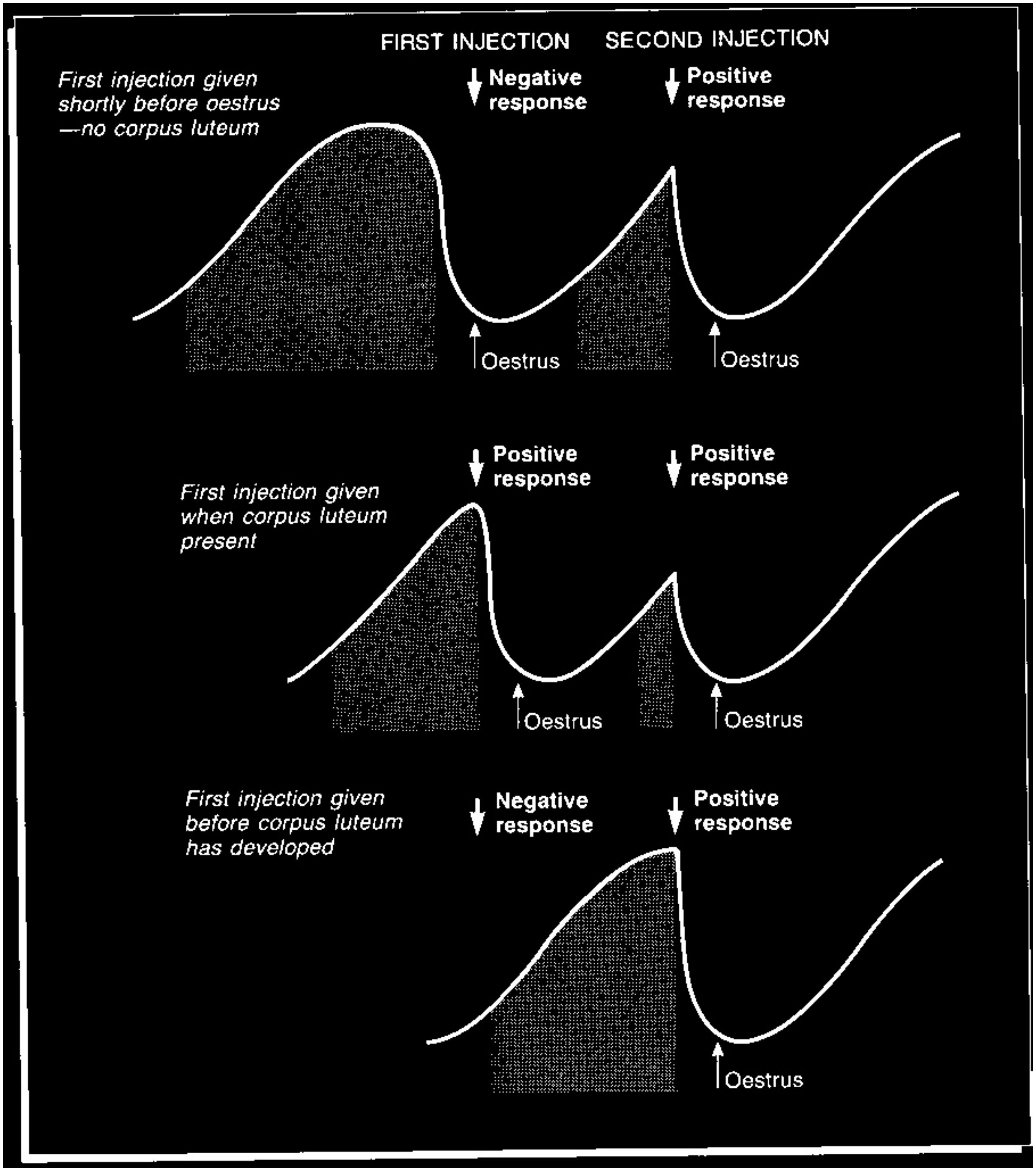

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Fig. 42.2

The effect on progesterone

concentrations of giving two injections

of prostaglandin 11 days apart. (MAFF,

1984).

(4)

A further method of using prostaglandins that

a dominant follicle being present at the time of induc-

has been quite popular is the so-called '11/2 method'.

tion of luteolysis seven days after the administration

Cows are injected with prostaglandin and those that

of the GnRH. Regimes involving this approach to

show oestrus are inseminated. Those that have not been

'priming' of the oestrous cycle have been tested in the

seen in oestrus are injected again 11 days after the first

UK (Mawhinney et al., 1996). In most cases a second

injection and may be inseminated either at a fixed

administration of GnRH has been used in an attempt

time(s) or at observed oestrus. Although requiring

to further synchronize the timing of ovulation after

further effort in terms of oestrous detection, this

luteolysis. The second GnRH is administered 48 to 56

method tends to give better results than the 'two plus *hours after prostaglandin administration, with insemi-*

two' regimen and is the current method of choice. Its

nation being carried out 18 to 24 hours after the post

main advantage, however, is the reduction in cost by the

luteolytic GnRH (Roche, 1999).

reduction of both the number of treatments used and

the number of inseminations per cow.

Use of progestagens

The third method of controlling the cycle is to simulate

the function of the corpus luteum by the administration

Trophic hormone and

of progesterone or one of its derivatives. In this method,

prostaglandin combinations

gonadotrophin release, and hence ovarian follicular

Gonadotrophin releasing hormone (GnRH) or its

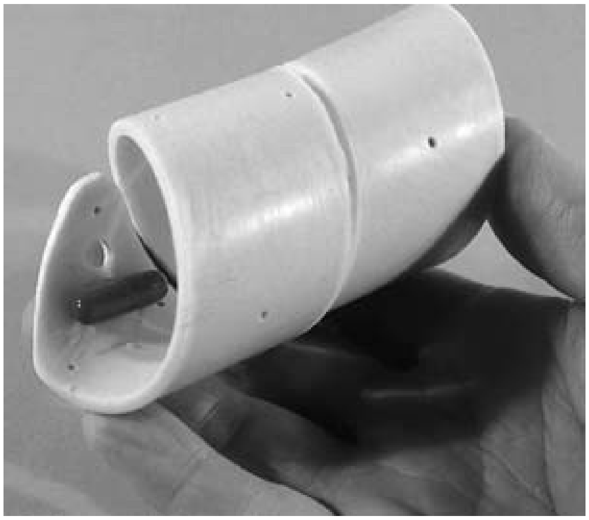
maturation, is suppressed until progesterone with-

analogues can be used to reprogram the developing

drawal. If progesterone is used to treat a group of cows

waves of ovarian follicles to maximize the possibility of

and then it is withdrawn from all cows simultaneously,



this will theoretically synchronize ovulation in the whole group.

In order to synchronize a group of randomly cycling cows effectively, it is necessary to treat them with progesterone for a period at least equivalent to the length of the natural luteal phase, i.e. 16 days. This is because exogenous progesterone has little or no effect on the life span of the natural corpus luteum and therefore, in a small proportion of cases, the natural corpus luteum might outlive a short-term progesterone treatment, resulting in a failure of synchrony. However, it has been shown that longer-term progesterone treatments (18–21 days) result in poor pregnancy rates. It is *thought that this is due to adverse changes in the intra-*

uterine environment that may inhibit sperm transport.

Shorter-term progesterone treatments (7 to 12 days)

generally result in more acceptable pregnancy rates,

Unfortunately, short-term progesterone treatment does

Fig. 42.3

A progesterone-releasing intravaginal device (PRID).

not control the cycle adequately since, if treatment is

started early in the cycle, the natural corpus luteum

may outlast the progesterone treatment. Therefore, it is

often necessary to incorporate a luteolytic agent with

short-term progesterone treatments in order to elimi-

covered by a layer of grey inert silastic (Fig. 42.3) in

nate any existing corpus luteum.

which 1.55 mg progesterone is impregnated. A gelatin

Progestagens (progesterone-like compounds) can be

capsule containing 10 mg oestradiol benzoate is

administered in the feed, by injection or by implant.

attached to the inner surface of the coil. The oestradiol

Administration in feed requires that the compound

benzoate in the PRID is intended to act us a luteolytic *is 'orally active', i.e. it is absorbed into the systemic agent. The CIDR is a Y-shaped device consisting of a circulation unchanged. Progesterone itself is rela- nylon spine covered by a similar silicone elastomer tively inactive orally and thus synthetic analogues, for impregnated with 1.9 g progesterone. These devices are example medroxyprogesterone acetate (MPA) and inserted into the vagina by means of specialized appli- melengoestrol acetate (MGA), were developed for this cators and are then left in place for up to 12 days. purpose. However, this route of administration presents The progesterone is continuously released from problems of controlled dosing and the possibility the elastomer until removal of the device. Removal is of tissue or milk residues, particularly in dairy cows. effected by pulling on the string (PRID) or plastic 'tail' Therefore, such techniques are not favoured in the UK (CIDR) which is left protruding from the vulva after for oestrous control in cattle; however, they are used insertion. Removal after 7 to 12 days causes peripheral widely in the USA and other countries, particularly in* *plasma progesterone concentrations to fall, thus simu-*

heifers.

lating natural luteolysis. Consequently, the cow should

Progestagens can be given by injection, but as the

show oestrus 48–72 hours later and fixed-time AI may

half-life of progesterone and its analogues is short,

then be used.

repeated treatments may be necessary. The rate of

There has been some interest in the use of low doses

absorption is often imprecise, so synchronized with-

of oestrogens after the removal of the progesterone

drawal of the compound can be unreliable. Implants

delivery device. Doses of 1 mg have been used in an

appear to be the most suitable method of administra-

attempt to further synchronize the onset of oestrus

tion of progestagens since withdrawal can then be pre-

subsequent to the fall in plasma progesterone concen-

cisely controlled by implant removal.

trations. Questions remain regarding the fertility

consequences of this approach (Roche, 1999).

Intravaginal progestagen-containing device

(e.g. PRID or CIDR)

Norgestomet (Crestar)

The PRID (CEVA Animal Health) or CIDR (InterAg/

Norgestomet,

17a-acetoxy-b-methyl-19-nor-preg-4-

ART) are specialized forms of implant that are inserted

ene, 20-dione (Crestar, Intervet), is marketed for

into, and held within, the cow's vagina for a period of

planned breeding of beef cows and dairy and beef

7 to 12 days. The PRID consists of a stainless steel coil

heifers. It is an example of a synthetic analogue of

progesterone and consists of an impregnated silastic

Synchrony after prostaglandins

subcutaneous implant. The implant is inserted sub-

Three major circumstances in which asynchrony can

cutaneously behind the ear for a period of nine or ten

arise have been reported in the literature (Jackson

days, during which time the progesterone is absorbed

et al., 1979; Baishya et al., 1980; Peters et al., 1980).

into the circulation. The implant is removed by making *a small scalpel incision in the skin of the ear over the*

implant. At the time of the implantation an intramus-

Failure of complete luteolysis

cular injection of 5 mg oestradiol valerate is given as

luteolysin, in combination with an initial injection of 3

This has occurred in 10 per cent or more of cows treated

mg norgestomet.

with prostaglandins. It takes the form either of com-

plete lack of effect on progesterone concentrations

Factors affecting pregnancy rate after

or, for example, a fall to half of pre-injection levels, fol-

controlled ovulation

lowed by luteal recovery, usually within 24–48 hours.

Causes of luteolytic failure are not clear but may be

It cannot be overemphasized that in order to maximize

related to several factors including the following:

results obtained with pharmacological control of the

oestrous cycle, nutritional status and general manage-

• Non-responsiveness of some corpora lutea even in

the appropriate phase of the cycle.

ment must be of a high standard. The efficacy of the *pharmacological control of ovulation can be considered*

• Treatment too early in the luteal phase.

as two components:

• Incorrect injection site or technique: in the case of

intramuscular injections, occasionally the material

(1)

The degree of synchrony obtained following treat-

may be injected accidentally into fat or ligamentous

ment. This may be defined as the proportion of

tissue.

animals beginning to show oestrus or ovulating

• Short half-life of the chosen exogenous

within a specified time period after the end of hor-

prostaglandin in the animal.

monal treatment. For the purposes of this discus-

The extent of these various problems is not known

sion the target of synchrony is for the maximum

and it must be admitted that all are to some extent

number of animals to show oestrus within approx-

speculative.

imately 48 hours of progesterone withdrawal or 72 *hours after prostaglandin injection (or to ovulate*

approximately 24 hours later in each case).

Long follicular phases after injection

(2)

Reproductive performance,

which may be

expressed, for example, as the pregnancy rate

In up to 20 per cent of cows injected with prostaglandin,

achieved after treatment.

although luteolysis appears to occur normally, proges-

terone concentrations remain low for an unusually

Obviously in some circumstances the pregnancy rate

long period. This may be associated with a delay in

may be highly dependent on the degree of synchrony,

the timing of ovulation relative to oestrus. However,

particularly if fixed-time AI is used. For example, if

extended follicular phases (longer than eight days)

there is a poor degree of synchrony there will be a wide

also occur in about 17 per cent of untreated dairy cows.

variation in the timing of ovulation between cows

Thus it is likely that this phenomenon is related to a *or, more correctly, a proportion of cows will ovulate*

natural aberration in the adult cow's ovarian cycle. The

beyond the specific period anticipated. Therefore

problem has not been reported in heifers and certainly

insemination would not be accurately timed and the

the cycles of adult cows would appear to be less uniform

pregnancy rates following fixed-time AI may be

than those of heifers.

poor.

In view of the natural variation in timing of the

behavioural and ovarian events around natural oestrus,

Acyclic cows

it is perhaps not surprising that even after hormone

treatments there is still considerable variation in the

The ovary can only respond to prostaglandin if there is

timing of responses between animals. Hence where

a functional corpus luteum. Therefore, cows with little

fixed-time AI is used, two inseminations are usually rec-

ovarian activity at the time of injection do not respond.

ommended in order to maximize the probability of con-

The proportion of cows in this state will vary from herd *ception. In addition, other problems occur that appear*

to herd and the average stage after calving, but it is gen-

to be specific to the particular compounds used and

erally regarded as a more serious problem in suckling

these are described below.

beef cows. For this reason some advisors recommend

that prostaglandins are not used before day 42 after

without a luteolytic agent. Synchronization rates of 70

calving.

per cent have been reported in practice (e.g. Drew et

al., 1979) Oestradiol is not always an effective luteolytic agent and, like prostaglandins, does not always prevent

Synchrony after trophic

formation of the corpus luteum when administered

hormone–prostaglandin

early in the cycle (Peters, 1984).

combination techniques

It has been shown that more than 90 per cent of cattle

Failure to maintain high blood concentration

treated with GnRH followed by prostaglandin and *of progesterone*

a second GnRH (the so-called 'GPG' system) can be

induced into a low progesterone phase at the time of

It has been shown that in some circumstances proges-

planned insemination. The proportion of cattle either

terone concentrations in the cow may fall before with-

failing to respond in this way or failing to show oestrus

drawal of the progesterone source (Roche & Ireland,

and ovulation as expected may be influenced by several

1981). Obviously this could result in oestrus and ovula-

factors:

tion occurring before removal of the device. This

premature fall has occurred particularly with the

• Some cows may fail to be in the luteal phase at

intravaginal method of administration. It has been

the time of prostaglandin administration. This is

suggested that this is related to progesterone-induced

thought to occur to a greater extent in heifer groups

changes in absorption across the vaginal wall rather

and may be a consequence of a difference in the

than to exhaustion of progesterone in the device.

frequency of follicular waves in immature cattle.

The GPG system is usually less effective in heifer

groups.

Possible methods of overcoming

• Failure to respond to prostaglandins as previously

problems of asynchrony

discussed.

Failure to undergo complete luteolysis

• Earlier than expected expression of oestrus. The

normal recommendation is to serve on observed

An alternative to the use of oestradiol as a luteolytic

oestrus should cattle be available for service earlier

agent in combination with progestagens is to use a

than the time planned for insemination.

prostaglandin. Whilst problems of prostaglandin usage

• Failure to exhibit behavioural oestrus due to slow or

have been referred to above, they are clearly far more

abnormal follicular development or true anoestrus

potent luteolytic agents than oestradiol. Prostaglandin

is usually injected on the day before progestagen with-

drawal. Various studies have shown that such com-

Synchrony after progestagens

binations give well-synchronized oestrus and endocrine

There are two major circumstances in which synchrony

responses (Beal, 1983; Peters, 1984). However, there

may be incomplete following progestagen treatment.

have been few reports where fixed-time AI has been

used (Smith et al., 1984). Unfortunately, such a treatment combination would obviously add further expense

Ineffectiveness of the luteolytic agent

to a controlled breeding programme.

As discussed above, oestradiol is often used as a lute-

olytic agent, along with progestagen treatments. If, for

The use of low dose oestradiol

example, a nine-day progestagen treatment is started,

without a luteolytic agent, at day 9 of one cycle and

As detailed earlier, low (1 mg) doses of oestrogen have

finishing before day 1 of the next, then these animals

been used in the pro-oestrus period after removal of

should synchronize adequately, since the end of treat-

an intravaginal device. This is said to enhance the pos-

ment either coincides with, or occurs after, luteolysis (or *itive feedback that promotes the pre-ovulatory surge of*

the progesterone blocks ovulation). However, if treat-

the pituitary gonadotrophin, luteinizing hormone,

ment is started between days 2 and 8, then the corpus

which leads to ovulation. It is also said to enhance the

luteum can outlive the progestagen treatment. Hence,

behavioural expression of oestrus.

it is for cows in the early stages of the cycle that the

luteolysin is required. If it is assumed that the group of

Prolonged follicular phases

cows is cycling at random, then one would expect about

30 per cent of them to be in this category and to respond

This phenomenon has been associated with a delay in

poorly to oestrous synchronization using a progestagen

oestrus and ovulation. Therefore a logical approach

Table 42.2

Effect of cloprostenol treatment of cyclic cows that had not been observed in oestrus by day 50 after calving (from Ball, 1982).

Treatment

Time of insemination

No. of cows

Calving-to-conception

interval (days)

None until 90 days after calving

Observed oestrus

166

107.4

Cloprostenola

Observed oestrus

61

98.1

Cloprostenola

2 and 3 days after injection

75

104.0

a 0.5 mg cloprostenol (Estrumate, ICI) was injected intramuscularly 10–14 days after ovulation had occurred as judged from three times weekly milk progesterone measurements.

might be to attempt artificially to induce ovulation

formance. These will not be discussed in detail here but

at a standard time after prostaglandin treatment. A

they may be summarized as follow:

single injection of gonadotrophin-releasing hormone

• In adult cows the calving rate of control groups

(GnRH) administered approximately 60 hours

to single AI at observed oestrus is of the order of

after prostaglandin injection (Coulson et al., 1980) has 50 per cent. Most studies report equivalent rates

the effect of inducing a preovulatory-type LH surge

in treated cows.

normally associated with ovulation. This procedure has

• Fertility results are often up to 20 per cent better in

been used following synchronization of follicle devel-

heifers than in cows.

opment with GnRH as described earlier. There are also

• In general, single fixed-time AI might be expected

many reports on using GnRH after observed oestrus to

to result in 10–15 per cent lower pregnancy rates

produce a predictable ovulation in order to enhance

than two fixed-time AIs.

conception success. This approach is discussed later.

• It is clear that the best reproductive performance is

achieved when oestrous cycle control is combined

Acyclic cows

with insemination at observed oestrus. In that situ-

ation the reproductive performance of treated cows

This problem may be due to ineffective management in

may often be higher than that of controls. This may

that either the cows are being treated too early after

happen particularly in a herd where the efficiency

calving or that nutritional management is, and has been,

of oestrous detection is normally low. Following

inadequate (see Chapter 9). Assuming these problems

a synchronization treatment, it is to be expected

are not present, then acyclicity may he overcome in

that the vast majority of cows should show oestrus

a proportion of cows by the use of progestagens as

within 10 days after treatment. Therefore, the effect

opposed to prostaglandins.

of treatment in this situation is to concentrate the

occurrence of oestrous periods, so that detection

Effect of the length of progestagen treatment on

efficiency can be increased over a relatively

pregnancy rate

short time. Results of studies on the use of the

prostaglandin analogue cloprostenol with either

The deleterious effects of long-term progestagen

fixed-time AI or observed oestrus are shown in

treatment on fertility have already been discussed.

Table 42.2 and help illustrate the advantage of

However, there is some evidence that even short-term

insemination at observed oestrus. Following retro-

treatments can cause reduced fertility, particularly

spective analysis of data from 17 published trials

where the treatment is started during the late luteal

McIntosh et al. (1984) concluded that prostaglandin

phase of the cycle. It is possible that this occurs because

treatment combined with insemination at observed

the animal has been exposed to an uninterrupted long-

oestrus improved conception rates over controls by

term progestagen treatment, albeit a combination of

an average of 7 per cent.

endogenous and exogenous sources.

Field evaluation of oestrous

Establishment of pregnancy

synchronization techniques

Many field trials have been carried out to assess the

The ability to conceive is clearly vital in determining

effect of the various treatments on reproductive per-

reproductive performance. A low pregnancy rate to first

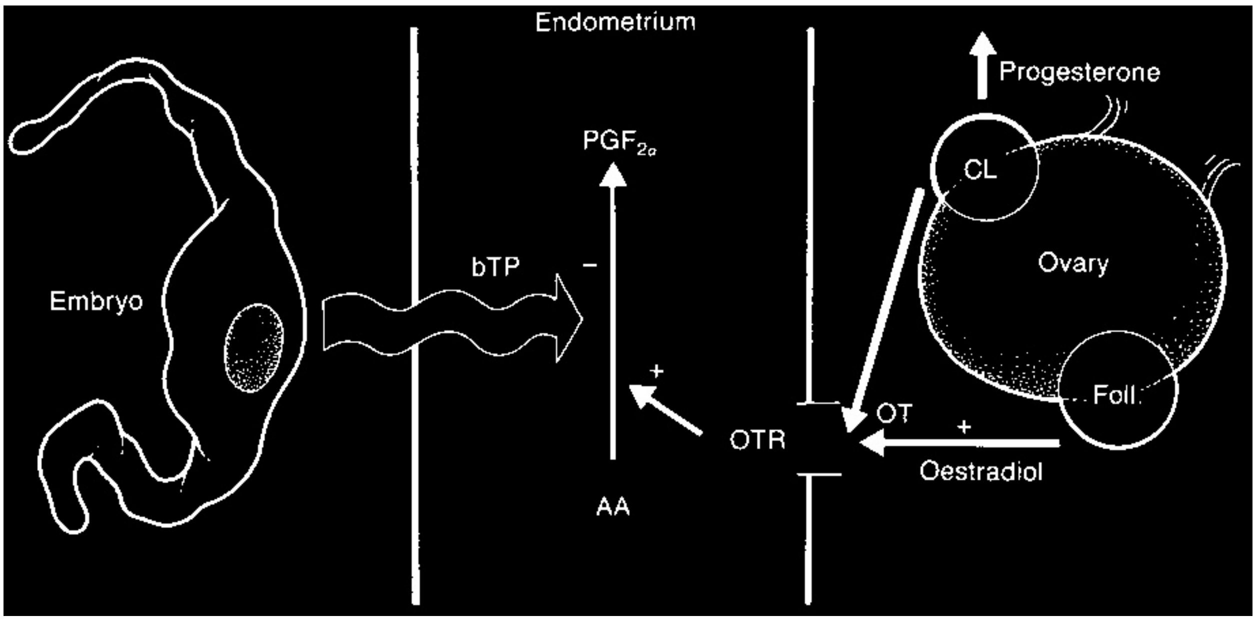


Fig. 42.4

Possible endocrine relation-

ship between the early embryo. endo-

metrium and ovary. BTP, bovine

trophoblast protein; AA, arachidonic

acid; OT, oxytocin; OTR, oxytocin

receptor; CL, corpus luteum; Foll,

follicle.

service is a major cause of poor reproductive perform-

length of the luteal phase in non-pregnant animals

ance. In the absence of specific infectious disease it

(Stewart et al., 1989; Thatcher et al., 1989). This work led has been shown that the major problem here, at least in

to the conclusion that some embryo mortality may be

cattle, is early embryonic death. Total embryonic and

related to a failure of some embryos to produce suffi-

fetal mortality is estimated to be around 38 per cent and

cient trophoblast protein.

it is thought that 70 to 80 per cent of that loss occurs

A number of methods have been used in the field to

between days 8 and 16 after insemination (Sreenan &

improve pregnancy rates in cattle. Diskin and Sreenan

Diskin, 1986).

(1986) reviewed the studies on comparisons of proges-

Pregnancy establishment involves active and passive

terone concentrations in pregnant and non-conceiving

communication between the embryo and the uterus.

cows before and after insemination and concluded

The exact cause(s) of embryonic death is unknown but
that the data were conflicting and inconclusive in all
it is circumstantially related to premature regression of
respects. Progesterone supplementation during early
the corpus luteum. In other words, the corpus luteum
pregnancy has given equivocal results, but does seem to
is normally maintained for the whole of gestation and
be effective where control pregnancy rates are particu-
early embryonic mortality is associated with its early
larly low, i.e. 40 per cent or below. In summarizing the
loss. This results in a decrease in progesterone concen-
results of progesterone supplementation during early
trations allowing the animal to return to oestrus, prob-
pregnancy, Mann and Lamming (1999) conclude that
ably at the normal time.
while progesterone concentrations during the luteal
Before examining methods of reducing embryo
phase are an important determinant of the outcome of
mortality it might be useful to provide a brief review of
pregnancy, they do not appear to be as important as the
findings in relation to the establishment of pregnancy.

timing of the post ovulatory progesterone rise.

This is illustrated in Fig. 42.4. In the non-pregnant

More recently attention has been paid to the use of

animal PGF2a secreted by the endometrium causes

gonadotrophin or GnRH in enhancing early luteal

regression of the corpus luteum. There is evidence that

performance in support of the developing embryo.

oestradiol-17b from developing ovarian follicles stimu-

Peters (1996) found that 1500 iu of human chorionic

lates the synthesis of receptors for oxytocin on endome-

gonadotrophin on day 12 of the cycle resulted in a sus-

trial cells. Oxytocin, produced by the corpus luteum

tained increase in progesterone concentration and an

(Wathes, 1984; Lamming & Mann, 1995), binds to these

increased diameter of the corpus luteum.

receptors, thereby stimulating the synthesis and secre-

It has been common veterinary practice for many

tion of PGF2a. In early pregnancy a protein of molecu-

years to inject cows at the time of service with a

lar weight of approximately 18 000 is secreted by the

'holding' injection using either human chorionic gona-

embryo. This protein appears to exert an anti-luteolytic

dotrophin (HCG) (luteinizing hormone (LH)-like)

effect and has been termed bovine or ovine trophoblast

or GnRH to stimulate endogenous LH release. The

protein 1 (e.g. oTP-1). Stewart et al. (1989) showed that exact physiological rationale for this has not always

the amino acid sequence of oTP-1 has 70.3 per cent sim-

been clear since such treatment could potentially

ilarity, with bovine a2-interferon. Further studies have

have at least two effects. Firstly, there is a widely

shown that oPT-1 and bTP-1 bind to receptors on the

held belief that under some circumstances ovulation

endometrium and intrauterine infusion of trophoblast

may be delayed relative to the timing of oestrus.

proteins or recombinant interferon can extend the

Administration of GnRH will result in preovulatory

gonadotrophin release and subsequent ovulation.

Table 42.3

Pregnancy rate (per cent) to first insemination with

Secondly, LH is considered to be the major luteotrophic

10 mg buserelin injected between days 11 and 13 after insemi-

hormone, at least during the first few days of pregnancy.

nation (from MacMillan el al., 1986).

Therefore, GnRH-induced LH release may facilitate

Trial

Treated

Control

the development and maintenance of the corpus luteum

in the post ovulatory period. Numerous trials have been

A

75.4

62.2

carried out where either HCG (LH) or GnRH has

B

67.5

57.8

been given on the day of service. In a meta-analysis of

Overall

72.4a

60.9

many studies Valks (1996) illustrated that a small effect *was generally achievable (around 8 per cent) and that*

a $P < 0.01$.

the magnitude of any effect was influenced by factors

including body condition score. Study results varied,

with some showing good responses and others showing

no differences from control animals. This could be for

Table 42.4

Pregnancy rates (per cent) to second insemination

one or more of the following reasons:

(from MacMillan et al., 1986).

(1)

Poor design of trials, involving a few animals in

Trial

Treated

Control

each study group. This is a common problem

where fertility rates are being studied. Due to the

A

78.6

69.0

fact that pregnancy rate is discrete variable and

B

94.7

70.8

that rates are very different between farms, very

Overall

85.1a

69.5

large numbers (several hundred per group) may

a $P < 0.05$.

be required to establish statistically significant

differences between groups.

(2)

The actual cause of pregnancy failure may differ

widely between farms and therefore one may

Thatcher et al. (1989) suggested that buserelin acts in be attempting to rectify many different primary

these situations by disrupting normal waves of ovarian

problems by the use of such a treatment. The

follicular growth and oestradiol secretion, resulting in a

primary cause is often impossible to diagnose, at

failure of the luteolytic mechanism (see Fig. 42.4).

least at that time.

Mann and Lamming (1995), however, maintain that

(3)

Thus it is probably a fair summary to state that

GnRH causes a short-lived reduction in oestradiol

the best results for the improvement of pregnancy

secretion which reduces the stimulus to the develop-

rates have been achieved where the control or

ment of the luteolytic mechanism.

background fertility of the herd is poor, although

there are some exceptions to this.

MacMillan et al. (1986), attempted to support the

corpus luteum when it became susceptible to the lute-

Pharmacological induction

olytic mechanism, i.e. approaching day 16 after oestrus in

of parturition

the cow. Treated cows (approximately 225) were given a

single injection of 10 mg buserelin (a synthetic analogue

Many attempts have been made to induce parturition

of GnRH) on day 11, 12 or 13 after AI. Treated and

artificially in the final days of gestation. These methods *control cows were palpated at six to nine weeks to deter-*

have used exogenous hormones to simulate the mech-

mine pregnancy status,cows returning to service were re-

anisms involved in the normal parturition process.

inseminated. Pregnancy rates at six to nine weeks were

These have included the use of corticosteroids, oestro-

72.5 per cent and 60.9 per cent for the treated and control

gens and prostaglandins since these are all involved in

cows respectively (see Table 42.3). Of those cows return-

the endocrine pathway (see Fig. 42.5).

ing to service the pregnancy rates to second service were

These are several indications for the induction of

85.1 per cent and 69.5 per cent for treated and control

parturition in cows. Firstly, in countries such as New

cows, respectively (see Table 42.4).

Zealand, where a tight seasonal calving pattern is often

In the UK a similar approach was adopted, with 1619

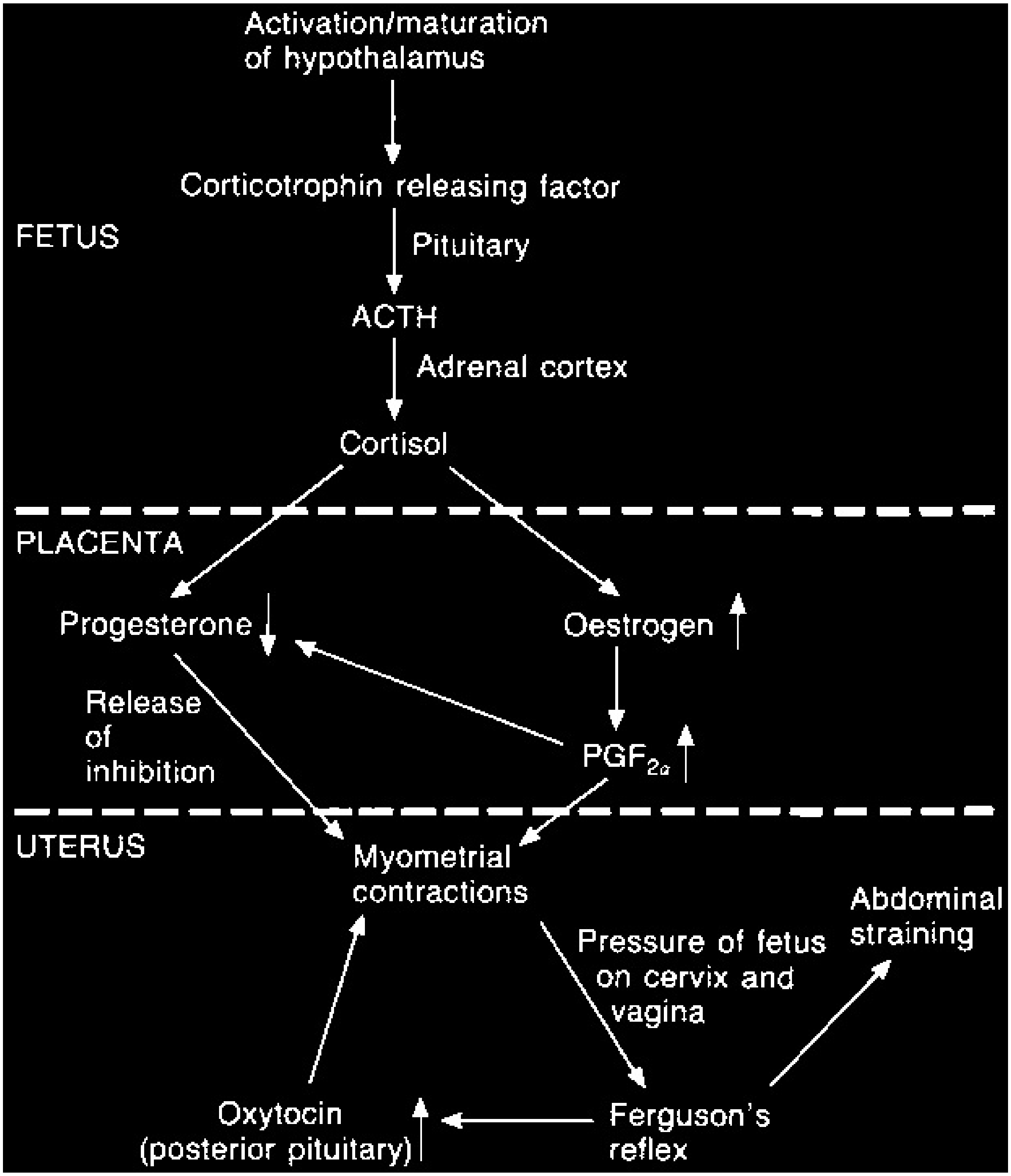
required, this is considered to be an important aid to

cows studied (Sheldon, 1993). When GnRH was used at

optimum management and utilization of feed resources.

11 days after insemination first service pregnancy rates

Secondly, cows can be induced to calve at a time when were enhanced by 9.4 per cent when compared with supervision is most readily available. Thirdly, if it is untreated controls. This benefit rose to 30 per cent in suspected that a high calf birth weight might result in cows treated at third and subsequent services. dystokia, early induction may alleviate the problem.



Oestrogens

There is no clear evidence that exogenous oestrogen is effective in inducing parturition in cows, although in *one trial cited by First (1979) treatment with oestradiol-17b before corticosteroid treatment shortened the time to delivery and reduced the variation between cows.*

Prostaglandins

Prostaglandins, both PGF2a and synthetic analogues, may be used to induce parturition in cows, although treatment before day 270 of gestation is not recommended. Parturition usually occurs between one and eight days after injection, but at an average of three days. A higher incidence of retained placenta compared to non-treated cows may be expected.

A study under UK conditions (Murray et al., 1984) used a treatment regimen whereby cows were injected with 20 mg dexamethasone and those that had not calved 10 days later received an injection of 0.5 mg cloprostenol (an analogue of PGF2a). Although there was a high incidence of retained placenta, this did not

Fig. 42.5

The endocrine pathways controlling the induction of

affect subsequent reproductive performance. It was

parturition.

concluded that, provided management was organized

adequately to supervise parturition and to take care of

the newborn calves, then this procedure could be

Methods of induction of parturition

carried out to advantage.

A characteristic of early studies on the pharmaco-

Corticosteroids

logical induction of parturition was the high rate of

Parturtition can be induced quite reliably from about

calf mortality and post calving problems, particularly

day 255 of pregnancy onwards by a single injection of

retained placenta. An important determinant of the

a synthetic glucocorticoid, such as dexamethasone,

incidence of retained placenta appears to be the oestro-

betamethasone or flumethasone. It is assumed that such

gen status of the cow at the time of induction. As dis-

therapy simulates the effect of the fetal adrenal cortex

cussed above, oestrogen concentrations rise during late

at term.

pregnancy, hence the oestrogen status may simply be

Induction of parturition using corticosteroids is an

a reflection of the proximity of term or ‘readiness to
important part of management in many New Zealand
calve’. From an exhaustive review of the available
dairy herds and considerable experience of the tech-
literature, First (1979) concluded that if induction
nique has been gained (Welch et al., 1979; Verkerk et al.
is carried out when oestrogen levels are elevated,
1997). Both short- and long-acting formulations have
both glucocorticoids and prostaglandins are effective.
been used.
However, glucocorticoids were the most appropriate
Short-acting formulations, generally in the form of a
treatment if induction was to be attempted earlier. The
soluble ester of the steroid, usually result in parturition
earlier that interference is attempted, the higher the
two to three days later. Although the calves are usually
probability of calf mortality, retained placenta and
viable, this method has been associated with a high rate
other related problems.
of retention of the fetal membranes. Verkerk et al.
(1997) used 21 mg dexamethasone isonicotinate fol-

Delay of parturition

lowed by a short acting formulation of dexamethasone

sodium phosphate 10 to 14 days later. Using this regime

It is also possible to delay parturition for several hours

35 per cent of cows calved before the second corticos-

by pharmacological means. This is carried out so that

teroid had been administered. This was more common

supervision for calving can be more conveniently and

if the cow was in the last 30 days of gestation. A 14

readily available. Injection of the potent adrenergic

per cent incidence of retained fetal membranes was

drug clenbuterol inhibits myometrial contractions, thus

recorded.

slowing down the first stage of labour. However, if treat-

ment is started after second stage labour has already

esterone during early pregnancy in cattle. Reproduction in commenced, it would have little effect. Clenbuterol is

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Adult Cattle

Major Infectious Diseases

Chapter 43

Viral Diseases

(a) Bluetongue

691

Not all the BTV types are found throughout this

(b) Enzootic bovine leukosis

693

enzootic region, and the distribution of the different *(c) Foot-and-mouth disease*

700

types can vary between years. BTV types found within

(d) Rinderpest

707

a region tend to have greater genome sequence homol-

(e) Vesicular stomatitis

710

ogy, in genome segments other than those which encode

(f) Bovine immunodeficiency virus (BIV)

713

the serotype-specific outer capsid proteins, than their

designated serotype number would suggest. The type is

defined by the outer capsid proteins alone, and while

(a) Bluetongue

these are found to differ between different serotypes

found in a particular region, the remaining genome

R.P. Kitching

segments show high levels of sequence homology. The

BTV types have therefore been additionally grouped

into Australian types and African types, with the

Bluetongue (BT) is an infectious, non-contagious North American types being more closely related to disease of ruminants characterized by congestion, the African. The Australian BTV type 1 has more in oedema and haemorrhage. The disease is caused by common with other Australian types than with the strains of orbivirus, within the family Reoviridae. African type 1, although sharing with the African type The genus orbivirus, Reoviridae also contains Ibaraki its antigenic determinants. This diversity may explain disease virus of cattle, epizootic haemorrhagic disease the marked difference in pathogenicity of the strains of virus of deer (EHD), African horse sickness virus and BTV which does not appear to be related to a specific Colorado tick fever virus. The outer shell of bluetongue type designation; it also makes epidemiological studies virus (BTV) has a diameter of 65 nm, within which is an based on serotype determinations of doubtful sig- inner shell of 32 ring-shaped capsomers. The genome nificance. Recombination can occur between different consists of ten segments of double-stranded RNA *strains of BTV which adds further to the potential for*

which code for the structural and non-structural viral

diversity of BTV isolates.

proteins and which can be separated according to their

The closely related EHD group of viruses has been

relative sizes by polyacrylamide or agarose gel

isolated in the USA, Canada, Nigeria and Australia,

electrophoresis. Two of these segments (numbers two

whereas Ibaraki disease virus is restricted to South

and five) code for the outer structural proteins (VP2

Korea, Japan, Philippines and Indonesia.

and VP5) which determine the serotype of the virus.

Twenty-four immunologically distinct BTV serotypes

History

have so far been identified by virus neutralization tests;

however, it is probable that more types will be identi-

Bluetongue was first diagnosed in South Africa in sheep

fied in the future. BTV is sensitive to low pH and

at the beginning of the twentieth century. It was first

storage at -20°C; it is partially resistant to lipid solvents.

seen outside Africa in 1943 in Cyprus, although it had *possibly been present in Cyprus as early as 1924.*

Subsequently BT was diagnosed in Israel in 1951, in

Distribution

Pakistan in 1959 and in India in 1963. A disease at

The distribution of BTV is approximately defined by

first identified as sore muzzle of sheep in Texas in 1948

the latitudes 40°N and 35°S, which includes most of

and California in 1952 was the following year diagnosed

Africa, the Middle and Far East, Northern Australia,

as BT. Between 1956 and 1960, BTV caused a major

United States of America, Central America and South

epizootic in sheep in Portugal and southern Spain,

America north from Southern Brazil, Paraguay and

which reportedly resulted in the loss of 180 000 animals,

Bolivia.

but the virus then disappeared from the region.

Epidemiology and transmission

isolated on less than three occasions and those which

shed virus over a two to three week period. BTV could

The distribution of BTV between 40°N and 35°S

only be isolated from the semen when there was a

reflects the distribution of its main biological vectors,

concurrent viraemia. Six out of nine susceptible

certain tropical and subtropical species of Culicoides

heifers inseminated with the BTV-contaminated semen

midges, in particular C. imicola in Africa and the Middle became pregnant and three of the nine became

East, C. variipennis in North America and C. brevitar-viraemic. None of the calves born at term showed any

sis, C. fulvus and C. wadai in North Australia.

clinical abnormality. Considerable importance has been

The adult female Culicoides lays her eggs in damp

attached to reports of a bull which was persistently

muddy areas containing decaying vegetable material

infected but seronegative from birth and intermittently

or in cattle dung, two to six days after a blood meal.

shed virus in semen over an 11-year period (Luedke

Depending on the temperature these eggs may hatch in

et al., 1982). Attempts to duplicate the conditions which two to three days into larva. The larval stage lasts 12–16

produce persistently BTV-infected, seronegative calves *days, followed by pupation and, two to three days later,*

have been unsuccessful.

the emergence of the adult Culicoides. In the

subsequent 24 hours the adult females take a blood

Host range

meal and mate, and they will continue to take a blood

meal every three to four days until the end of their life,

Sheep, goats, cattle, water buffalo, camels and many

which may last for 70 days, but probably rarely exceeds

wild ruminants are susceptible to infection with BTV.

10. Optimum conditions are between 13°C and 35°C.

BT is predominantly a disease of sheep and has only

Larvae of temperate species can remain dormant over

been reported as a disease of cattle in the USA, South

winter and pupate the following spring. Seven to ten

Africa, Israel and Portugal.

days after taking a BTV infected blood meal, vector

species of Culicoides midge are able to transmit virus.

Pathogenesis

Culicoides usually feed at dusk, during the night or at dawn, and are subject to being transported, sometimes

Infection follows the bite of an infected Culicoides

over considerable distances, by strong wind currents.

midge. The virus is carried to the local lymph node

The passive movement of infected Culicoides may

where primary replication occurs before dissemination

be responsible for the introduction of BT into areas

of virus throughout the body. Viral replication then

usually outside the enzootic region, such as Western

continues in the spleen, lungs, bone marrow and other

Turkey and Cyprus. This introduction of BTV into an

lymph glands. In sheep, BTV also replicates in the

area may be associated with abnormal wind currents

endothelial cells of the blood vessels and, unlike in

or may be a regular occurrence. The winds of the

cattle, has been clearly shown to cross the placenta and

Intertropical Convergence Zone annually reintroduce

can replicate in the developing fetus causing fetal

BTV-infected Culicoides to South Africa from Central

resorption, abortion or developmental abnormalities.

Africa. The movement of BTV into Sudan from Central

The peak viraemia occurs two to three weeks after

Africa is also associated with a prevailing wind from the

infection, its duration and severity depending on the

South. However, BTV may also become enzootic in

strain of BTV.

new regions as climatic changes allow the main vectors

to extend their breeding sites or, alternatively, virulent

Clinical signs

strains of new serotypes of BTV may be introduced into

an area already infected with mild or avirulent strains.

BT in cattle is seen as a transient fever followed by

Within BT enzootic regions the prevalence of sero-

hyperaemia and erosions of the buccal and lingual

positive animals may be very localized around areas

mucosa and nose and, rarely, the teats. Affected cattle

particularly suitable for the breeding and survival of

salivate excessively and may walk with a stiff gait.

Culicoides, so called 'hot spots'. The possibility also The skin of the nose appears mottled and dark and has

exists for new species of Culicoides to take on the role been described as 'burnt muzzle', and may completely

of BTV vectors; it has recently been shown that some

slough. Fewer than 1 per cent of cattle in the USA

British species of Culicoides can biologically transmit infected with BTV show signs, and the lesions may be

BTV under experimental conditions.

due to a delayed type hypersensitivity reaction. There

Bulls may shed BTV in their semen intermittently

is considerable controversy over whether BTV can

during the viraemia following infection. Bowen et al.

cross the placenta of the pregnant cow. If the virus is

(1985) classified bulls into three categories, those from

able to cross the placenta it may only do so in associa-

which virus could not be isolated from the semen (the

tion with other placental pathogens, or be restricted to

majority), those from which only low titres of virus were

only certain strains of BTV.

Diagnosis

erologous protection against a third serotype (Jeggo,

1986). There would still be the difficulty of predicting the

It is not possible to make a diagnosis of BT on solely

probable challenge BTV serotypes. The distribution of

clinical signs. Cattle infected with BTV develop precipi-

the serotypes of BTV tends to be dynamic, with some

tating antibody detectable on an agar gel precipitation

serotypes being present one year to be replaced the fol-

test (AGPT) which is not BTV serotype specific. Type-

lowing year by other serotypes.

specific neutralizing antibodies can be titrated in a virus

There is no evidence to indicate that BT can be

neutralization test using BHK21 cells in a microplate

transmitted during embryo transfer using standard

against each of the BTV types present or suspected

techniques. BTV can be transmitted in the semen col-

present in the area. Some cross-reaction is seen on the

lected from viraemic bulls, but reports of a persistently

AGPT with antibodies to EHD virus, however a group-

infected, seronegative animal (Luedke et al., 1982) have specific competition ELISA using monoclonal antibody

not been confirmed by further research.

which does not cross-react with EHD antibody is now

available. The viraemia associated with BTV infection

can persist up to 120 days, in the presence of neutraliz-

Economic significance

ing antibodies. The virus is attached to the red blood

The cost of BTV infection in a 1400 dairy cow herd in

cells and appears to be protected from the developing

California, in terms of reduced fertility was $23 000 over

immune response. Intravenous inoculation of sonicated

a 52-week study period (Osborn et al., 1986). Of parti-blood into eight to ten-day old embryonated chicken

cular interest in this study was that the dairyman

eggs is a very sensitive laboratory method of isolating

responsible for the herd was unaware of the passage of

virus from blood, whereas the inoculation of sus-

BTV through the herd and the associated increase in

pect material directly into sheep and the examination

return to service of the affected animals. There is, there-

of sequential serum samples for evidence of serocon-

fore, the possibility that BT has a greater economic sig-

version is the most sensitive test available. Virus can

nificance in cattle than previously thought and should

also be grown in the yolk sac of six-day old eggs kept

not be considered solely in terms of isolated epizootics.

between 33.5°C and 35°C, lamb kidney cells, hamster

Animals and semen from BTV enzootic areas are

lung cells, BHK21 cells, some mosquito cell lines and

subject to movement and export restriction, the costs of

following intracerebral inoculation of day old mice.

which are of greater significance than the direct effects

Chick embryos which die from BTV infection have a

of disease. Many of these restrictions have been

characteristic haemorrhagic appearance.

formulated on unconfirmed experiments, but they re-

flect the cautious attitude of the veterinary authorities

of importing countries.

Control

Bluetongue is a non-contagious disease and can only

spread by the bite of infected Culicoides or the direct transfer of blood or semen from an infected to a

(b) Enzootic bovine leukosis

susceptible animal. Bluetongue may be controlled by

eliminating the vector or vaccinating susceptible

C. Venables and M.H. Lucas

animals against the serotypes prevalent in the area.

Control of insects has usually been directed towards *those insects which carry human disease, and experi-*

Two forms of bovine leukosis have been recognized,

ence gained in these programmes could undoubtedly be

enzootic bovine leukosis (EBL), which occurs in adult

of value in BT control. However, there would be little

cattle and is associated with bovine leukaemia virus

economic justification for attempting to control Culi-

(BLV) infection, and, less commonly worldwide, spo-

coides solely to prevent BT in cattle

radic bovine leukosis (SBL), which affects calves and

Cattle can be protected against BTV infection by vac-

young cattle and is of unknown aetiology.

cination (p. 1018) with live attenuated vaccine, although

it would be extremely unlikely for it to be considered

Enzootic bovine leukosis

worthwhile. The practice of mixing together vaccines

against each of the prevalent serotypes may result in the

Enzootic bovine leukosis was first described over 100

failure of one or more of the serotypes present in the

years ago in Europe. Clinical disease, in the form of

vaccine to replicate (Jeggo, 1986). However, vaccination *multiple cases of lymphosarcoma, occurs most fre-*

against one serotype, followed one month later with a

quently in animals from three to eight years of age.

second serotype can provide protection not only against

Tumours may develop in peripheral lymph nodes, and

the two serotypes in the vaccines, but can provide an het-

are therefore easily detectable, or they may be confined

to internal organs, producing rather ill-defined signs. In

significant animal health problems, EBL can also rep-

some areas of the world appreciable economic losses

resent a major cause of economic loss.

occur through the tumorous form of the disease. Early

workers recognized that the disease could spread slowly

Transmission

from known foci to adjoining regions, and because lym-

phosarcoma often occurred in familial aggregations it

Virus is present in colostrum and milk, in tracheal and

was interpreted as evidence that the disease was her-

bronchial secretions and sometimes in nasal secretions

itable. It has since been established that EBL is caused *and saliva of infected animals. Virus is also found in the*

by bovine leukosis virus (BLV). This virus was first

cellular fraction of blood, but not in plasma or serum

isolated from mitogen-stimulated, peripheral blood

unless haemolysis has occurred. However, it has not

mononuclear cells by Miller et al. (1969) in the USA.

been found in faeces or urine and is probably absent

from the semen of most infected bulls. Very small

numbers of infected blood cells are capable of trans-

The virus

mitting BLV. As little as 0.1 ml of whole blood from an

Bovine leukosis virus is an RNA virus belonging to the

infected cow can be infectious when given intra-

Retroviridae family. The family includes tumour and

dermally to cattle.

non-tumour inducing viruses of many species including

man. The virus particle is spherical, 80–100 nm in

Experimental transmission: Cattle can be infected

diameter and enveloped with surface glycoprotein pro-

by the intratracheal route, although not as reliably as by

jections. The virus envelope glycoprotein, gp51, is be-

the subcutaneous route. Infection can be transmitted lieved to interact with a cell surface receptor, initiating by instillation of infected lymphocytes into the nose and receptor-mediated endocytosis, leading to entry into the by aerosol exposure to cell-free BLV. A calf can be host cell. Within the particle are three non-glycosylated infected orally when newborn, but is probably resistant protein structures, the matrix, the nucleocapsid and the to infection by this route by three weeks of age. Adult core. Three enzymes, reverse transcriptase, integrase cattle are not susceptible to infection by the oral and a protease, are also packaged within the virion. The route. Adult cows can be infected by the instillation retrovirus genome is composed of two identical copies of infected lymphocytes into the reproductive tract. of positive sense, single-stranded RNA. During replica- Semen mixed with the inoculum may, however, have an tion, viral RNA is converted to DNA by means of the inhibitory effect on transmission, and susceptibility of enzyme reverse transcriptase. This enables retroviruses the genital tract of cows may decrease at the time of *to integrate into the host DNA, establishing infection*

oestrus. The virus has been transmitted experimentally

that persists for the life of the animal. Bovine leukosis

to sheep and cattle by rectal inoculation of whole blood

virus is present in a subpopulation of circulating B-

from infected cattle.

lymphocytes where its genetic information may be found

Sheep can readily be infected experimentally by par-

integrated at multiple sites in the cellular DNA. Lym-

enteral routes, but not consistently by the oral route.

phocytes of BLV-induced tumours appear to be of the

Between 103 and 106 lymphocytes from infected cattle,

B-cell lineage. Tumour cells are monoclonal or oligo-

given intravenously, are sufficient to infect sheep.

clonal for the site of BLV integration. No evidence has

Tumours arise at a higher frequency and after a much

been observed so far for a common integration site for

shorter time than in cattle and may develop after 10

BLV provirus in different tumours.

months to three years. As in cattle, various lymph nodes

BLV probably does not remain viable for long *and visceral organs including heart, abomasum, uterus,*

outside the host environment. It is readily inactivated

kidney and urinary tract are commonly affected. Per-

by exposure to ultraviolet light, heating at 56°C for 30

sistent lymphocytosis is not usual in sheep; once the

minutes and pasteurization. The virus can, however,

number of circulating lymphocytes rises it invariably

remain viable in blood stored at 4°C for at least two

indicates the onset of tumour development. In contrast

weeks.

to cattle, contact transmission does not occur when

infected sheep are kept in close contact with uninfected

sheep. Goats inoculated with BLV orally and parenter-

Distribution

ally become infected and develop antibody but do

BLV is distributed worldwide, but with marked regional

not usually develop persistent lymphocytosis or lym-

differences in prevalence. It is most common in North

phosarcoma. The incubation period in sheep and goats

and South America, Australia and some regions of

is variable, ranging from about two to 16 or more weeks.

Africa. In Western Europe BLV has largely been eradi-

Experimental infection with BLV as indicated by per-

cated in recent years, but it continues to be common in

sistent antibody production has been reported for chim-

many areas of Eastern Europe. In addition to causing

panzees, macaques, pigs, domestic rabbits, cats, dogs,

deer and rats. There is no evidence for the production

It was concluded that it was safe to transfer embryos

of BLV antibodies following BLV inoculation in the

from infected cows providing that the embryos were

mouse, chipmunk, ground squirrel, Japanese quail and

washed before transfer. Virus transmission to dam or to

chicken.

progeny is not associated with the use of semen from

infected bulls for artificial insemination (Al). Naturally

Natural transmission: Transmission of virus by contact occurring
lymphosarcoma in sheep is rare. A retrovirus

is one of the most important means of spread of BLV

has been isolated from a diseased sheep and was found

in a herd. The rate of spread of virus is influenced by *to be identical to BLV. Where BLV is found in sheep a*

management and husbandry practices that determine

bovine origin must be suspected. The virus has also

the degree of contact between animals. Because the

been found in capybaras and water buffaloes. Human

virus probably does not survive for long in the envi-

beings potentially exposed to BLV do not develop anti-

ronment and because infectivity is associated with the

BLV antibodies.

cellular fraction of secretions it is therefore assumed

that transmission takes place by direct exchange of

Signs

infected lymphocytes in nasal, saliva and tracheo-

Following infection of an animal with BLV disease

bronchial fluids and possibly vaginal discharges. The

progression depends on genetic, environmental and

role of milk in transmission under natural conditions

unknown factors. Over 60 per cent of infected cattle are

does not appear to be very great. The presence of spe-

asymptomatic, however almost all develop detectable

cific antibody in these secretions inhibits virus trans-

antibodies. Between 30 and 70 per cent of infected

mission, and also the susceptibility of the calf to oral

animals show persistent lymphocytosis, but less than 10

infection decreases with age. Vertical transmission of

per cent develop lymphosarcoma. Persistent lymphocy-

the virus genome via the gametes does not occur.

tosis is seen in 28–85 per cent of tumour cases. In BLV-

However, congenital transmission by the transplacental

infected cattle with leukaemia the increase in leukocyte

route occurs occasionally. Not all infected cows produce

count is due to an increase in B-lymphocytes. The per-

infected fetuses and individual cows may give birth to

centage of B-lymphocytes in the blood can rise to 80

some infected and some uninfected calves. Fetuses

per cent, compared with normal values of 15–20 per

infected in utero vary in their serological and virologicent. In clinically normal BLV-infected cattle without

cal status, and some may develop neoplastic lesions in

lymphocytosis there can still be an increase in B-

the lymphatic tissue. Transmission by biting insects may

lymphocytes to 40–50 per cent.

be important in tropical and subtropical climates, but

Clinical signs (Figs 43.1, 43.2) in animals that develop

statistical evidence of seasonal trends is inconclusive.

tumours depend on the particular organ or organs

Iatrogenic transmission is probably one of the main

involved. One or more superficial lymph nodes may be

reasons for the high prevalence of infection in some

enlarged and these can be felt as lumps beneath the

herds. Infected blood transferred from one animal to

skin, especially in the neck and hind flank areas.

another on a hypodermic needle can transmit bovine

However, when the internal lymph nodes are the only

leukosis virus. The use of multidose syringes has been

ones affected diagnosis may be more difficult. Tumours

incriminated in virus spread, however there is no

can occur in the abomasum, right side of the heart,

published evidence to associate intradermal tuberculin

spine, uterus, lymph nodes, central nervous system (Fig.

testing with an increased incidence of enzootic bovine

43.3) and the retrobulbar aspect of the orbit. Clinical

leukosis. Dehorning and ear tattooing have been iden-

signs may include depression, indigestion, chronic bloat,

tified as possible methods of transmission. It has been

displaced abomasum, lameness or paralysis. Abdominal

suggested that the technique of rectal palpation to

tumours are sometimes detected by rectal palpation

examine the reproductive tracts of cows could be a

during pregnancy examination. Infection with BLV

means of transmission if separate clean gloves were not

does not appear to be associated with lower milk pro-

used for each animal.

duction, impaired reproductive capacity in either sex, or

Transfer of embryos from BLV-infected cows into

with mastitis, lesser longevity or increased susceptibil-

uninfected cows is not associated with transmission of

ity to other diseases. Bovine leukosis virus does not

virus. Virus has nevertheless been found in uterine flush

appear to cause significant immunosuppression in the

fluid, but this may be due to contamination with blood

fetus or adult animal.

cells. Virus has not been found in eggs or embryos from

infected cattle. Ova, morulae and blastocysts have been

Diagnosis

exposed in vitro to BLV, but after washing no virus

could be detected. Embryos similarly exposed to virus

Haematology: Herds with a high incidence of lym-

were washed and then transferred to uninfected cows,

phosarcoma often contain many clinically normal cattle

which did not subsequently develop antibodies to BLV.

with persistent lymphocytosis. The development of

Fig. 43.2

Adult cow with enzootic bovine leukosis showing loss of condition, with wasting of lumbar muscle, brisket and sub-mandibular swelling. (Courtesy of J. Miller, USA.)

Fig. 43.1

A cow with enzootic bovine leukosis showing enlarge-

ment of the mammary lymph nodes. (Courtesy of Dr J. Miller,

USDA National Animal Diseases Center, Ames, Iowa, USA and

editors and publishers of Modern Veterinary Production.) lymphosarcoma is often preceded by persistent lymphocytosis in the absence of any clinical signs. Haema-

tological methods were the main diagnostic tools for a

number of years and various 'keys' were developed

Fig. 43.3

Brain from a cow with neoplasm between cerebellum

relating lymphocyte counts and age, presenting

and medulla. (Courtesy of J. Miller, USA.)

maximal values above which an animal was declared to

have persistent lymphocytosis. The percentage of B-

lymphocytes in normal cattle varies from 18 to 28 per

cent. In BLV-infected cattle with persistent lymphocy-

sensitive than the p15 and p24 tests or haematology for

tosis the percentage of B-lymphocytes can increase to

the detection of infected animals. The test is simple and

as high as 70 per cent. In clinically normal BLV-infected

practical and has been very widely used. The glycopro-

cattle without lymphocytosis the B-lymphocytes are

tein antigen employed in the test is prepared from the *increased to 40–50 per cent.*

supernatant fluid of a cell line persistently infected with

BLV.

Serology: The agar gel immunodiffusion test (AGIDT)

Using BLV-infected cell monolayers, sera can also be

can be used to detect specific antibody to viral antigens

tested for specific antibodies by indirect immunofluo-

p15, p24 and gp51. The test for gp51 antibody is more

rescence or immunoperoxidase techniques. Various

neutralization tests have also been described, based on

and politics may all be significant. Increasingly, driven

the ability of antibodies to inhibit the effects of BLV in

by trade advantages, EU Member States and other

cell cultures. These include a virus neutralization and

European countries have set in place surveillance and

syncytia inhibition tests. The complement fixation test

eradication strategies. Many of these have been

using viral antigens from a cell line infected with BLV

successful and the countries are now officially EBL-

has been used, but seems to be less sensitive than the *free. The types of actions used, linked with serological*

agar gel immunodiffusion test for antibodies to the gp

monitoring, to produce BLV-free herds are detailed

antigen. A reverse transcriptase inhibition test, based

below:

on the fact that serum of some leukaemic cattle inhibits

• BLV-positive animals are kept physically separated

the activity of the reverse transcriptase of BLV, has

from BLV-negative animals. Check testing of nega-

been described. Radioimmunoassay is very sensitive

tive animals is carried out at regular intervals.

but has the disadvantage that radiolabelled reagents

• Calves born to negative cows are kept apart from

and special equipment are required.

infected animals.

Enzyme-linked immunosorbent assay (ELISA) is the

• Calves born from infected cows are reared only on

currently preferred method for the detection of BLV

colostrum and milk from negative cows and are

antibodies. The test can be used with milk or tissue

kept isolated. If serologically negative at seven *fluids as well as serum samples. ELISA is rapid, sensi-*

months of age these calves join the negative

tive and suited to the testing of large numbers of

herd.

samples. Commercially available ELISA kits, suffi-

• Replacement animals should be introduced from

ciently sensitive to permit the examination of pooled

sources known to be virus-free, and should be sero-

sera and milk for screening and surveillance, have

logically screened. Any originating from herds of

formed the basis of successful EBL eradication pro-

unknown status should demonstrate two clear tests

grammes in several European countries.

at six-month intervals before joining the main herd.

• Embryo transfer and Al are sometimes used as part

Isolation and detection of virus: Bovine leukaemia

of a control programme so that new genetic stock

virus particles can be demonstrated by electron

can be introduced with minimal risk of introducing

microscopy in short-term cultures of lymphocytes from

BLV.

BLV-infected animals. Virus can also be recovered from

infected cattle by cocultivation of peripheral blood

Where the prevalence of infected cattle has been low,

mononuclear cells with a susceptible indicator cell, e.g.

as has been the case in most Western European coun-

fetal lamb kidney cells. Several passages of the cultures

tries now free of EBL, serological screening followed

may be required before syncytia can be observed in

by slaughter of reactors has been successfully used.

Giemsa-stained monolayers. Infected cells may be

However, increased prevalence of infection rapidly

specifically visualized, often in advance of syncytium

makes this approach uneconomic.

formation, using immunofluorescence or immunoper-

oxidase techniques. However, as with other retro-

viruses, neither electron microscopy nor virus isolation

Vaccination

is a particularly sensitive method for demonstrating

Preliminary experiments using inactivated BLV, per-

infection.

sistently infected cell lines or purified gp51 indicated

Nowadays, techniques including assaying for reverse that high antibody titres to gp51 could produce some transcriptase activity or demonstrating the presence of short-term protection to BLV infection. However, no specific BLV nucleic acid sequences are frequently successful vaccine is currently available.

used. Polymerase chain reaction (PCR) assays, generally developed to detect BLV proviral DNA and offering exquisite sensitivity and specificity, are rapidly

Public health

gaining the advantage over cultural methods in the research, diagnostic and surveillance fields.

The structural similarities between BLV and the human T-cell leukaemia viruses, HTLVI and II, have led to speculation about the zoonotic potential of BLV. Serological reactions to BLV p24 in two small studies of

Control

people with these diseases and multiple sclerosis have Control measures appropriate to any particular situa- also been reported, but current opinion indicates sero- tion are largely dictated by local factors. Prevalence *logical cross-reactions with HTLV proteins to be the*

of infection is probably the primary consideration,

cause. This is supported by repeated failure to demon-

but economics, husbandry practices, cattle movements

strate BLV proviral DNA in other studies on human

Fig. 43.4

Sporadic bovine leukosis in

calf with parotid lymph node enlarge-

ment. (Courtesy of J. Miller, USA.)

Fig. 43.5

Sporadic bovine leukosis in

calf with submandibular, parotid and

retropharyngeal lymph nodes on the

head and prescapular lymph node

enlargement. (Courtesy of J. Miller,

USA.)

leukaemia patients and the failure of epidemiological

marrow (Figs 43.4–43.7). During the early stages of

studies to demonstrate a link between BLV and human

disease, marked enlargement of superficial lymph

disease.

nodes may be the only clinical sign. But as the

disease progresses internal organs such as the heart

and liver may also become affected, leading to the

Sporadic bovine leukosis

death of the animal.

Lymphosarcoma may be found in young animals in the

• The thymic form is seen in animals 6–30-months

absence of BLV. Three distinct forms are recognized

old. There is massive tumour formation in the

that are collectively classified as sporadic bovine leuko-

thymus and tumorous changes are also seen in

sis (SBL):

the lymph nodes of the neck and thorax (Fig. 43.8).

The condition is fatal.

• The juvenile form in calves under six months of

• The cutaneous form is a rare condition occurring

age involves lymph nodes, liver, spleen and bone

in animals 18 months to three years of age, in

Fig. 43.6

Same calf as in Fig. 43.5 showing gross distension of the head lymph nodes and the prefemoral lymph nodes. (Courtesy of J. Miller, USA.)

Fig. 43.7

Liver from a calf with sporadic bovine leukosis showing the *surface and cut surface with focal neo-*

plastic areas. (Courtesy of J. Miller,

USA.)

which nodular lymphocytic neoplasia is seen in

the skin. The first signs are urticaria-like nodules

(1–2 cm in diameter) in the skin, especially round

the neck, back and thighs (Fig. 43.9). These become

encrusted with thick scabs, and alopecia and

hyperkeratosis follow. Apparent recovery may

take place over several weeks (Fig. 43.10).

However, the remission is temporary, and lesions

reappear together with general lymph node

involvement,

leading to the death of the

animal.

The cause or causes of all forms of sporadic bovine

Fig. 43.8

Bullock showing thymic neoplasm. (Courtesy of J.

leukosis remains unknown.

Miller, USA.)

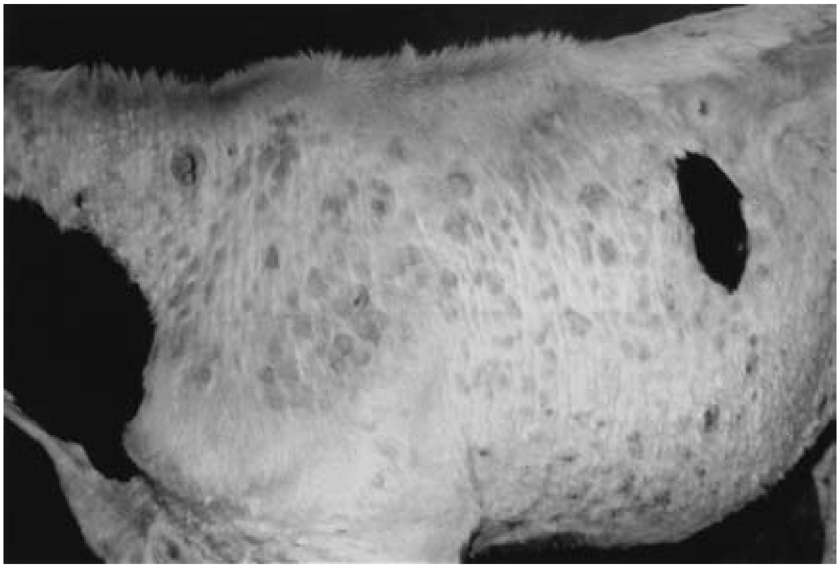

Fig. 43.9

A heifer with acute cuta-

neous leukosis. (Courtesy of J. Miller,

USA.)

Fig. 43.10

Same heifer as in Fig. 43.9

with cutaneous leukosis lesions subse-

quently resolving. (Courtesy of J. Miller,

USA.)

(c) Foot-and-mouth disease

naviridae. There are seven antigenically distinct types

of FMD virus, identified as types A, O, C, SAT (South

R.P. Kitching

African Territories) 1, SAT 2, SAT 3 and Asia 1. Within

each of these seven types there are a large number of

strains which form an antigenic spectrum, from closely

Foot-and-mouth disease (FMD) is a highly contagious

related strains to strains so antigenically different as to

disease of domesticated and wild ungulates character-

almost justify the establishment of additional types.

ized by vesicles in the mouth and on the feet. Hedge-

Attempts to classify the strains into subtypes within the

hogs and very rarely man may also become infected.

types foundered on the ever increasing number of

strains which fulfilled the criteria for creating a new

subtype. New isolates of FMD virus are now referred

Aetiology

to by the World Reference Laboratory for FMD by

Foot-and-mouth disease is caused by infection with a

their type, country of origin, a sequential number relat-

virus of the genus aphthovirus, in the family Picor-

ing to the number of isolates received in that year from

the same country and the final two numbers of the year

Epidemiology

in which they were received, e.g. O India 53/79, Asia 1

India 8/79. The cause of recent infections in Europe,

Foot-and-mouth disease is an extremely contagious

South Africa, Asia, the Far East and the Middle East

disease, with as few as ten infectious units being able to

(Pan Asia strain) was first isolated from an outbreak

initiate disease in a bovine by the respiratory route. The

of FMD in northern India in 1990 (Knowles et al.,

virus can survive in dry faecal material for 14 days in

2001). Classical subtyping is now only of historical

summer, in slurry up to six months in winter, in urine

interest.

for 39 days and on the soil between three days in

Aphthovirus has an icosahedral symmetry and a

summer and 28 days in winter. FMD virus is, however,

diameter of 24 nm. The outer capsid consists of 32 cap-

very susceptible to inactivation by extremes of pH, i.e.

someres and surrounds a single-stranded molecule of

below pH 6.0 and above pH 10.0. It is most stable

RNA of approximately 8000 bases and molecular

between pH 7.2 and 7.6. Within this range at 4°C the

weight 2.8 ¥ 106 daltons. This RNA codes for a single

virus can survive in suitable media up to a year but, as

large polyprotein which is cleaved into eight non-

the temperature is increased, its survival time is reduced

structural proteins (L, 2A, 2B, 2C, 3A, 3B, 3C and 3D)

to eight to ten weeks at 22°C, ten days at 37°C and to

and the four structural proteins (VP1, VP2, VP3 and

less than 30 minutes at 56°C. The survival of airborne

VP4), 60 copies of which make up the outer capsid. The

virus is optimal when the relative humidity is above 60

RNA base sequence is extremely variable, which is

per cent. Natural ultraviolet light in sunlight has little *reflected in variations in the amino acid sequence of the*

direct effect on the FMD virus.

proteins for which it codes. The structural characteris-

Like many diseases, FMD is most commonly spread

tics of the outer capsid proteins of the virus stimulate

by the movement of infected animals; of particular sig-

an immune response in the infected host animal. Thus

nificance are sheep, goats and wild ungulates, because

mutations in the genome which change the structure of

disease in them can be mild, and pigs because of the

these proteins can reduce the ability of a vaccinated

amounts of virus they can excrete. An infected pig

or previously infected animal to resist challenge with

excretes up to 400 million infectious units per day, 3000

mutated virus.

times more than an infected bovine, sheep or goat. In

infected cattle, milk products and semen many contain

FMD virus up to four days before the appearance of

clinical signs and can also be responsible for the spread

Distribution

of disease. Pigs can carry virus for ten days before

Foot-and-mouth disease is endemic throughout sub-

disease is manifested. Lorries, fomites and stockmen

Saharan Africa as far south as Tanzania, and also

may also be contaminated with virus from infected car-

Equador, Bolivia, Peru, part of Brazil, Columbia and

cases, although the reduced pH of the carcase follow-

Venezuela in South America and most of the Middle

ing rigor mortis is sufficient to inactivate the virus in the and Far East. Canada, Central and North America, Aus-meat.

tralia, New Zealand, Japan, Argentina, Chile and South

The possibility of windborne spread of FMD virus

Korea are free of FMD. Most of Europe is also free of

has been given considerable significance, particularly in

FMD, but suffers occasional outbreaks of disease in

temperate countries where the climate is conducive to

spite of strict import regulations. When disease occurs,

the survival of the virus. There is evidence to indicate

however, it can be severe, as in the European and in

that FMD virus has been carried up to 250 km over the

particular the British outbreak commencing February

sea and up to 60 km over land. The spread of disease by

2001. From 1992 routine vaccination against FMD

the wind is dependent on the amount of virus generated

ceased in all countries of the European Union and has

by infected animals, the weather conditions, the topog-

since also stopped in Eastern Europe, other than parts

raphy over which it is carried and the susceptibility of

of Russia. In Southern Africa FMD virus is usually

the animals contacting the airborne virus. A plume of

restricted to wildlife in the game parks, although it

virus will be subjected to vertical and horizontal dis-

rarely escapes into cattle areas bordering the parks.

persion, which is related to wind speed and turbulence,

Types O and A of FMD virus are the most wide-

the vertical air temperature gradient and ground topog-

spread, especially in S. America, the Middle East and

raphy; the survival of the airborne virus will depend on

Asia; types SAT 1, SAT 2 and SAT 3 are generally

relative humidity. Cattle have a large respiratory tidal

restricted to Africa, although they have periodically

volume compared with other FMD susceptible stock

spread into the Middle East; Asia 1 occurs in the Far *and can be infected following inhalation of relatively*

East and India, although it also has spread into the

low quantities of virus and thus are most at danger to

Middle East. Type C only rarely causes outbreaks in

infection from the airborne virus. Windborne spread of

Asia and has all but disappeared (Kitching, 1998).

FMD virus is believed to have occurred in 1981 when

Fig. 43.11

A recently ruptured vesicle in the

mouth of a cow with foot-and-mouth disease,

showing epithelial separation.

In tracing the movement of FMD between countries,

and identifying specific strains of FMD virus, molecular

epidemiology has proved very valuable (Samuel et al. , 1997). By precisely characterizing the RNA of an outbreak strain by its nucleotide sequence, it is possible to

show its relationship to strains previously isolated in

other countries or in use in vaccines. For instance, in

Europe between 1970 and 1990 there were a number of

FMD outbreaks attributed to the use of improperly

inactivated vaccines and escape of virus from estab-

lishments producing vaccine. In several instances bio-

chemical analysis of the outbreak strains showed a clear

identity with a vaccine strain in contemporary use.

Monoclonal antibodies, which specifically identify

Fig. 43.12

Recently ruptured vesicles on the tongue and

some of the individual antigenic determinants on the

dental pad of a cow with foot-and-mouth disease. (Courtesy of

FMD virus, are becoming important in FMD virus

A.I. Donaldson.)

strain characterization. These determinants may change

as the virus mutates through the course of an outbreak.

Cattle recovered from FMD and vaccinated cattle in

infected pigs in Brittany, France, spread disease to cattle

contact with FMD virus may retain virus in their pha-

in the Isle of Wight, England, over a distance of 250 km,

ryngeal region for many months. This is the carrier

predominantly over sea. Computer models now exist

state. Vaccinated cattle which have had contact with

which can predict the likely windborne spread of virus

disease may also develop a pharyngeal infection

from an infected herd. The maximum daily excretion of

without showing any clinical signs. The significance of

virus can be calculated by establishing the number of

these carrier animals is not clear but, although it has

clinically infected animals and the species infected, and

proven difficult to show transmission from a carrier to

estimating the duration and quantity of airborne virus

a susceptible animal under experimental conditions,

excreted. The local meteorological office provides *there is considerable circumstantial evidence supported*

information about wind speed and direction, relative

by sequencing of carrier and outbreak strains suggest-

humidity and precipitation. When combined with local

ing that carriers may have initiated outbreaks.

topographical information and local distribution of live-

stock holdings, the computer model can give an indica-

tion of which herds are most at risk from secondary

Transmission and pathogenesis (Figs 43.11–43.13)

windborne spread of FMD. Manpower resources for

surveillance activity can then be concentrated on the

Cattle are most susceptible to FMD by inoculation of

herds adjudged to be at greatest risk.

the virus intradermally into the tongue and this is a

An infected bovine can excrete up to log105.1 infectious doses50/day by the respiratory route and can provide a potent source of FMD virus to the remaining uninfected cattle in the herd. This may be sufficient to overcome a waning vaccinal immunity.

The incubation period for FMD can be up to 14 days with low infecting doses and with strains of virus of low virulence. However, as the quantity of virus in the environment of an FMD outbreak increases, the incubation period in cattle decreases. For susceptible cattle in *contact with an infected animal it is frequently between two and four days.*

Clinical signs

The incubation period is between two and 14 days, depending on the route of infection, the dose, the strain of virus and the susceptibility of the host. Following an initial pyrexia in the region of 40°C (104°F), lasting one or two days, a variable number of vesicles develop on the tongue, hard palate, dental pad, lips, muzzle, coronary band and interdigital space. Vesicles may also be seen on the teats, particularly of lactating cows. Young calves may die before the development of vesicles because of a predilection by the virus to invade and destroy the cells of the developing heart muscle.

The vesicles in the mouth quickly rupture, usually

Fig. 43.13

Vesicular lesions of the interdigital skin of the foot

within one to two days of their formation, leaving a

in foot-and-mouth disease. (Courtesy of A.I. Donaldson.)

shallow ulcer surrounded by shreds of epithelium. The vesicles on the tongue frequently coalesce and a large *proportion of the dorsal epithelium of the tongue may commonly used method of challenging cattle during be displaced. The vesicles on the feet may remain for vaccine trials. However, natural infection is most fre- two to three days before rupturing, depending on the quently by inhalation of droplets containing FMD virus terrain or floor surface of the cattle accommodation. or by ingestion of FMD virus contaminated material. Healing of the mouth lesions is usually rapid; the ulcers One infectious unit of FMD virus is sufficient to in- fill with fibrin and by day 10 after vesicle formation they fect a bovine by intradermolingual inoculation, while appear as areas of pink fibrous tissue, still, however, between 10 and 100 infectious units can initiate disease without normal tongue papillae. Healing of the lesions in a bovine following inhalation. Many thousand infec- on the feet is more protracted and the ulcers are sus- tious units may be required to infect an adult bovine by ceptible to secondary bacterial infection. The horn of ingestion, although less will be required by a calf fol- the heels may become under-run, as a consequence* *lowing insufflation of infected milk.*

of both the initial vesicle and secondary bacterial

The primary site of replication of inhaled virus is in

infection.

the pharynx and lymphoid tissue of the upper respira-

Acutely infected cattle salivate profusely and

tory tract. FMD virus then enters the blood stream, is

develop a nasal discharge, at first mucoid and then

distributed around the body and following secondary

mucopurulent, which covers the muzzle. They stamp

replication in other glandular tissues appears in the

their feet as they try to relieve the pressure on first one

body fluids such as milk, urine, respiratory secretions

foot and then another. They may prefer to lie down and

and semen, before the appearance of frank clinical signs

resist attempts to raise them. Lactating cattle with teat

of FMD. However, it is during the early vesicular stage

lesions are difficult to milk and the lesions frequently

of the disease that the majority of virus is excreted into

become infected, predisposing to secondary mastitis.

the environment. Milk may contain log106.7 infectious

Affected cattle quickly lose condition; the drop in milk

doses50/ml, semen log106.2 infectious doses50/ml, urine

yield can be dramatic and will not be recovered dur-

log104.9 infectious doses50/ml and faeces log105.0 infec-

ing the remaining lactation. Some animals fail ever to

tious doses50/g.

completely regain their previous condition, due to the

development of lesions in the thyroid gland – 'hairy

when diagnosis is performed within a country, it is rec-

panters'.

ommended that duplicate samples also be sent to the

An outbreak of FMD can be economically devastat-

WRL or regional laboratory for confirmation of diag-

ing in an intensively farmed region. However, in the

nosis and strain identification. Details of the method of

extensive husbandry systems of South America and

submission of samples are described by Kitching and

Africa, where expectations of cattle productivity are

Donaldson (1987), although new regulations now also

low, FMD may seem insignificant compared with the *apply to sending pathological specimens by air.*

prevalent clostridial, haemoparasitic and deficiency

Foot-and-mouth disease virus is very sensitive to pH

diseases. This attitude frustrates programmes to com-

values away from neutrality and is, for example, quickly

pletely control FMD and attempts to introduce

inactivated below pH 6. Virus can also be isolated with

intensive farming or a dairy industry.

heparin from vesicular fluid or from whole blood col-

lected from the viraemic animal (up to four days after

the initial appearance of vesicles). Although high titres

Pathology

of virus can be recovered from milk and internal

The epithelial cells of the stratum spinosum of the skin

body organs such as lymph nodes and muscle, these

undergo ballooning degeneration. As the cells disrupt

specimens should only be sent in addition to, and not

and oedema fluid accumulates, vesicles develop which

instead of, epithelium samples. Negative tests on these

coalesce to form the aphthae and bullae that charac-

tissues could be misleading and cause a false sense of *terize FMD. The cells of the squamous epithelium of*

security.

the rumen, reticulum and omasum may also become

On receipt at the WRL, epithelial samples are pre-

involved. In young animals the virus invades the cells

pared as 10 per cent suspensions for the enzyme linked

of the myocardium and macroscopic grey lesions may

immuno-sorbent assay (ELISA). This test identifies

be seen particularly in the wall of the left ventri-

virus antigen within the sample and can distinguish

cle, giving it a striped appearance (tiger heart). Cells

between the seven FMD virus types; it has now

of the skeletal muscles may also undergo hyaline

replaced the classical complement fixation test for

degeneration.

FMD diagnosis. Results from this test are available

within three hours of arrival. At the same time as the

ELISA test is being prepared, samples of the epithelial

Diagnosis

suspension are inoculated onto primary bovine thyroid

Initial diagnosis is usually on the basis of clinical signs,

cells and pig kidney cells (IB-RS-2 cells). If a clear posi-
with or without a history of contact between the herd
tive is not obtained from the ELISA test, virus growth
and an infected animal or reports of FMD in the vicin-
on either or both of these two cell systems would
ity. In a fully susceptible herd the clinical signs are
provide sufficient antigen after 24 or 48 hours for a
frequently severe and pathognomonic. However, in
second ELISA test. In the absence of virus growth on
endemic regions in herds which have a partial natural
thyroid or pig kidney cells after 48 hours (first passage)
or vaccinal immunity, clinical signs may be mild and
the cells are inoculated onto fresh thyroid and pig
may be missed. All vesicular lesions in cattle should be
kidney cells (second passage). Samples are considered
investigated as potential FMD (OIE, 1996).
negative following negative ELISA and failure of virus
The success of the laboratory confirmation of a pre-
growth after 48 hours on second tissue culture passage,
sumptive diagnosis of vesicular virus infection depends
i.e. after a minimum of 96 hours following arrival at the

on the submission of adequate material, sent under suit-

WRL. The polymerase chain reaction (PCR) is also

able conditions. A minimum of 2 square cm of epithe-

available for detection of FMD virus genome in diag-

lium from a ruptured vesicle in a 50/50 mixture of

nostic samples.

glycerine and 0.04 molar buffered phosphate (pH

In countries which use vaccination to control FMD,

7.4–7.6) should be sent to a laboratory designated for

there is a requirement to relate the outbreak strain to

handling FMD virus and equipped with the reagents

existing vaccine strains. This can be shown using a two-

required to type a positive sample.

way microneutralization test. Mixtures of field virus

Diagnosis of FMD is usually controlled by a govern-

and antisera to a vaccine virus, usually prepared in

ment department. Where laboratory diagnosis cannot

guinea pigs, are incubated at 37°C for one hour and

be adequately carried out within a country, samples

then inoculated with BHK-21 cells into the wells of a

should be sent by the relevant government department *microtitre plate. The plates are placed in a 37°C incu-*

to the regional FMD laboratory or to the World Refer-

bator and examined daily for evidence of a virus-

ence Laboratory (WRL) for Foot-and-Mouth Disease,

induced cytopathic effect in the cells. The titre of serum

Institute for Animal Health, Pirbright Laboratory, Ash

which neutralizes 100 tissue culture infective dose

Road, Pirbright, Woking, Surrey, GU24 ONF, UK. Even

(TCID)50 of virus is calculated and compared with the

titre of the same serum which neutralizes 100 TCID50

Control

of the vaccine virus. The ratio of titre of serum against

field virus to titre of serum against vaccine virus is the

The control of FMD depends on prevention of the

r 1 value, and gives an indication of the antigenic rela-introduction of virus, prevention of infection of stock

tionship between the field and vaccine strains and

and the prevention of spread of virus from infected

therefore the probable usefulness of that vaccine in

animals. How this is achieved by individual coun-

controlling the outbreak of FMD.

tries depends on a variety of economic and practical

A similar r 1 value can be derived using the ELISA

considerations.

(Kitching et al., 1988).

Exotic FMD virus may enter an area or country

The serum antibody titre against FMD virus of cattle

in infected animals and this can include certain zoo

vaccinated against FMD can also be measured using the

animals. Acutely infected animals are usually recog-

virus neutralization (VN) or ELISA test. Immunity in

nized, but sheep and goats frequently only develop very

cattle to FMD can be correlated with the level of serum

mild clinical signs. Vaccinated cattle can also develop

antibody at 30 days after primary vaccination, although

only local lesions of FMD, particularly in the mouth,

the relationship is not absolute, being dependent on the

and may carry infection if imported to FMD-free

challenge dose of virus and the closeness of its antigenic

areas. The importance of cattle and buffalo that are car-

relatedness to the vaccine strain. The VN and ELISA *rying FMD virus in the pharynx is not proven, although are FMD virus type-specific, so that when used to deter- there is ample field evidence of FMD having been intro- mine whether an animal has had contact with FMD the duced with such carrier animals. In order to prevent the tests must be performed separately against each of the introduction of FMD in this manner, FMD-free coun- FMD serotypes with which the animal may have had tries may refuse entry of any ungulate from FMD contact. In some parts of the world, e.g. Africa, this endemic areas or may insist that any ungulate entering could be any one of up to six different FMD serotypes. the country has no serum antibody to FMD virus Such testing can be time-consuming, expensive and and that oesophageal-pharyngeal scrapings taken by present results difficult to interpret. A non-type-specific probang are negative for the presence of FMD virus. screening test has been developed which estimates the Any animal vaccinated against FMD is, therefore, presence of antibody to the non-structural proteins of prohibited.*

FMD virus; these are formed in an infected animal as

FMD virus could also enter in the carcase or prod-

the virus replicates and the non-structural proteins are

ucts of an animal infected before slaughter. In skeletal

expressed.

muscle the virus is inactivated as the pH of the meat

The antigenic characteristics of these proteins are

falls as the carcase ‘sets’, but virus in the bone and

conserved between serotypes. Traditionally the 3D non-

lymph glands is not subject to this increased acidity

structural protein or virus infection associated antigen

and will escape inactivation. Regulations in FMD-free

(VIA antigen or polymerase) was used, but better

countries require that meat imported from endemic

results, particularly in distinguishing between vacci-

areas has had the bones and lymph glands removed

nated and recovered animals, have been obtained by

and may also impose additional requirements such as

detecting antibody to the polyprotein 3ABC (Mackay

regular vaccination and certification of the absence of

et al., 1998) together with antibody to the 2C protein FMD from the farm of *origin of the meat, the slaugh-*

(Lubroth & Brown, 1995). Both can be produced as

ter house and the surrounding areas. If infected meat

pure reagents for an ELISA test by expression in a

should still enter in spite of these restrictions, an addi-

plasmid vector system. Because animals vaccinated

tional safeguard is the prohibition of feeding uncooked

with the dead FMD vaccine produce relatively little

meat or other swill to pigs. There are many examples of

antibody to the non-structural proteins (some may be

pigs being the first animals to be infected in an FMD

produced against the 3D protein), the tests will also dis-

outbreak. The Office International des Epizooties

tinguish animals which have been vaccinated – these

(OIE) provides guidelines for trade between countries

are positives only for the antibodies to the major

of different FMD status (OIE, 2001)

structural proteins (see above) – from recovered

The early detection of an FMD outbreak requires the

animals which have antibodies to both structural and

existence of an efficient veterinary service and a rapid *non-structural proteins. This would therefore also iden-*

diagnostic capability. The World Reference Labora-

tify potential virus carrier animals. The problem still

tory, Pirbright, offers a worldwide diagnostic service,

remains of how to detect the vaccinated animal which

although by the time samples are received from abroad

has had contact with live virus and thus become a

an FMD outbreak could be well established. Neverthe-

carrier, but because of its protected status therefore

less, the service can provide valuable additional support

remains negative for antibodies to the non-structural

and identify the most suitable vaccine for use to control

proteins.

an outbreak.

Following suspicion of an FMD outbreak the move-

again at six months of age. Subsequently cattle should

ment of all infected animals must be prevented and

be vaccinated twice yearly, or even three times yearly

local markets and abattoirs closed. The slaughter of all

in areas where FMD is prevalent.

cattle, sheep, goats and pigs on infected premises is
The method used by different countries to control
practised by countries that do not routinely vaccinate
FMD is dependent on a number of factors. Countries
against FMD, and by many countries that do vaccinate,
free of FMD and protected on their borders by natural
as this will eliminate the source of virus emission and
barriers such as desert, sea or mountain ranges can
prevent the establishment of a nucleus of potential
maintain their status by strict import controls and can
carrier animals. Cattle, sheep and goats on surrounding
avoid the recurring cost of vaccination or the possibil-
farms that have already been vaccinated should be
ity of initiating an outbreak through the use of improp-
revaccinated with a vaccine antigenically related to
erly inactivated vaccine or escape of FMD virus from a
the outbreak strain. Pigs are generally also included
vaccine production plant. In addition, should FMD
in emergency vaccination programmes. All previous
virus enter a non-vaccinating country it can usually be
movement of animals, animal products and other

immediately identified clinically because of the com-
potentially infected material up to 21 days prior to the
plete susceptibility of the livestock, whereas FMD virus
estimated appearance of the first clinically infected
has been known to circulate in countries that do vacci-
animals must be investigated. This will not only indicate
nate without the knowledge of the veterinary authori-
which other farms may develop secondary outbreaks of
ties. Finally, countries free of FMD which do not
FMD, but may also identify the source of the infection.
vaccinate have a privileged international trading status.
Subsequent movement on and off the infected premises
However, should FMD virus enter, there is always the
must then be kept to a minimum and adequate facili-
possibility of rapid uncontrollable spread, with severe
ties for cleaning and disinfection provided. Such con-
consequences.
trollable precautions will identify and considerably
Many countries have no choice but to control FMD
reduce the chance of secondary spread. Windborne
by mass vaccination. The movement of nomadic people

spread of FMD virus prior to the slaughter of the

with their animals, and of wild animals across interna-

infected animals is, however, uncontrollable. Numerical

tional borders in Africa, the Middle and Far East, makes

models developed to predict this windborne spread can

disease regulations impossible to enforce. The airborne

be used to indicate those farms most at risk and have

spread of FMD virus cannot be controlled by legisla-

proved their value in helping to control outbreaks of

tion. Barrier vaccination can reduce the danger of FMD

FMD in Europe.

entering a country or area and has been successful

Vaccination against FMD is an effective method for

in preventing exotic strains of FMD entering Europe

protecting livestock against disease (p. 1016). Only

through Turkey and Greece, and in allowing South

inactivated vaccines are used and they are assessed by

Africa and Zimbabwe to restrict vaccination to their

their antigen content and the results of potency trials,

borders and around game reserves. Countries which do

ideally carried out in fully susceptible cattle (OIE, *not vaccinate or vaccinate against two or three strains*

2000). An FMD vaccine is most effective against infec-

may use emergency vaccination to control an outbreak

tion with the homologous strain from which the vaccine

due to a new strain of FMD by slaughtering affected

was prepared. However, a good vaccine must also

animals and ring vaccinating around the infected area

protect against closely related strains of FMD virus,

with a monovalent vaccine specifically against the

although its effectiveness will be reduced the more the

exotic strain.

antigenic characteristics of the outbreak strain differ

from the vaccine strain. It is therefore necessary to

Economic importance

identify the types and strains of FMD virus that pose

the most significant threat. Nowhere has it been neces-

The economic importance of FMD is hard to quantify

sary to use more than a quadrivalent vaccine, although

accurately. The direct costs of vaccination, slaughter of

there are frequent situations when it is necessary to

infected animals, movement restrictions and closure

include more than one strain of the same serotype. In
of markets can be measured. The indirect local and
addition, the characteristic variability of FMD virus has
national costs, e.g. loss of potential export markets, may
rendered some vaccine strains no longer effective, and
be the most significant and yet most uncertain cost.
new ones must be introduced.

Assuming that a country wishes to prevent FMD
Maternal antibody can interfere with the develop-
remaining or becoming endemic, two options are avail-
ment of active immunity in young animals. It is there-
able. Either all cattle (and possibly sheep, goats and
fore recommended that if calves of immune dams are
pigs) are routinely vaccinated or no vaccination is
vaccinated in their first three months of life they should
carried out and outbreaks are controlled by slaughter
be vaccinated twice more at four and five and possibly
as they occur. Which policy is the most economic can

be assessed by critical point analysis or by estimating
occurred. Rinderpest has however continued to persist

the critical point at which the cost of one policy equals
in Asia and the Indian subcontinent and is still present
the cost of the other policy. Costs that must be consid-
in Pakistan, India, Bangladesh and Nepal. Occasional
ered are the cost of vaccine and its administration or its
outbreaks occur in the Near and Middle East. Rinder-
storage as a strategic reserve. If it is also assumed that
pest was introduced into Africa in the early 1800s and
neither policy will eliminate the possibility of FMD
was responsible for a massive pandemic between 1889
outbreaks, the cost of controlling an outbreak must be
and 1897. Africa has not been free of rinderpest since,
assessed and multiplied by the estimated total number
although it has largely been confined to countries north
of outbreaks.
of the Tropic of Capricorn. An international vaccination
The cost of an FMD outbreak must include the cost
programme carried out between 1962 and 1975 almost
of controlling the outbreak, including ring vaccination,
eradicated the disease (Scott, 1985). A second interna-
the cost of slaughtered animals, the loss of production

tional vaccination programme, commencing in the mid-

and the interruption of domestic and international

1980s, has reduced the incidence in West Africa to a

trade. The international trading status of a country that

level where eradication may be achieved (Rossiter,

vaccinates already will be considerably less affected

1996). Extensive outbreaks have, however, continued in

than that of a country that does not vaccinate. Similarly,

eastern Africa where vaccination coverage has been

the status of a country that does not use routine FMD

hampered by civil unrest. The disease is still endemic in

vaccine but vaccinates in order to control an FMD out-

the horn of Africa and southern Sudan.

break may be affected by lengthy trade restrictions with

other non-vaccinating countries following the cessation

Aetiology

of vaccination (OIE, 2001).

The difficulty in assessing these uncertain costs may

The causal agent of rinderpest is a paramyxovirus of the

be illustrated by an analysis of the cost of annual vac-

genus morbillivirus. The other members of the morbil-

cination (policy A) and the cost of a stamping out with

livirus genus are measles, canine distemper, phocine dis-

ring vaccination (policy B) carried out in the Federal

temper (Osterhaus & Vedder 1988; Mahy et al., 1988; Republic of Germany (Lorenz, 1987). The average

Kennedy et al., 1988) and peste des petit ruminants

annual cost of policy A was estimated to be between 52

(PPR) to which rinderpest virus is antigenically related.

and 286 million DM, while the average annual cost of

Recently morbilliviruses have been isolated from dis-

policy B was between 2.5 and 321 or more million DM.

eased marine mammals (Barrett et al., 1993) and a

The wide range reflected the number of assumed FMD

morbillivirus-like agent caused fatal respiratory disease

outbreaks that could occur under each regime. The

in man and horses in Australia. The morbilliviruses are

estimates considered most likely, however, were

pleomorphic, enveloped, helical particles of between

between 183 and 227 million DM for policy A and

150–300 nm diameter and contain a non-segmented

between 47 and 61 million DM for policy B.

negative-strand RNA genome. This codes for six struc-

Any scenario for assessing the cost of FMD control

tural proteins and possibly one non-structural protein.

must ultimately assume the existence of an efficient

The virus structural proteins comprise the nucleocapsid

veterinary service, capable of diagnosing the disease

protein (N), which surrounds the genomic RNA, a large

and with facilities available to control it. Without this

polymerase protein (L) and a small polymerase-

infrastructure any, even approximate, estimate of the

associated protein (P), a matrix protein (M) associated

economic significance of FMD becomes academic.

with the virus envelope and two envelope glycoproteins,

the haemagglutinin (H) and fusion protein (F). The P

gene shows significant homology between members of

the morbillivirus group (Barrett & Underwood, 1985).

(d) Rinderpest

There is only one serotype of rinderpest virus and

rinderpest virus can be distinguished from PPR virus in

by E.C. Anderson

reciprocal cross-neutralization tests. Alternatively, the *two viruses may be distinguished by comparing their*

protein patterns in polyacrylamide gels as the N pro-

The State Veterinary Service in the UK was brought

teins have been shown to have markedly different

into being specifically to deal with rinderpest or cattle

molecular weights (Diallo et al., 1987). They can also be plague. In the eighteenth and nineteenth century dev-distinguished by nucleic acid hybridization using cDNA

astating outbreaks of rinderpest were responsible for

probes to the H gene (Diallo et al., 1989) and by the

millions of deaths in cattle in Europe. By 1930, with the

reverse transcription-polymerase chain reaction (PT-

exception of parts of Turkey, Europe was free of the

PCR) (Forsyth & Barrett, 1995). It is now also possible

disease and since that time only small outbreaks have

to distinguish the two diseases in recovered animals by

means of a competitive enzyme-linked immunosorbent

from two to five days. The virus is shed in all secretions

assay (ELISA) based on the use of monoclonal anti-

and excretions, the peak of virus production being

bodies (Mabs) to the haemagglutinin of each virus *during the prodromal fever but continuing after the*

(Anderson et al., 1991).

appearance of erosive lesions. Virus levels fall as anti-

The virus is sensitive to lipid solvents, is relatively

body begins to be produced with viraemia ceasing

heat sensitive and is unstable at low pH. It is also labile

before the disappearance of the virus from the tissues,

when exposed to light and survives best at low or high

about 14 days after the onset of fever. Viraemia lasts on

relative humidities but is rapidly destroyed when the

the average about six days but there is considerable

relative humidity is between 40–60 per cent. Infectivity

variation between strains of virus. Viraemia can occur

is lost when it is suspended in glycerol or water but it

following exposure to some strains that lasts four to six

is stable in 0.86 per cent sodium chloride at low tem-

days without the development of lesions.

peratures with the loss in infectivity rising exponentially

with temperature. The use of molar concentrations of

Clinical signs

magnesium sulphate improves the thermostability of *the virus.*

The clinical signs of rinderpest in cattle and other

natural hosts are essentially the same but show wide

variations in severity depending on the strain involved,

Species susceptible

and the resistance of the animal, natural or acquired.

Rinderpest is potentially infective for all members of

The disease may be hyperacute, acute, subacute or

the order Artiodactyla (Scott, 1964) but in particular

chronic (Plowright, 1968). The typical acute disease can

infects members of the families Bovidae, Suidae

be divided into four phases: incubation, prodromal,

and Cervidae (Plowright, 1968). Of these cattle, water

mucosal and convalescent.

buffalo, Cape buffalo (Syncerus caffer) and yak are

most susceptible. The disease occurs in sheep and goats

Incubation phase

and, in India, also in pigs. It also affects camels. It has

been recorded in a large number of wildlife species in

Africa including eland (Taurotragus oryx), lesser kudu Prodromal phase: This is characterized by a sudden

(Tragelaphus imberis), giraffe (Giraffa camelopardis) onset in fever reaching a peak on the second or third

and warthog (Phacochoerus aethiopicus). In 1994 the

day after onset. It is accompanied by depression or rest-

disease caused significant mortality in buffalo, lesser

lessness, loss in appetite and a fall in milk yield in cows.

kudu and eland in the Tsavo National Park in Kenya

The visible mucous membranes are congested, the

(Barrett et al., 1998).

muzzle is dry and there may be the beginning of a

serous discharge from the eyes and nostrils. There is

tachycardia and accelerated respirations, ruminal stasis

Transmission

and constipation. This phase lasts about three days with

Rinderpest is spread by direct contact between infected

lesions appearing between two to five days following

and susceptible animals, by the inhalation of virus-

the onset of pyrexia.

containing aerosols or by ingestion of infected secretions

and excretions. On rare occasions it has spread through

Mucosal phase: The first lesions comprise small foci of indirect contact with contaminated fodder and water.

necrosis, superficial erosion and capillary haemorrhage

Pigs have been infected through eating meat from con-

in the mucosae of the mouth cavity, which are particu-

taminated carcasses. Different strains of virus vary in

larly noticeable on the lower gum and tips of the buccal

their invasiveness and infectivity for different species.

papillae. They extend to involve the lips, upper gum,

hard palate and ventral surface of the tongue. Similar

lesions occur in the nasal, vulval and preputial mucosae

Pathogenesis

where they may occur earlier than in the oral cavity.

Infection is through the upper respiratory tract with

The lesions extend and fuse to produce extensive areas

primary replication of the virus in the tonsils and local

of necrotic erosion with a characteristic fetid smell.

lymph nodes (Plowright, 1968). The virus is dissemi-

There may be excessive salivation and at this stage

nated in the blood, where it is closely associated with

the lacrimal and nasal secretions become profuse and

the mononuclear leucocytes, to all lymphoid tissue and

purulent.

the mucosae of the alimentary and respiratory tracts.

Animals at this stage of the disease are very

The incubation period lasts from two to nine days

depressed and respirations are laboured, but pneumo-

and viraemia can be detected one to two days before

nia is rare. Diarrhoea appears usually between four and

the onset of pyrexia. The prodromal phase usually lasts

seven days of pyrexia and one to two days after the

appearance of lesions. It is at first watery but later

virus. Retrospective diagnosis is obtained by the detec-

dysentery develops and it may contain pieces of intes-

tion of specific antibody (Scott et al., 1986).

tinal mucosa. Dehydration is rapid resulting in weak-

ness, prostration and death between six and twelve days

Antigen detection: Virus is present in the secretions and after the onset of pyrexia. The mortality rate is over 90

excretions within two days of the onset of fever. Spe-

per cent when susceptible animals are infected with

cific antigen can be detected from this time particularly

virulent strains.

in the lacrimal secretions but also later in swabs or

Mild forms of the disease in partially immune

material from lesions in the mouth, vagina or prepuce.

animals or following infection with less virulent strains

Lymph node biopsies may also be taken.

give rise to reduced general signs and less extensive

Early diagnosis is desirable and a rapid chromato-

mucosal lesions. However, these may be completely

graphic strip test based on Mab-labelled latex particles

absent with the only sign a transient diarrhoea. Even

is now available for pen-side diagnosis (Buning et al., this may be absent, and some strains of virus result in a

1999). The most sensitive method is, however, RT-PCR

complete spectrum of signs from the classical acute

and this can also be used with lacrimal secretions as well

febrile disease with extensive lesions and eventual

as material from mouth lesions and lymph node biop-

death to a form in which there is fever but no lesions

sies. This method also has the advantage of generating

although antigen can be detected in lacrimal secretions

DNA fragments whose sequence may help in defining

(Anderson et al., 1990; Forsyth et al., 2003).

the origin of the outbreak or differentiating the disease

from PPR (Forsyth & Barrett, 1995). Specific antigen

Convalescent phase: Visible mouth lesions may heal

can also be detected by the less sensitive immunodiffu-

within as little as two to three days beginning from the

sion or counterimmunoelectrophoresis (CIEOP) tests

third to the fifth day after their appearance. Diarrhoea

in field laboratories. The ELISA is a very sensitive test

may persist for longer. Complete recovery from the

used in suitably equipped laboratories and is prefera-

acute form takes about four weeks depending on the

ble to the complement fixation test (Libeau et al., 1994).

environment and plane of nutrition.

Histochemical methods using fluorescein or enzyme-

conjugated antiserum may be used on smears, biopsy

material or tissue sections (Scott et al., 1986; Saliki et al., Pathology

1994).

The gross pathology has been described by Maurer et

Virus isolation: Virus may be isolated in tissue cultures al. (1956). The mucosae of the upper alimentary and *of primary or secondary calf or sheep kidney cells or*

respiratory tract are eroded and necrotic often being

Vero cells. It may be isolated from swabs of lesions or

coated with a mucopurulent exudate. Erosions, ulcers

secretions, from the leucocyte fraction of blood col-

and oedema occur in the abomasum, which may also be

lected in EDTA or from lymphoid tissue collected at

congested. Peyer's patches in the small intestine are

post mortem. Specimens should be transported on ice

haemorrhagic, oedematous and necrotic. The mucosal

but glycerol should not be used as a transport medium,

surface of the caecum, colon and rectum frequently has

as it inactivates the virus.

characteristic haemorrhagic stripes due to the conges-

tion of the capillaries. Erosion and ulcers also occur in

Antibody detection: The detection of a rising antibody the urogenital tract. The virus has a predilection for

titre in paired serum samples or in disease surveys may

lymphoid tissues in which there is extensive necrosis

be done using the virus neutralization test. This is suit-

of the lymphocytes of the germinal centres, and the *able for small numbers of diagnostic samples but for*

appearance of multinucleated giant cells about eight

disease surveillance requiring the screening of large

days after infection. The appearance of cytoplasmic and

numbers of samples the ELISA is the test of choice.

intranuclear inclusions has been described (Plowright,

Other tests that are used include indirect immunodif-

1968). The stratified squamous epithelium, particularly

fusion and CIEOP.

of the upper part of the alimentary tract shows syn-

cytium formation and degenerative changes, which are

followed by necrosis and detachment to form erosions

Differential diagnosis

and ulcers.

In cattle the one disease that cannot be distinguished

from rinderpest without laboratory tests is bovine virus

diarrhoea. In sheep and goats peste des petits rumi-

Diagnosis

nants is identical to rinderpest. Otherwise there are few

Laboratory confirmation of rinderpest is based on the

conditions that should be confused with the acute form detection of specific antigens and the isolation of the

of rinderpest. The mild forms in particular, where

diarrhoea is the only clinical sign, are indistinguishable

Enzootic VS has a limited geographical location, within

from other enteric conditions.

which the appearance of disease is cyclical, apparently

related to season or rainfall. The majority of infections

Control

are inapparent and can occur in animals isolated in

cages or otherwise separated from other susceptible

Rinderpest spreads slowly in endemic countries where

species. Epizootic spread of VS is associated with simul-

it affects mainly immature animals. In these countries

taneous outbreaks over a wide area, although some

control is by vaccination annually of all immatures. In

herds within this area may remain unaffected. Of the

such countries attempting eradication, vaccination of

domesticated species, cattle are the most commonly

the entire cattle population, as well as sheep and goats

affected, followed by horses and then pigs; sheep and *in those countries where the disease occurs in these*

goats never show clinical signs of VS. Few cases are

species, for three to five years is practised.

reported in young cattle, most cases appearing in

In high risk countries adjacent to endemic regions or

milking cows. Mouth lesions are most frequently

those importing livestock from endemic countries quar-

reported, although in some outbreaks only teat lesions

antine and vaccination are combined (see p. 1013).

are seen. Insects have been strongly implicated in the

All rinderpest vaccines in use are live attenuated

transmission of VS, but this has not yet been conclu-

vaccines. Most countries use a tissue culture vaccine

sively demonstrated. The cyclical appearance of VS sug-

(Plowright, 1968). New lyophilization techniques have

gests the existence of interepizootic reservoir hosts, but

improved the thermostability of these vaccines (House

these have also resisted identification.

& Mariner, 1995). Goat adapted vaccine and lapinized

A number of theories have been put forward to

vaccine are still used in some countries.

explain these observations. It has been suggested that

VSV circulates in feral pigs, elk, mule deer and antelope

and possibly also in water birds and rodents such as

(e) Vesicular stomatitis

wood rats and deer mice. In support of this theory anti-

body against VSV has been found in all these species

and, in some areas, prior to the onset of a VS epizootic

in domesticated animals. It has also been suggested,

without much supporting evidence, that VSV could

Vesicular stomatitis (VS) is a vesicular disease of cattle,

persist in the soil and be circulated by arthropods or

horses and pigs which can also infect a large range of

even that VSV is primarily a plant virus.

wild animal species (see p. 366). The virus belongs to the

Studies using T1 oligonucleotide mapping of VSV-NJ

genus vesiculovirus, within the family Rhabdoviridae.

(Nicol, 1987) and nucleotide sequencing of VSV-NJ and

There are two serologically distinct types of VS virus

VSV-IND (Rodriguez, 1999) have helped to identify

(VSV): New Jersey (NJ) and Indiana (IND). The IND

the origin of VS epizootics in the USA. By precisely

type can be further subdivided into Indiana 1 (Indiana

characterizing the outbreak strains it has been shown

strain), Indiana 2 (Cocal and Argentina strains) and

that a VS epizootic is not caused by the simultaneous

Indiana 3 (Alagoas and Brazil strains). In common with

eruption of many strains of VSV within the United

all other rhabdoviruses VSV is a single-stranded RNA

States but the rapid spread of a single strain north from

virus, the RNA being arranged in an enveloped helical

the enzootic region of Mexico. A correlation has been

nucleocapsid. The intact virus is bullet shaped, measur-

shown between outbreaks of VS in North America and

ing 180 nm by 75 nm, and is covered with 10 nm spikes.

wind direction from VS infected areas, indicating a pos-

Vesicular stomatitis virus will grow in a wide range of

sible involvement of insect vectors carried by the pre-

primary cells and continuous cell lines, and laboratory

vailing wind.

animals such as mice, rats, ferrets, guinea pigs, hamsters

VSV-IND appears to have different epidemiological *and chick embryos. Humans are susceptible to VS, the characteristics from VSV-NJ, and its spread is less asso- disease being characterized by fever, myalgia, nausea, ciated with clinical disease and has consequently vomiting, headaches and occasionally vesicles on the attracted less attention. It is also apparent that the mucosa of the mouth and throat. No deaths have been behaviour of VSV need not remain consistent; its mode reported, and the disease rarely lasts more than a week. of transmission, for instance, can vary even during epizootics.*

Epidemiology

Distribution

The behaviour of VS in the field has been well docu- mented but in spite of detailed observations there are VSV is restricted to North, Central and South America many aspects of its epidemiology which are still unclear. and the Caribbean islands. The disease was transported

with horses from America to South Africa in 1884 and tinuation of the North American 1982/83 epizootic

1887, and to France in 1915, but did not persist in either

through the winter.

country. The first report of VS in N. America was in

Transmission of VS can also occur by direct contact

horses during the American Civil War, and there were

between infected and susceptible cattle, this being fre-

further reports in 1889, 1904 and 1907. In South

quently associated with subclinical infections. An asso-

America VS was first diagnosed in Argentina in 1939,

ciation has been made between the feeding of abrasive

in Venezuela in 1941 and in Colombia in 1943.

feeds, which compromise the integrity of the buccal

Indiana 1 and New Jersey strains of VSV are enzootic

mucous membranes, and the spread of VS.

in southern Mexico and Central America, but a char-

acteristic of both is their periodic movement out of the

enzootic areas to cause epizootics in the southern

Clinical signs

United States and northern South America. VSV-IND

Vesicular stomatitis in cattle may be an inapparent, mild

has spread as far north as the United States–Canadian

or severe disease, animals over nine months of age
border. These seasonal epizootics occur typically at the
being most commonly affected. Following an incuba-
end of the summer, or in the tropics at the end of the
tion period of two to three days, a usually mild fever
rainy season, and usually finish in the temperate regions
develops accompanied by depression, lameness and
at the onset of the frosts. The 1982 VSV-NJ epizootic
excessive salivation. The fever reduces as vesicles
did not, however, follow this cycle and persisted
develop on the coronary bands of the feet, or in the
through the winter. Epizootics which spread into the
mouth or on the teats; rarely are vesicles seen on more
mid-western and western states of North America tend
than one of these sites. In severe cases over 50 per cent
to occur at intervals of approximately five to ten years,
of the tongue epithelium may be affected and the
while major epizootics have been occurring every 30
resultant difficulty in eating can cause dramatic weight
years. The predominant serotype causing vesicular
loss. Milk yield is depressed. True vesicles may fail to

disease in the United States is VSV-NJ, and it is endemic

develop, lesions appearing as crusts or ulcers. Recovery

in at least one site in the USA – Ossabaw Island,

is usually rapid, although milk yield frequently fails to

Georgia. Vesicular stomatitis has not been reported in

recover during the remaining lactation and secondary

the New England area, eastern Canada or Alaska.

mastitis may be a problem. Some animals fail to recover

fully and remain in poor condition. The lesions pro-

Transmission

duced by vesicular stomatitis virus in cattle are clini-

cally indistinguishable from lesions of foot-and-mouth

The epidemiological characteristics of VS suggest that

disease.

the disease is predominantly spread by insects. Culex

and Aedes species of mosquitoes, Phlabotomine sandflies, Culicoides, Simulium blackflies, Musca species, Pathogenesis

Hippelates eye gnats and Anthromyidae have all been

implicated in the transmission of VS. Transovarial trans-

Vesicular stomatitis virus enters the animal through a

mission of VSV has been shown in the sandfly Lut-

skin or mucosal abrasion or it may be inoculated by

zomyia trapidoi and biological transmission of VSV-NJ

an infected insect bite. Aerosol infection has been

by Simulium sp. (Mead & Maré, 1999). However, the reported in humans and may also occur in cattle. A low

very low or possibly absent viraemia associated with VS

titre viraemia has been detected in some experimen-

rules out traditional concepts of vector transmission.

tally infected animals between 11 and 56 hours after

The vesicular lesions of clinical VS are rich in virus and

infection, but even this must be considered a rare event.

could provide a potent source for insect infection, but

Replication of virus occurs at the site of infection in the

this fails to explain the transmission of VS between sub-

prickle cells of the Malpighian layer, but there is no

clinically infected animals. Nevertheless, the climatic

information on subsequent sites of virus replication. As

conditions which predispose to the spread of VS and the

the cells degenerate and transudate from the blood

more frequent appearance of VS in animals at pasture

stream accumulates, vesicles develop and the animal *strongly implicate the involvement of insects. In addi-*

becomes febrile. It is not clear why lesions are rarely

tion, the characteristic termination of a VS epizootic

generalized, but are usually restricted to the teats,

with the onset of subzero night time temperatures is

mouth or feet. Immunosuppressed or overcrowded

typical of many vectorborne diseases. Experimentally

animals are more likely to develop lesions. VSV does

inoculated sandflies and Aedes aegypt have been shown not cross the placenta and there are no reports of calves

to transmit VSV to vertebrate hosts (Letchworth et al., from infected dams being viraemic or having pre-1999). The virus does not appear to be totally depend-

colostral antibodies to VSV. However, VSV-NJ has

ent on insect transmission, as evidenced by the con-

once been recovered from an aborted fetus.

Diagnosis

ity that animals can remain carriers of VSV. It has been

observed that recovered cattle have appeared to spread

Diagnosis of VS is by clinical examination of affected

VSV to susceptible animals, and that some of these

animals and the demonstration of the presence of VSV *recovered cattle have again developed vesicles, usually, or of a rising antibody titre to VSV. Laboratory con- but not invariably, on a site different from the original firmation of VS is essential in order to distinguish the area of infection. These recurrent lesions have usually disease from foot-and-mouth disease.*

occurred within 48 hours of moving the recovered VSV has a characteristic appearance under the elec- cattle, and this has led to the suggestion that the tron microscope. The virus will also grow on a wide recrudescence of clinical disease was brought on by range of primary and continuous cell lines, on the stress. Although it has not been possible to isolate virus chorioallantoic membrane or in the allantoic cavity of from clinically normal animals recovered from VS, the fertile eggs and in many laboratory mammals. The persistence of high levels of neutralizing antibodies in Vero-M (green monkey) cell line is used extensively for these animals does suggest the presence of a continu- the growth of VSV for assay of VS antibodies in the ous antigentic stimulation.

virus neutralization test. The complement fixation test
An additional problem is the high proportion of sub-
and fluorescent antibody test are also used in the diag-
clinical cases during epizootics and the possibility that
nosis of VS, although indirect sandwich ELISA is now
VS could circulate in an area unobserved.
considered the most economic and rapid (OIE, 2000).
Measures designed to eliminate virus shed in the
Details given for the submission of samples for FMD
saliva of infected cattle do reduce transmission; 10 per
diagnosis (see p. 704) apply also to the submission of
cent household bleach used on utensils and dairy equip-
samples for VS diagnosis, although VSV is much less
ment, and for washing hands, has proved useful. In addi-
susceptible to pH outside the range of 7.2 to 8.0. As a
tion, replacement of hard or abrasive feed with a softer
differential diagnosis is usually required between FMD
alternative reduces mouth lesions and thereby intro-
and VS, the more stringent requirements of FMD virus
duction of the virus.
should be followed.

Within the USA, animals infected with VSV are

Virus neutralization and liquid phase blocking

quarantined for at least 30 days after all signs of VS

ELISA antibodies may be detected 96 hours after

have disappeared. Countries free of VS are usually con-

experimental inoculation, and they reach a peak by day

siderably more stringent and will not import any animal

12. These antibodies persist for many years and are

with virus neutralizing antibodies to VS. This precau-

valuable in showing evidence of previous infection.

tion is intended to exclude the possibility of importing

Their persistence has led to the suggestion that the virus

a persistently infected animal.

itself may persist in an animal long after recovery from

Living and formalin-inactivated vaccines have been

the disease, although it may remain in a defective, non-

prepared against VSV-NJ (see p. 1018). The dead

infectious form. Complement fixing antibodies recede

vaccine reduces the incidence of overt disease, while the

three to six months after infection. A four-fold or

live vaccine, given by intramuscular inoculation, gives a *greater increase in VSV neutralizing antibodies*

better protection and does not spread to in-contact sus-

between early infection and convalescent serum is diag-

ceptible animals. A recombinant vaccine has also been

nostic of infection. The presence of neutralizing anti-

developed by inserting the gene for the VSV glycopro-

bodies does not appear always to prevent reinfection or

tein into the genome of vaccinia virus. This vector

the development of clinical signs.

vaccine against VS is reported to be highly effective, but

Prior to the establishment of suitable laboratory

has not been used in the field due to its potential danger

tests, VS was diagnosed by scarifying infective material

to humans (Letchworth et al., 1999).

into the snout of swine and the tongues of cattle and

horses, and by intramuscular inoculation of cattle. VSV

produced lesions on pigs, cattle and horses, but not in

Economic importance

cattle when given by intramuscular injection. FMD

It is difficult to assess the full economic importance of

virus produced disease in swine and cattle, but not

VS because of the effect the presence of disease has on

horses, and vesicular exanthema virus affected only

export markets. Direct losses due to disease can be

swine, although occasionally lesions were also produced

severe, particularly in high yielding dairy herds, and

on the tongues of horses.

have been calculated to have been between $97 and

$253 per clinical case during the 1982 epizootic in the

United States (quoted by Monath et al., 1986). Losses

Control

due to reduced growth rates in beef cattle in South

Measures designed to control VS reflect the poor

America are also reported to be significant. Conse-

understanding of its epidemiology, notably the possibil-

quent movement restrictions and the closure of local

markets can also cause considerable loss. Nevertheless,

natural infection is probably confined to cattle. Labo-

it is the exclusion of animals in VS enzootic or previous

ratory workers exposed to infection have not serocon-

epizootic areas from countries free of VS that causes *verted. The virus is heat labile and is killed by milk*

the most significant economic losses.

pasteurization.

The disease appears to be expressed in few clinical

signs, although in some herds in the USA and possibly

in Europe disease can be infrequently expressed. This

(f) Bovine immunodeficiency

lack of ability to identify the organism or detect it con-

sistently serologically means that its economic impor-

virus (BIV)

tance cannot be properly assessed. In many instances

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infection appear to be concomitant with another viral

disease, such as enzootic bovine leukosis (EBL) (see

p. 693).

In infected animals the infection follows a progres-

The virus

sion similar to that seen with HIV. Thus the animals

The bovine immunodeficiency virus (BIV) is a

have a persistent and chronic lifelong infection. The

lentivirus first isolated as strain R29 in the USA from a *period of development for natural infection is not*

cow with lymphoproliferative lesions. The organism has

known, although following experimental infection

also been known as bovine immunodeficiency-like

cattle become seropositive in two to four weeks. Trans-

virus, bovine visna virus and bovine lentivirus. The virus

mission is thought to be horizontal, although proviral

is difficult to isolate, thus there have only been two sub-

DNA has been detected in the blood and semen of bulls

sequent isolates in the USA and also two in Japan. The

experimentally infected (Gradil et al., 1999). However, virus has a similar morphology to other lentiviruses

transplacental BIV infection has been demonstrated

with a viral envelope of structural gene products and a

between seropositive dams and their calves (Scholl

core of viral nucleic acid, p26 capsid, p16 nucleocapsid,

et al., 2000).

reverse transcriptase and integrase proteins. The RNA

genome is 1842 nucleotides in length. While the BIV

Clinical signs

contains the same non-structural accessory genes as

HIV, it lacks the addition gene nef found in primate

There is much debate as to the severity of the disease

lentiviruses. A genetically related virus to BIV,

in cattle. It does appear that in many instances the virus

Jembrana disease virus, has been isolated but is

causes no detectable signs, although in a few herds it

restricted to Indonesia (see p. 766) and causes a severe

does appear to cause major problems. It has been diffi-

disease in Banteng cattle (Bos javanicus) but a milder cult to define whether the virus caused problems on its

problem in Bos taurus.

own or whether infection predisposes animals to oppor-

tunistic infections by other cattle disease pathogens.

There is still argument as to whether or not BIV causes

Distribution

true immunodeficiency and this is why it is often

Although the virus has been rarely isolated there is

referred to as bovine immunodeficiency-like virus.

serological evidence to suggest that it is distributed

The main signs in severely affected animals include

worldwide. While it is said to be more prevalent in *loss of weight and poor condition, unthriftiness leading*

the southern states of the USA, it is also present in

to emaciation in some animals. There is a variable

the United Kingdom, Portugal, Switzerland, Croatia,

degree of lympadenopathy, which may be localized

France, The Netherlands, Italy and Germany in Europe.

or generalized. Lameness or stiffness may be general-

It is also reported to be present serologically in New

ized or result in one or more legs showing lameness.

Zealand, Australia, Canada, China, Korea and Pakistan.

There are nervous signs including changes in behaviour,

It probably is found in other countries but testing is dif-

nervousness, hyperaesthesia and also aggression in

ficult. Serological data suggest the highest prevalence

some animals, but other cases exhibit depression, dull-

of infection is in the USA and Canada, ranging from 20

ness and lethargy. Some animals become ataxic and will

to 60 per cent. A recent seroprevalence study in Great

on occasion fall over. Milk yield is depressed or even

Britain suggested a level of 5.9 per cent for dairy cattle

absent. A few animals may show prolapse of the third *and 5.0 per cent in beef cattle (Scobie et al., 2001). While eyelid.*

sheep, goats and rabbits have all been infected experi-

In some infected herds, outbreaks of common disease

mentally, there is no evidence to suggest that this

problems in calves and older animals such as diarrhoea,

happens naturally. There is nothing to suggest that BIV

pneumonia and abortion will result in particularly

is of any significant risk to man. It would appear that

severe disease in some individuals and not in others.

Pathology

Jeggo, M.H. (1986) A review of the immune response to

bluetongue virus Revue Scientifique et Technique d'Office

The pathological changes are very variable in extent

International des Epizooties, ***5***, *357–62.*

and severity. In some animals there is lymph node

Luedke, A.J., Jochim, M.M. & Barber, T.L. (1982) Serologic hyperplasia and mild perivascular cuffing in the brain.

and virologic responses of a Hereford bull persistently

The most common finding at post mortem examination

infected with bluetongue virus for eleven years. Proceedings has involved body lymph nodes which become or *of the American Association of Veterinary Laboratory*

contain large spheroidal haemal nodes, black in colour.

Diagnostics, ***25***, *115–34.*

These haemal nodes vary considerably between

Mertens, P.P.C., Burroughs, J.N. & Anderson, J. (1987) Purifi-infected animals in size, distribution and number

cation and properties of virus particles, infectious subviral

particles, and cores of bluetongue virus serotypes 1 and 4.

(Munro et al., 1998).

Virology, ***157***, *375–86.*

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Economics of bluetongue in the United States. In Arbovirus Reseach in Australia, Proceedings 4th Symposium, Brisbane, Diagnosis is difficult because the virus is not easily

May 1986, pp. 245–7.

isolated. Thus virus isolation in tissue culture is of

Verwoerd, D.W., Els, H.J., DeVilliers, E.M. & Huismans, H.

limited use as it is of low sensitivity and is also usually

(1972) The structure of the bluetongue virus capsid. Journal complicated by the presence of other viral agents.

of Virology, ***10***, *783–94.*

However, polymerase chain reaction (PCR) techniques

have been successfully used to detect the presence of *proviral DNA. Very variable results have also been*

Enzootic bovine leukosis

obtained by serological methods. The unreliability of

Burny, A., Brock, C., Chantrenne, H., Cleuter, Y., Dekegel, D., some assay methods has meant that there may have

Ghysdael, J., Kettman, R., Leclercq, M., Leunen, J.,

been false positive results during testing in the past. At

Mammerickx, M. & Portetelle, D. (1980) Bovine leukemia

present, most diagnostic methods involving serology

virus. In Molecular Biology and Epidemiology in Viral

use indirect immunofluorescent antibody (IFA),

Oncology (ed. by G. Klein), pp. 231–89. Raven Press, New enzyme linked immunosorbent assay (ELISA) or

York.

western blot. The tests most likely to be of use in screen-

Burny, A., Bruck, C., Cleuter, Y., Couez, D., Deschamps, J.,

ing large numbers of cattle would appear to be based

Ghysdael, J., Gregoire, D., Kettmann, R., Mammerickx, M.,

on ELISA and one currently in use is based on the TM

Marbaix, G. & Portetelle, D. (1985) Bovine leukaemia virus: region of BIV.

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Treatment and control

Burny, A., Bruck, C., Cleuter, Y., Couez, D., Deschamps, J.,

Gregoire, D., Ghysdael, J., Kettman, R., Mammerickx, M.,

There is no available treatment for BIV infection. The

Marbaix, G. & Portetelle, D. (1985) Bovine leukaemia virus best that can be done at present is to ensure full and

and enzootic bovine leukosis. Onderstepoort Journal of

adequate treatment of all secondary infections. In some

*Veterinary Research, **52**, 133–44.*

herds where clinical signs have been present it has been

Burny, A., Bruck, C., Cleuter, Y., Couez, D., Gregoire, D.,

the result of management deficiencies such as poor

Kettmann, R., Mammerickx, M., Marbaix, G., Portetelle, D.

nutrition or poor housing. In some herds where those

& Willems, L. (1986) Bovine leukemia virus as an inducer

deficiencies have been improved, the clinical signs have

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been reduced or become latent.

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Bovine immunodeficiency virus

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Chapter 44

Bacterial Conditions

A.H. Andrews and the late B.M. Williams

Anthrax

717

vegetative bacilli are not very resistant to environmen-

Bacillary haemoglobinuria

719

tal conditions or to physical and chemical agents,

Botulism

721

and are rapidly destroyed by putrefactive processes in

Clostridial myositis: blackleg and malignant oedema

723

unopened carcasses (Sterne, 1959). However, sporula-

Blackleg

723

tion occurs when carcasses are opened or when dis-

Malignant oedema

724

charges containing bacilli are exposed to air. Mature

Contagious bovine pyelonephritis

725

spores are extremely resistant to environmental condi-

Endocarditis

726

Haemorrhagic septicaemia

728

tions and certain disinfectants, and in soil they remain

Infectious necrotic hepatitis (black disease)

729

viable for many years.

Pericarditis

731

Anthrax has been reported from most if not all cattle

Tetanus

733

rearing countries of the world, but the incidence of

Leptospirosis (other than Leptospira hardjo infection) 734

disease is dependent on a number of factors, including

Leptospira hardjo infection (flabby bag)

735

climate, soil, animal husbandry and disease control

Haemophilus somnus infection

737

methods. Serious outbreaks of disease are more com-

Pyaemia

737

monly encountered in tropical and subtropical coun-

tries. In such areas, infection persists in the soil – spores

Anthrax

can survive for decades – and is a major source of infec-

tion. The disposal of animal carcasses also presents a

Bacillus anthracis infection in cattle causes a per-

serious problem unless whole carcasses are removed.

acute or acute disease, which is characterized by a

Otherwise cattle and other animals readily come into

septicaemia and sudden or rapid death. The disease is

contact with the tissues, particularly bones, of animals

a zoonosis and is subject to official control measures in

that die from anthrax. This method of infection is very

a number of countries. Infection in man usually results

important in phosphorus deficient areas where cattle

in the cutaneous form of the disease. Inhalation

develop pica and chew bones in an attempt to remedy

producing 'woolsorter's disease' is very severe but

the deficiency.

uncommon.

In temperate countries sporadic outbreaks occur

involving single or a small number of animals, arising

from the ingestion of contaminated feedingstuffs.

Aetiology

Campbell (1969) reported that the vast majority of

Bacillus anthracis is a Gram-positive capsulated

anthrax outbreaks in cattle in England and Wales were

bacillus and its morphology, together with the staining *associated with compound feedingstuffs containing*

reaction of the capsula, is of diagnostic importance.

meat and bone meal derived from imported materials

When stained by Giemsa's, Wright's or similar stains,

from Asia and South America, but he also emphasized

the capsule stains a reddish mauve colour, is square

that often vegetable protein became contaminated with

ended and its outline is rather ragged or 'shaggy' (Plate

anthrax organisms in the holds of ships that were being

44.1). A similar reaction is produced by methylene blue,

or had been used for the transport of meat and bone

but because of the variability in the content of its oxi-

meal. Hugh-Jones & Hussaini (1975) confirmed that in

dized products, azur A and B, which have an affinity for

Great Britain, contaminated feedingstuffs were the

the capsule, the staining reaction is less consistent and

major source of infection, although infection was some-

the staining of the capsule is a less intense mauve

times derived from tannery effluent and soil at sites

colour. The organism produces a lethal toxin that causes

where the carcasses of animals had been buried some *death through shock and acute renal failure.*

years previously.

The organism is a spore-forming bacillus, but mature

Infection is acquired through the ingestion of soil or

spores are not formed in the animal before death. The

effluent-contaminated fodder or contaminated com-

pound feedingstuffs. Schlingham et al. (1956) have

carcass must be carried out. If anthrax cannot be elim-

demonstrated that clinical disease in cattle can be reg-

inated, then a blood sample should be taken from a

ularly produced by the oral administration of organisms

superficial blood vessel and a stained smear examined

in feed pellets. The spores penetrate the intact mucosa,

microscopically. It is more difficult to identify anthrax

or through small abrasions in the mucosa of the mouth

bacilli if animals have been treated with antibiotics. The

and pharynx, and are then transported to the local

procedures for dealing with suspected anthrax cases

lymph nodes where germination and multiplication *vary from country to country and those currently in*

occurs, followed by passage via the lymphatics into the

force in Great Britain are discussed below.

bloodstream, leading to a septicaemia with an explosive

Rapid decomposition of the carcass sets in soon after

invasion of all body tissues.

death and in most instances rigor mortis is absent and

dark tarry blood exudes from all the body orifices.

There is bloodstained fluid in all body cavities and

Signs

there are widespread haemorrhages throughout the

All ages of cattle are susceptible to infection. The

carcass, particularly on the parietal pleura and peri-

incubation period is thought to be one to two weeks,

toneum. Unclotted or poorly clotted blood oozes from

although in some incidents it would appear to be

the cut blood vessels and there is an intense inflamma-

three to five days.

tion of the mucosa of the abomasum and both small and

At the beginning of an outbreak, the peracute form

large intestine. The spleen is almost invariably greatly *of the disease is more common, animals usually being*

enlarged with sometimes a rupture of the capsule, and

found dead within a few hours of being seen in normal

a dark semifluid pulp. The lesions in animals that have

health. On the rare occasions that animals are seen

been treated with antibiotics before death are similar

ailing, fever, muscle tremors, dyspnoea, collapse and

but much less spectacular.

terminal convulsions are the predominant signs, with

death occurring in 1–4 hours. In the acute form, which

Diagnosis

runs a course of 24–48 hours, fever, depression, rapid

and laboured respirations, diarrhoea or dysentery,

The diagnosis of anthrax is based on the demonstration

haemorrhagic congestion of the visible mucous mem-

of capsulated bacilli in peripheral blood and subsequent

branes and in dairy cattle a sudden drop in milk yield

confirmation by laboratory isolation and identification.

are the main signs. Pregnant animals may abort.

In Great Britain and many other countries, anthrax is a

Atypical signs have been recorded in calves receiv-

notifiable disease and the State Veterinary Service is

ing prophylactic levels of oxytetracycline or chlortetra-

responsible for confirmation.

cycline for the control of salmonellosis. In such animals,

There are numerous causes of sudden death in cattle,

a mild fever, bleeding from the nose and eyes and

including clostridial infections, hypomagnesaemia, lead

melaena were the only signs observed before death,

poisoning and lightning strike, all of which can be con-

which occurred 48–72 hours after onset (B.M. Williams,

firmed by a post-mortem examination and appropriate

unpublished data).

laboratory examinations. As emphasized earlier, such

procedures should not be undertaken until anthrax has

been eliminated.

Pathology

Because of the peracute/acute nature of the disease

Treatment and prevention

in cattle, there is little opportunity for ante-mortem

laboratory examinations. It may be possible to detect

Bacillus anthracis is sensitive to a number of antibiotics organisms in appropriately stained smears of peripheral blood, but sufficient numbers of organisms are only likely to be present during the later stages of the disease. A haematological examination may reveal a leucocytosis and a shift to the left, but because of the relatively short course of the disease, these changes are not marked.

Before a necropsy is carried out on an animal that has died suddenly or after a very short illness, it is essential that anthrax be eliminated, to prevent contamination of the environment and ensure proper disposal of

and treatment of animals during the early stages of the disease is likely to be successful, although severely ailing animals are unlikely to recover. Greenough (1965) successfully treated animals with 5 megaunits of penicillin alone or with streptomycin. The recommended dosage of penicillin is 10 000 units/kg body weight administered twice daily for at least three to five days. Streptomycin, in 4–5 g doses, should also be administered twice daily for the same period. Lincoln et al. (1964) consider that septicaemic anthrax is best

treated with a combination of large doses of penicillin
the carcass. Thus a careful evaluation of the circum-
and streptomycin twice daily, although oxytetracycline
stances and a thorough preliminary examination of the
and chlortetracycline are the next antibiotics of choice.

Bailey (1953) also recommends tetracycline for the
where MBM can be legally used, it is essential to use
treatment of anthrax. Anthrax antiserum administered
sterilized meal and minerals in their finished feeds.
intravenously is effective but the high cost and large
volumes required makes its routine use impractical.
When anthrax has been confirmed in a herd, all

Bacillary haemoglobinuria

animals should be carefully observed at frequent
intervals and any that are showing signs of ill health
Bacillary haemoglobinuria or infectious ictero-haemo-
isolated, their temperatures taken and, if elevated,
globinuria of cattle was described by Roberts (1959) as
immediately treated with antibiotic.
a rapidly fatal infectious disease, manifested clinically

In Great Britain and elsewhere, anthrax is a notifi-

by a high fever and haemoglobinuria, and pathologi-

able disease under the provisions of the Anthrax Order

cally by the presence of an infarct in the liver.

of 1938 for the protection of both animal and human

health. An owner or veterinary surgeon must report any

Aetiology

suspicion of disease to a police constable, who informs

the Local Authority, which then immediately imposes

The causal organism is Clostridium novyi type D,

restrictions on the movement of animals onto and off

previously designated Cl. haemolyticum. Like other the premises. The carcass(es) of the suspected animal(s)

clostridia it is a soil-borne anaerobe, the spores of which

must be detained and the skin must not be incised other

are resistant to environmental factors and may survive

than for the removal of a blood sample for diagnostic

in soil for weeks if not months. The disease is con-

purposes by the owner's veterinary surgeon or a vet-

sidered to be one essentially of poorly irrigated or wet

erinary officer appointed by the Minister, usually the *swampy land, which favours survival of the organism*

Divisional Veterinary Manager or a veterinarian acting

and is likely to harbour Lymnaea spp., the host snail on his/her behalf.

of the liver fluke. The principal toxin produced by

This State Veterinary Service is responsible for the

the organism is beta, which is haemolytic, necrotizing

disease investigation and a stained smear is made from

and lethal.

a superficial blood vessel and examined microscopi-

After ingestion the organism is transported from the

cally. If the Veterinary Inspector is satisfied that disease

alimentary tract to various organs. Smith (1957) recov-

does not exist, the Local Authority is informed and the

ered the organism from the liver, kidneys and bone

movement restrictions are withdrawn. If the inspector

marrow of normal cattle, where it remains as a latent

is not satisfied, an unfixed blood smear and a sample of

infection. It is thought that, as in infectious necrotic

blood is submitted to the Central Veterinary Labora-

hepatitis, the latent spore infection is activated by

tory for cultural and biological examination and the *liver damage, especially by migrating immature liver*

Local Authority informed accordingly: On receipt of

fluke. The disease has been produced experimentally by

this information the Local Authority is responsible for

infecting calves orally with the spores of Cl. novyi type disposal of the carcass, usually by burning, and carrying

D and carrying out a liver biopsy, and by implanting the

out disinfection of the premises as prescribed in the

organism in the liver suspended in calcium chloride

Order. The disinfectants of choice are 5 per cent lysol,

solution (Blood et al., 1983). It has also been postulated 5 per cent formalin or 5–10 per cent caustic soda. When

that telangiectasis may also be a precipitating factor.

these procedures have been completed, movement

When conditions are favourable for the activation of

restrictions are withdrawn.

the latent infection, the damaged liver tissue provides

Confirmation of the disease is dependent on the

a focus for initial multiplication of the bacteria. An

results of the examinations at the Central Veterinary

organized thrombus develops in a subterminal branch

Laboratory, which may take seven or more days. On

of the portal vein resulting in a large anaemic infarct in
rare occasions disease is not confirmed; even so the
which further rapid bacterial multiplication and toxin
existing procedures are considered effective in view of
production occurs. The toxin produces a haemolytic
the serious nature of the disease and the human health
anaemia, and later a bacteraemia develops. The dura-
implications.
tion of illness may vary from about 18 hours to four
Where enzootic disease exists, then an avirulent
days. Bacillary haemoglobinuria has been observed in
spore vaccine is available, and all cattle should be
North and South America, Australia and New Zealand.
vaccinated on an annual basis. Vaccination is seldom
Few incidents have been reported in Great Britain.
necessary in Great Britain (see p. 1005).
The number of confirmed incidents in Great Britain
Signs
is now very low. This is largely due to the efforts of
feedingstuffs compounders, who no longer use meal
Cattle at pasture that are inspected at infrequent inter-

and bonemeal (MBM) in their feeds. In other countries,

vals may be found dead. The onset of disease is usually

Fig. 44.1

Bacillary haemoglobinuria: a

large infarct in the bovine liver caused by

Cl. novyi type D.

sudden, with cessation of feeding, rumination and defe-

coloured with a characteristic yellow infarct, up to

cation. Cows in lactation suffer a sudden and dramatic

20 cm (8 inches) in diameter, surrounded by a zone of

drop in milk yield. Animals are disinclined to move and

hyperaemia (Fig. 44.1). The kidney cortex is petechi-

the temperature is elevated to 39–41°C (102–106°F).

ated and deep-red coloured urine may be present in

The mucous membranes are jaundiced and there may

the kidney pelvis and bladder. Evidence of liver fluke

be oedema of the brisket, submaxillary region and con-

damage is not a constant feature.

junctiva. Small amounts of bloodstained faeces may be

passed in the early stages, but later there may be a frank

dysentery. Not all these signs may be seen in individual

Diagnosis

cases and the variation may be due, in part, to different

strains of organisms.

Bacillary haemoglobinuria must be differentiated from

other conditions in which haemoglobinuria is one of

the clinical signs. Acute leptospirosis, due to Leptospira Pathology

interrogans serovar pomona (p. 734), is one of these and One of the obvious features of the disease is the

to confirm a diagnosis in the live animal serological tests

profound anaemia that develops before death. Blood

and cultural examination of the urine is necessary,

samples from ailing animals show a depressed erythro-

although there should be little difficulty in differentiat-

cyte count, which may be as low as 106/mm3 and haemo-

ing the two diseases at necropsy. Babesiosis (p. 748)

globin values are in the range of 40–80 g/l. Leucocyte

and anaplasmosis (p. 761) can be differentiated by the

counts are normally elevated to around 20 000/mm3.

demonstration of the organisms in blood smears.

The organism may be recovered from blood cultures

Post-parturient haemoglobinuria is accompanied by a

taken during the acute phase. There is a very obvious

hypophosphataemia (see p. 792), whilst blood and liver

haemoglobinuria in a proportion of cases, but there are

copper levels are elevated in chronic copper poisoning

no free red cells in the urine.

(p. 948). Both these conditions and haemoglobinuria

In the typical case, the necropsy picture is considered

due to the consumption of cruciferous plants (p. 941),

to be pathognomonic, the main features being gen-

such as rape and kale, are afebrile.

eralized jaundice often with anaemia; subcutaneous

Confirmation of diagnosis of bacillary haemoglobin-

oedema especially over the brisket; accumulation of *uria is based on the clinical signs, necropsy findings and slightly bloodstained fluid in the pericardial sac, pleural demonstration of the causal organism in the liver lesion and peritoneal cavities; widespread haemorrhages in and other sites by fluorescent antibody techniques. It the subcutaneous tissues, over the pleural and peri- may also be possible to culture the organism from tissue toneal serosa, and endocardium; haemorrhagic abo- and demonstrate toxins in the liver infarct, but both mastitis and enteritis. The liver is usually mahogany procedures are time-consuming and laborious.*

Treatment and prevention

ference with the secretion of acetylcholine, which is the chemical mediator of nerve impulse transmission.

Bacillary haemoglobinuria can be successfully treated

Two forms or types of botulism are recognized in by the administration of wide-spectrum antibiotics in cattle. The first is the form that develops after the con- the early stages (Smith & Holdeman, 1968). Early treat- sumption of, or contact with, carcasses or skeletons of

ment with large doses of penicillin is also effective
dead animals containing botulinum toxins. The second
(Williams, 1964). Supportive treatment by the adminis-
form of the disease follows the consumption of con-
tration of electrolyte solutions orally and parenterally
served fodder that is contaminated by the toxins.
and the provision of mineral supplements containing
The first type of botulism has been widely reported
iron, copper and cobalt is also necessary, as well as
in South Africa (lamsieket), Australia (bulbar paralysis)
careful nursing.
and in the USA (loin disease). In these countries it
The disease can be successfully prevented by
has been associated with low phosphorus levels in soil,
vaccination with an aluminium hydroxide adsorbed,
poor pastures and drought. Under such circumstances
formalinized whole culture and it is also claimed
animals including the local fauna, which carry Cl.
that infectious necrotic hepatitis vaccines also confer
botulinum in their intestines, die and the organisms
immunity. Annual vaccination is necessary in enzootic

invade the carcass tissues and produce large amounts

areas (see p. 1005).

of toxin. Muller (1961) has demonstrated that the levels

of toxin may reach 105–106 mouse lethal units/g of

tissue. Animals that consume tissue from such carcasses,

Botulism

because of a phosphorus deficiency and a subsequent

pica, or feed shortage, ingest both toxin and Cl. botu-

Botulism may be defined as a lethal type of food

linum spores and will subsequently become a source of poisoning in man and several species of animals,

toxin and spores for other animals. In Europe, similar

caused by the ingestion of Clostridium botulinum

circumstances may arise after the spreading of litter

toxins, which have been produced by the organism in

from poultry houses on to cattle pastures. Investiga-

decaying plant or animal tissue.

tions into such outbreaks reveal the presence of poultry

carcasses in the litter, which are the source of the toxins

(Appleyard & Mollison, 1985; Clegg et al., 1985).

Aetiology

The second type of botulism, forage poisoning, occurs

Smith (1977) defines Cl. botulinum ‘not as a single

in those countries where conserved forage, especially

species, but as a conglomerate of several distinct culture

baled hay and silage, is fed to cattle. The source of toxin

groups, alike in that they are clostridia and produce

has usually been identified as the carcasses of small

toxins with a similar pharmacological action’. There

animals (mice, rats, rabbits and birds) accidentally killed

are a number of distinct serological types (A, B, C,

and subsequently baled in the hay or ensiled with the

D, E, F and G) and although the toxins are similarly

grass or cereal crop. Prevot & Sillioc (1955) recorded

designated, the serological specificity of the toxin

that more than half of the cattle botulism in France was

produced by any strain may not be entirely related to

associated with the presence of cat carcasses in the feed.

its serological classification.

Fjolstad & Kluna (1969) also reported an outbreak in

Like other clostridia, Cl. botulinum is a spore-

which the source of toxin was a cat carcass and demon-

forming organism, which under certain conditions

strated 500 000 mouse lethal doses/g of the carcass. A

thrives in putrefying animal tissue or decaying plant

hedgehog, discovered in a hay rack, was the source of

material. The organism has a world-wide occurrence

toxin in an outbreak in cattle with 20 000 mouse lethal

and is found in the intestinal tracts of herbivores and in

doses in its subcutaneous tissue (Ektvedt & Hanssen,

soil. It would appear that different soil types favour

1974). Recently, however, it has been demonstrated that

different types of the organism. Smith (1997) reported

proteolytic strains of Cl. botulinum may produce toxin that in the USA, type A strains were prevalent in

in silage under certain conditions and without the pres-

the alkaline soils of the south-west, types B and E in the

ence of animal tissue (Notermans et al., 1979a, b). It damp soils of most areas, type C in the acid soils of the

would appear that a low pH prevents toxin formation

Gulf Coast and type D in the alkaline soils of the west.

in silage. The incorporation of poultry manure and

The toxins of Cl. botulinum are neurotoxins, causing

poultry waste in cattle feed can also lead to outbreaks *motor paralysis without the development of any gross*

of botulism (Egyed et al., 1978) and brewers grains

or histological lesions in the nervous system. Although

contaminated with Cl. botulinum has also been

the mode of action is still debated, it appears that the

incriminated (Breuknik et al., 1978).

site of action of the toxins is at the synapses of efferent

Botulism in any species of animal tends to be associ-

parasympathetic and somatic motor nerves, by inter-

ated with certain types of the organism. Ruminants are

susceptible to types C and D, although in The

are non-specific and include haemorrhages on the

Netherlands disease has been associated with type

endocardium and epicardium and congestion of

B (Haagsma & Laak, 1977).

the parenchymatous organs and intestinal mucosa.

However, it may be possible to demonstrate toxin in the

intestinal contents or liver by mouse inoculation tests.

Signs

Whilst the presence of the organism in the intestine is

Clinical signs usually appear within two to fourteen

of little diagnostic value, its isolation from the liver is of days of ingestion of the toxin, although in peracute

significance. In many cases investigation of outbreaks is

cases the incubation period may be only a few hours.

unrewarding.

Illness is afebrile.

In peracute cases the onset of disease is sudden, char-

acterized by a rapid paralysis and death within 12–18

Diagnosis

hours. In less acute cases the onset is more gradual,

It must be emphasized that in many instances it is not

affected animals showing a progressive muscular paral-

possible to confirm all suspected cases of botulism by

ysis of the head, neck and limbs, leading to recumbency,

detection of toxin either in the sera of affected animals

often with the head and neck outstretched or deviated

or in the intestinal contents or liver at necropsy. As Cl.

towards the flank.

botulinum is not normally found in the liver of cattle, The majority of cases, however, appear to be of the

isolation from the liver is regarded as significant.

subacute type. The first signs are periodic periods of

Attempts may be made to demonstrate toxin in sus-

restlessness, incoordination especially of the hindlimbs,

pected feed, but such an approach has its limitations.

and an apparent difficulty in chewing and swallowing.

Suspected feed may be fed to experimental animals of

These signs progress to ataxia, difficulty or inability to

the same species, or an infusion of the feed may be

rise, recumbency and in some an obvious paralysis

administered to experimental animals. However, toxins

of the tongue, which protrudes from the mouth. There

in feedingstuffs are not distributed evenly, rather in

is usually partial or complete anorexia and adypsia.

pockets, and samples of feed for testing must therefore

Animals may survive for up to seven days after becom-

be carefully selected, e.g. from near carcasses or areas

ing recumbent, but during the terminal stages respira-

of contamination. It is also possible that all the botu-

tion becomes laboured and of the abdominal type due

linum-contaminated feed will have been consumed

to paralysis of the thoracic muscles. An animal often *before the onset of clinical signs.*

appears to rest its chin on the ground and will lift it

Postparturient paresis/hypocalcaemia (p. 781) can be

when stimulated. A foreleg may be extended. As the

differentiated from the disease by the examination of

condition progresses nominal movements reduce. Later

blood samples and the response to calcium therapy. In

stages often involve lateral recumbency with extended

some cases of listeriosis (p. 904) there is a paralysis of

legs which can be flexed. The animal is conscious.

the tongue, but it is acompanied by fever and other clin-

Some animals may recover after showing relatively

ical signs such as unilateral facial paralysis and panoph-

mild clinical signs over a period of three to four weeks

thalmia. Bovine spongiform encephalopathy (p. 911) in

(Clegg & Evans, 1974; Davies et al., 1974). Clegg & its later stages might be confused but there is no paral-Evans reported that surviving animals developed a pro-

ysis and the animal will still eat.

nounced respiratory roaring sound, which persisted for

three months after recovery.

Treatment and prevention

Pathology

There is little value in the administration of antitoxin,

A number of authors have reported on the value of

except possibly in the very early stages, and there are

certain biochemical tests on blood and urine from

conflicting views on the merits of purgatives to remove

affected animals as aids to diagnosis, but in cattle such

the toxins from the intestine. However, Breuknik et al.

tests are of little help in the live animal. However, it is

(1978) reported that symptomatic treatment for dehy-

possible in some cases to demonstrate circulating toxins

dration and acidosis seemed to assist recovery. As a

in the serum of clinically affected animals by mouse

general rule, treatment of subacute cases only should be

inoculation tests (Clegg et al., 1985), but such cases are undertaken, as these are the ones most likely to recover.

of the peracute or acute type.

Vaccination with toxoid is only necessary in enzootic

As already indicated, the toxins of Cl. botulinum do

areas and should be given every two years (p. 1005).

not produce any specific or detectable lesions in the

Where botulism is associated with the disposal of

central nervous system, nor do they produce specific

poultry litter on to pasture, every effort should be made

changes in the carcass. Those changes that are observed

to remove any poultry carcasses in it before application.

All poultry waste should ideally be heat treated

animals are related to the site of lesion. Limb involve-

before incorporation into compound feeds for direct

ment is manifested as a lameness with a swelling of the

feeding to livestock.

upper part which, at first, is hot and painful, but later

becomes cold and emphysematous. A lesion of the

tongue results in a tongue and throat swelling, with the

Clostridial myositis: blackleg and

tongue protruding from the mouth and marked respi-

malignant oedema

ratory distress. Stiffness and a reluctance to move is

apparent when the sublumbar muscles are involved.

In addition to these clinical signs, there is a marked

Two forms of clostridial myositis are recognized in *depression, anorexia, rapid pulse rate and high temper-*

cattle: blackleg, which is caused by Clostridium

ature, usually in excess of 40°C (104°F). Later there is

chauveoi, and malignant oedema, which is caused by

dypsnoea, recumbency and coma leading to death with-

a number of clostridial species and is nearly always

in 12–24 hours.

associated with wound infection. It is often difficult or

impossible to differentiate between the two conditions

at a clinical or post-mortem examination (Williams,

Pathology

1977).

The disease usually runs an acute course so that there

is little opportunity for collecting specimens for

Blackleg

laboratory examination before death. After death

the carcass becomes bloated and putrefaction occurs

Blackleg or blackquarter is defined as a gangrenous

rapidly. Bloodstained froth exudes from the body ori-

myositis caused by the activation of a latent Cl. chau-

fices. It may be possible to palpate the lesion, if it is in *veoi spore infection (Jubb et al., 1983). These authors a superficial muscle group, but this is usually difficult*

also refer to a 'false or pseudo-blackleg' caused by the

because of the rapid onset of putrefaction.

activation of Cl. novyi and Cl. septicum spore infection, Animals dying from blackleg are in good body condi-but this condition is more appropriately designated

tion. The body cavities contain bloodstained fluid and

malignant oedema.

the parenchymatous organs show evidence of degenera-

tion and post-mortem decomposition. All the skeletal

Aetiology

muscles must be carefully examined by palpation and

incision for lesions, which may not be extensive. The

Clostridium chauveoi is a Gram-positive, spore-bearing lesion produced by Cl. chauveoi has a characteristic

anaerobic bacillus, the spores of which are highly resist-

appearance (Williams, 1977) (Plate 44.2). The muscle is

ant to environmental conditions and therefore re-

blackened, dry and crepitant with a spongy appearance

main viable for many years. It is, like other clostridia,

and a rancid odour. Pale yellow serous fluid surrounds

regarded as a soil organism and following ingestion by *the affected muscle, but this becomes progressively more*

cattle, sheep and other animals, the spores localize in

bloodstained as post-mortem decomposition proceeds.

the spleen, liver and muscles (Kerry, 1964). The vegeta-

tive form of the organism produces a number of toxins,

which are capable of inducing local muscle necrosis and

Diagnosis

toxaemia. The trigger mechanisms responsible for the

A diagnosis can be reached on the basis of clinical signs

activation of the endogenous latent spore infection

and necropsy findings, but it is essential that when no

are unknown, but it is assumed that a lowered oxygen

clinical signs have been observed, anthrax (p. 717) is

tension and a degree of muscle damage are necessary.

eliminated before a necropsy is carried out. Clostridium

After activation, rapid bacterial multiplication and

chauveoi can be identifed by the staining of lesion

toxin formation produce the typical muscle gangrenous

impression smears by the specific fluorescent antiglob-

lesion and systemic toxaemia.

ulins that are now commercially available. Cultural

Most cases occur in animals between six months and

examination is likely to be unrewarding unless fresh

two years of age at pasture, although incidents may

tissue is available and special techniques used.

occur in housed animals.

Blackleg may be confused with other conditions

especially when death is sudden. Lead (p. 944) and

other chemical poisonings (pp. 941–3) require labora-

Signs

tory examination for confirmation, but the typical

Often when stock are infrequently inspected animals

lesions of blackleg are absent. Black disease (p. 729)

may be found dead without signs of illness having been

and bacillary haemoglobinuria (p. 719) may also have

observed. The clinical signs that are seen in ailing

to be considered in a differential diagnosis, but the

characteristic liver infarcts are a diagnostic feature of

nificance. There is still some uncertainty about the role

these two diseases.

of Cl. septicum in bovine malignant oedema.

Deep puncture wounds,

accidentally inflicted,

provide ideal conditions for the multiplication of anaer-

Treatment and prevention

obes and development of malignant oedema. It may

Antibiotic treatment of affected animals is likely to

also develop after surgical operations, parturition, intra-

be effective only if commenced early. Large doses of

muscular administration of non-antibiotic preparations

penicillin (10 000 units/kg body weight) should be

such as prostaglandlins (Harwood, 1994), anthelmin-

administered intravenously, followed by longer acting

tic and vitamin preparations, and vaccination. The

preparations, some of which should be given into

clostridia are soil organisms that persist in the animal

the affected tissue (Radostits et al., 2000). However, environment and therefore readily gain entry to

because of the extensive tissue involvement, even if

wounds. The tissue damage and low oxygen tension

the infection is eliminated, the subsequent muscle loss

allow rapid multiplication and toxin production so *is so great that recovered animals are of little econ-*

that clinical signs usually develop within 48 hours.

omic value. Treatment of animals with tongue infection

Occasionally, malignant oedema may affect a group of

should not be attempted, because even if successful the

animals that had previously been housed or penned for

whole tongue or most of it will be subsequently lost and

a short period of time and the absence of any form of

early slaughter on humane grounds should be consid-

wound suggests that some factor, perhaps trauma from

ered. Carcasses should be burned or undergo deep

bruising, may have activated a latent spore infection.

burial.

Blackleg can be successfully prevented by the use of

Signs

commercially available Cl. chauveoi vaccines and all

animals over six months of age should be vaccinated

The disease is usually sporadic involving single or small

prior to being turned out in the spring. There are,

numbers of animals. All ages of cattle are affected and

however, considerable advantages in the use of multi-

clinical signs appear within 48 hours of infection. The

valent vaccines containing the antigens of Cl. chauveoi, clinical signs will vary with the site of infection, but

Cl. novyi and Cl. septicum, which offer maximum proin all cases, anorexia, depression and fever are very

tection to cattle against blackleg, malignant oedema

marked. A local lesion develops at the site of infection

and black disease (p. 1005).

consisting of a swelling, which becomes tense and

depending on the type of infection may become emphy-

sematous. Lameness, stiffness and muscle tremors may

Malignant oedema

be evident. Animals usually die within 48 hours.

Malignant oedema is considered to be an acute wound

When infection is associated with parturition, the

infection caused by organisms of the genus Clostridium

vulva and perineum swell and there is a bloodstained

(Radostits et al., 2000). However, if blackleg is restricted discharge from the vulva. Death is rapid, usually within

to cover endogenous Cl. chauveoi infection then malig-24–36 hours after the onset of signs.

nant oedema must also include those incidents, albeit

relatively few in number, arising from activation of

Pathology

latent Cl. novyi and Cl. septicum, which undoubtedly occur.

In malignant oedema there is little opportunity for

the laboratory examination of specimens taken from

affected animals. As in blackleg, it is necessary for a

Aetiology

post-mortem examination to be carried out as soon

Clostridium chauveoi, Cl. novyi, Cl. perfringens, Cl. sep-

after death as possible, because of the bacterial invasion

ticum, Cl. sordelli and other clostridia have been iso-of the carcass and rapid onset of putrefactive changes.

lated from, or demonstrated in lesions of clostridial

The site of infection is surrounded by an extensive

myositis in cattle. Williams (1977) in a survey of 173

oedema of the subcutaneous tissues and intramuscular

cases in Wales demonstrated Cl. chauveoi in 75 (43 per fascia. It may be possible to identify the initial wound,

cent), Cl. chauveoi and Cl. septicum in 22 (13 per cent), but tissue damage is usually so extensive that the only

Cl. novyi in 53 (31 per cent), Cl. novyi and Cl. septicum trace is a small wound in the skin. The oedema fluid may

in nine (5 per cent), Cl. septicum in 11 (6 per cent) and be clear and gelatinous in Cl. novyi infections with very Cl. sordelli in three (1.7 per cent). In this series Cl. per-little muscle damage. Infection with Cl. septicum pro-fringens was isolated from about 50 per cent of the

duces an extensive bloodstained frothy oedema, with

lesions, but its presence was not considered to be of sig-

the underlying muscle a dark red colour permeated

with gas. Clostridium sordelli produces changes similar cattle and occasionally sheep, and can be readily cul-to those produced by Cl. novyi except that the oedema tured from the urine of affected and carrier animals.

is more bloodstained and has a foul odour. The lesion

Goudswaard and Budhai (1975) identified four

produced by Cl. chauveoi is similar to that described serotypes, of which type 1 is the most pathogenic.

under blackleg.

It has been demonstrated that the pathogenicity of C.

All body cavities contain bloodstained fluid and

renale is dependent to a large extent on the presence of the parenchymatous organs show degenerative changes

pili on the organism, which assist its adhesion to the

and post-mortem decompostion. If the infection

urinary epithelium. This process is pH dependent and

involves the reproductive tract, the uterus will contain

Takai et al. (1980) showed that the proportion of pili-a large volume of foul-smelling bloodstained fluid and *ated organisms adhering to bladder cells is high at a pH*

the uterine and vaginal walls will be greatly thickened,

above 7.6, but significantly lower at a pH below 6.8,

permeated with bloodstained fluid and gas.

a factor that is important in the pathogenesis of

pyelonephritis.

The disease is considered to be the result of an

Diagnosis

ascending infection, involving successively the bladder,

The clinical signs and necropsy findings are so charac-

ureters and kidneys. Hiramune et al. (1972) established teristic that diagnosis can be readily reached. It will,

infection in cattle after the introduction of organisms

however, be necessary to resort to laboratory examina-

into the bladder and the characteristic lesions devel-

tion of lesions for the identification of the organisms by

oped. Females are far more susceptible than males to

fluorescent antibody tests or culture.

infection and the short length of the urethra in the

female is thought to be a major factor in the establish-

ment of infection. Stasis of urine is an important pre-

Treatment and prevention

disposing factor in the pathogenesis of pyelonephritis

Affected animals should be treated with high doses of

and cystitis and such circumstances may occur when a

antibiotics, preferably parenteral penicillin or broad

permanent or temporary obstruction of the urinary

spectrum. In addition, wounds should be drained and

tract occurs through the presence of calculi or pressure

irrigated with antiseptic solutions, and packed with a

exerted by a gravid uterus.

suitable antibiotic preparation.

The disease is widely recognized in Europe and

Trivalent vaccines, containing the antigens of Cl.

North America, but the prevalence of infection is

chauveoi, Cl. novyi and Cl. septicum are available largely unknown. Morse (1950) found that C. renale

and are effective in preventing malignant oedema

could be recovered from the urine of 22.7 per cent of

(p. 1005).

cattle in herds in which pyelonephritis had been con-

Harwood (1984) highlights the dangers from intra-

firmed, whereas only 10.7 per cent of cattle in other

muscular injections administered to cattle, particularly

herds were infected. Clinically infected or carrier cows

if infection is introduced and if large volumes are used,

are the principal source of infection, the disease being

and under such circumstances routine vaccination is

mainly transmitted by direct contact, although Morse

recommended.

(1950) reported that infection was transmitted by indi-

rect contact from affected and carrier cows tethered in

stalls to those in adjacent stalls. In some herds there

Contagious bovine pyelonephritis

is circumstantial evidence to support the existence

of venereal spread and the organism has been readily

This disease is a specific infection of the urinary tract of

isolated from the prepuce of normal bulls (Hiramune

cattle, which results in a chronic purulent inflammation

et al., 1975).

of the kidneys, ureters and bladder.

Signs

Aetiology

In affected herds, clinical cases appear sporadically with

Corynebacterium renale is considered to be the speific animals under three years of age rarely affected. Most

causal agent, although other organisms, especially strep-

cases occur in dairy herds with the peak incidence

tococci, staphylococci, Arcanobacterium (Actinomyces, usually in winter.

Corynebacterium) pyogenes and Escherichia coli, as There is considerable variation in the clinical signs

well as C. renale are present in the urine of some

observed from case to case, particularly during the early

animals with pyelonephritis and may also be impli-

stages. Bloodstained urine may be passed intermittently

cated. Corynebacterium renale is an obligate parasite of by an apparently healthy animal over a period of weeks,

before other signs appear. In other animals, one, two or

Diagnosis

more attacks of acute colic lasting up to 6 hours or more

The diagnosis of pyelonephritis is based on the clinical

may be the first sign. More frequently, however, the

signs, the changes in the urine and the presence of C.

onset is insidious. The most common signs are a gradual *renale in the urine together with the detectable abnor-loss of condition, a slowly declining milk yield, fluctu-*

malities in the urinary tract. Enzootic haematuria

ating or capricious appetite, intermittent fever, and

(p. 947) has some clinical features in common with

the intermittent passage of bloodstained urine. As the

pyelonephritis, but it is afebrile, lesions are confined to

disease progresses, urination becomes more frequent

the bladder and the urine from such cases is sterile or

and painful with the passage of small volumes of urine

negative for C. renale. Similarly, non-specific cystitis containing blood and tissue debris. During the later

may also resemble pyelonephritis, but the bladder only

stages it may be possible to detect, by rectal examina-

is affected and the urine is sterile or negative for C.

tion, enlargement of one or both kidneys, a thickened

renale.

bladder and enlargement of one or both ureters,

particularly the terminal portions where they cross

the neck of the bladder. Frequently, palpation of

Treatment and prevention

the kidneys induces a pain response. The course *of the disease may run from a period of weeks to two*

Corynebacterium renale is sensitive to a range of antibi-or more months, death resulting from a combination

otics but penicillin remains the antibiotic of choice for

of kidney failure and blood loss with an extensive

the treatment of pyelonephritis in the bovine. A com-

loss of condition.

plete recovery can be achieved if treatment is

commenced during the early stages, when little tissue

damage has occurred. In advanced cases, however,

Pathology

when there is considerable tissue destruction, only a

The urine of clinically affected animals is turbid and in

temporary recovery can be achieved through antibiotic

the early stages intermittently bloodstained, but in the

therapy, although this may enable an animal to be fat-

later stages the urine is almost constantly bloodstained.

tened and subsequently sent for slaughter. Large

Microscopic examination of the centrifuged deposit of

doses of procaine penicillin G should be administered,

the urine reveals the presence of erythrocytes, leuco-

e.g. 10 000–15 000 iu/kg daily for at least 10 days.

cytes and epithelial tissue debris. Corynebacterium

The acidification of the urine by the administration of

renale can be readily demonstrated in Gram-stained

monobasic sodium phosphate is still considered by

smears and Ado & Cook (1979) have reported on the

some as useful supportive therapy and 100 g daily for

value of fluorescent antibody tests for the identification

a period of five days during antibiotic treatment is

of the organism. It can be readily isolated on blood agar

recommened.

and other media in common use. The clinical signs

There are no specific control measures other than

are so characteristic that haematological examination

isolation of affected animals and thorough cleansing

and blood chemistry estimations are seldom considered

and disinfection of the contaminated environment. In

necessary. In any case, such examinations are unlikely

affected herds where natural breeding is practised, the

to reveal any abnormalities until the disease is well

introduction of artificial insemination may achieve a *developed when anaemia and uraemia are the most*

reduction in the number of clinical cases.

prominent findings.

Animals dying from pyelonephritis are usually in

poor condition and the carcass pale and anaemic. Spe-

Endocarditis

cific lesions are confined to the urinary tract. One or

both kidneys are enlarged with less well marked lobu-

Endocarditis may be defined as inflammation of the

lation than normal and a markedly thickened capsule.

endothelial lining of the heart. The inflammatory

The surface is mottled by greyish white necrotic areas.

processes usually result in valvular insufficiency or

On section the renal pelvis is greatly dilated and con-

stenosis that interfere with the flow of blood into and

tains varying amounts of blood, pus and mucoid fluid.

out of the heart, leading to congestive heart failure.

Greyish white streaks of necrotic tissue radiate from

the pelvis towards the cortex and there may be numer-

Aetiology

ous abscesses in the cortex and medulla of each lobule.

The ureters are grossly enlarged and distended by

Most cases of bovine endocarditis appear to be caused

blood, pus and mucus. The bladder wall and the urethra

by bacterial infection. Several species of bacteria have

are thickened and the mucosa oedematous, haemor-

been incriminated, but streptococci especially entero-

rhagic and necrotic.

cocci of Lancefield's group D, A. pyogenes, staphylo-

cocci, Mannheimia and Pasteurella species are the com-heart involvement and the onset of the clinical signs of

monest (Evans, 1957; Larsen, 1963).

endocarditis may be insidious.

It would appear that a persistent bacteraemia is nec-

A recurrect or persistent fever of 40–41°C

essary for the development of endocardial lesions and

(104–106°F), anorexia, depression and a reluctance to

it is significant that in most, if not all, confirmed cases,

move are the usual early signs. Pinching of the withers

a primary focus of infection in the form of mastitis,

and ballottement of the sternum ventral to the heart *metritis, reticulitis, limb abscesses, etc. can be identified*

elicit a pain response. The heart rate is accelerated to

at post-mortem examination (Evans, 1957; Andersen,

100–120 beats/minute and in due course the jugular

1963; Larsen, 1963).

vein becomes engorged, which is followed by oedema

Although it is generally accepted that the causal

of the brisket and submandibular areas. The detection

organisms are transported to the heart via the blood-

of a heart murmur on auscultation is an important clin-

stream, the method by which they reach the endocar-

ical feature, but this is not easily detected when the right

dial lesion is still uncertain. It is possible that some

atrioventricular valves are involved. Lacuta et al. (1980) bacteria may be able to adhere to the intact endothe-have reported on the value of electrocardiography

lium. However, it is more likely that they adhere to

and echocardiography in the diagnosis of endocarditis.

damaged endothelium and it is assumed that trauma

Whilst echocardiography is of value in that it will

and debility are the main factors in producing sufficient

demonstrate reflected echoes from the vegetative *damage for the bacteria to localize in the endothelium.*

lesions and detect abnormal valve movements, electro-

This hypothesis is based on the fact that the usual sites

cardiography is less so because the abnormalities shown

of the lesions are on the free edges of the valves

are not diagnostic of endocarditis.

exposed to the blood flow and that they are in apposi-

As the disease progresses, secondary involvement of

tion to others. The heart valves of the bovine have their

other organs and systems occurs, leading to pneumonia,

own blood supply and it is thus possible for the bacte-

nephritis, arthritis, etc. Progressive weight loss, anaemia

ria to produce emboli in the capillaries, which form a

and weakness inevitably is followed by recumbency and

focus of infection.

death. The course of the disease may extend from one

The early lesions of endocarditis are seldom seen

or two weeks to two or three months.

except in experimental infections. Initially, the leaflet of

the valve becomes swollen and an irregular ulcer devel-

Pathology

ops on its surface, in which the bacteria localize. From this ulcerated area the characteristic vegetative struc- Blood samples from affected animals show a leucocy- tures develop. These have a similar composition to tosis and a shift to the left, although in the more chronic thrombi, except that they contain few platelets. Several cases these changes are less well marked. Plasma fib- layers of thrombus-like material are deposited on the rinogen levels are elevated (Wuijckhuise-Sjouke, 1984) affected valve in response to the bacterial activity, but this is a feature of inflammation of serous mem- so that vegetations assume a cauliflower or wartlike branes as well as endocarditis. The causal organism can appearance and the valves become distorted and be isolated on blood culture during periods of fever but shrunken and functionally incompetent. Fragments of at least 20 ml of blood are necessary and the cultures the vegetation may become detached to form emboli, may have to be repeated on a number of occasions. which lodge in other organs.

The heart lesions found at necropsy are fairly con-

stant (Plate 44.3). The pericardial sac is distended with

varying amounts of oedematous fluid and the heart

Signs

is enlarged and distorted, due to hypertrophy of the

All ages of cattle are affected although Larsen (1963)

myocardium and dilatation of one or more chambers,

found that nearly half of the 53 bovine cases he encoun-

because of the incompetence/stenosis of the affected

tered were in animals between two and three years of

atrioventricular valves. In the majority of cases the right

age. Both Evans (1957) and Biering-Sørensen (1963)

atrioventricular valves are affected. The affected valves

found that 3.9 per cent of cattle examined in abbatoir

are shrunken and thickened, particularly in the later

surveys had either died from, or been slaughtered

stages, and attached to them there are wart-like or

because of, endocarditis.

cauliflower vegetations.

The published descriptions of the clinical signs of

The parenchymatous organs may show pathological

bovine endocarditis are varied and reflect the stage to *changes. The lungs are passively congested with fre-*

which the endocarditis had progressed and also the

quently a number of embolic infarcts, and the liver is

extent to which the clinical signs were attributable to

usually enlarged due to passive venous congestion and

the primary focus of infection (Evans, 1957; Power &

may show evidence of cirrhosis. Numerous small haem-

Rebhun, 1983). Thus the initial signs may not indicate

orrhagic foci are scattered over the surface of the

kidneys and within the cortex and there may be a

of Great Britain in 1926. The lesions in the affected

number of infarcts or abscesses in the cortex.

animals were those of a bronchopneumonia and

although Pasteurella was isolated from the lungs it was not fully typed but likely to have been type B. Since

Diagnosis

then there have been no further reports of haemor-

The clinical diagnosis of endocarditis is dependent upon

rhagic septicaemia in Great Britain. In the USA only

the detection of heart murmurs, which may be *four outbreaks, three in bison and one in cattle, have*

extremely difficult when the lesions involve the right

been confirmed and Carter (1982) speculated on its

atrioventricular valves. Thus it may be difficult or

disappearance from that country.

impossible to differentiate between endocarditis and

Pasteurella multocida is not a very resistant organism pericarditis (p. 731) (John, 1947) or other causes of con-and it is unlikely to survive for long periods outside the

gestive heart failure. Cardiac lesions of enzootic bovine

animal body. In soil and mud, for example, where com-

leukosis (EBL) (p. 695) may also produce signs of con-

petition from other organisms is strong it does not

gestive heart failure, but affected animals show a per-

survive for more than 24 hours (Bain, 1963). Toxins

sistent lymphocytosis and are positive to the agar gel

have been demonstrated in culture filtrates, but all the

immunodiffusion and ELISA tests for EBL.

evidence suggests that the most significant of these are

endotoxins, which are important in producing the clini-

cal disease and rapid death.

Treatment

The main source of infection is the carrier animal, the

The organisms associated with bovine endocarditis are

organism localizing in the nasopharyngeal mucosa and

sensitive to a range of antibiotics. However, the nature

tonsils. In herds that experienced haemorrhagic septi-

of the heart lesions is such that therapeutic concentra-

caemia 44.4 per cent of healthy cattle were carriers,

tions of antibiotic may not penetrate through to the

whereas the carrier rates in three herds in which the

bacteria. Furthermore, the permanent damage inflicted

disease had not been confirmed were 3.89 per cent, 5.5

on the heart valves and the embolic lesions in other

per cent and nil (Mustafa et al., 1978). Furthermore, the organs cannot be effectively repaired. Thus treatment

carrier rate was higher in cattle under two years of age

of ailing animals is unlikely to lead to complete recov-

than in adult cattle. It is estimated that approximately

ery. Although temporary improvement may occur after

10 per cent of carrier animals become immune.

intensive antibiotic treatment for seven to ten days,

Spread of infection is through the ingestion of feed *a relapse within seven days is the usual outcome.*

contaminated by carrier or clinically affected animals.

However, Power and Rebhun (1983) reported that nine

The role of biting and blood-sucking ectoparasites in

cows, in which an early diagnosis had been made,

the spread of infection is still unclear, although

responded to long-term penicillin therapy.

Macadam (1962) suggested on the basis of experimen-

tal work in rabbits that ticks could transmit the disease.

It is generally accepted that environmental stress

is an important factor in precipitating outbreaks of

Haemorrhagic septicaemia

disease. Outbreaks occur when animals are exposed to

cold and wet weather, housed under poor conditions or

Haemorrhagic septicaemia, or more appropriately sep-

exhausted by prolonged periods of work. Under such

ticaemic pasteurellosis of cattle, is a peracute disease,

circumstances the immunity of carrier animals wanes,

which is characterized by a septicaemia and a very high

allowing a rapid multiplication of the organism and

mortality rate.

spread within the carrier animal and its subsequent

dissemination to susceptible contact animals.

Aetiology

Signs

Carter and Bain (1960) and Carter (1982) highlighted

the confusion and conflict in the terminology of dis-

The disease may be peracute with death frequently

eases attributed to Pasteurella infection in bovines. Thus occurring so rapidly that few, if any, clinical signs are

it is difficult to assess the accuracy of many of the early

observed. In the acute form, there is a sudden onset of

reports on haemorrhagic septicaemia. It is now consid-

fever (41–42°C, 106–108°F), severe depression, oedema

ered to be a primary pasteurellosis caused by Pas-

of the throat, profuse salivation and rapid death, usually

teurella multocida capsular serotypes B and E, which

in less than 24 hours. The oedematous form of the

appears now to be confined largely to the tropical coun-

disease is also acute with the development of hot

tries of Asia. Shirlaw (1938) reported on the occurrence

painful swellings of the head, throat, brisket, perineum *of septicaemic pasteurellosis in the Northumbrian area*

and limb(s). Severe oedema of the head and throat may

result in dyspnoea and eventually death through

neous swellings may develop in some animals and

asphyxiation rather than death from a septicaemia.

after the administration of some batches of vaccine,

anaphylactic shock has occasionally been recorded.

A live streptomycin-dependent mutant of P. multocida Pathology

vaccine has been developed (Wei & Carter, 1978) and

Large numbers of Pasteurella organisms can be demon-

successfully tested in field trials (De Alwis & Carter,

strated in the nasal discharges and saliva of clinically

1980), but does not appear to be commercially available

affected animals. The course of the disease is usually

as yet.

less than 14 hours, which limits the opportunities for

The observations of Sawada et al. (1985) on naturally

carrying out laboratory examination on specimens from

acquired immunity to P. multocida, capsular types B

ailing animals.

and E, are of considerable interest. They found, on the

On post-mortem examination the most prominent

basis of serological and passive immunity tests in mice,

features are widespread petechial haemorrhages on the

that 81 per cent of feeder calves were immune to type

serous membranes and in various organs, especially

B and 91 per cent to type E. The immunity appeared to

the lungs and muscles, and a subcutaneous oedema

develop in the absence of either of these serotypes in

of the throat region. The lungs are oedematous, may

the microbial flora of the calves.

also show an early interstitial pneumonia and often

there is a haemorrhagic gastroenteritis. In the oedema-

tous form of the disease, there is widespread oedema of

Infectious necrotic hepatitis

the head, tongue, brisket and/or one or more limbs as

(black disease)

well as widespread petechiation. The spleen is not

greatly enlarged.

Infectious necrotic hepatitis is a highly fatal acute or

peracute infectious disease of sheep and cattle, charac-

terized by the presence of one or more necrotic areas

Diagnosis

in the liver, in which Cl. novyi type B has multiplied and The regional occurrence of the disease is of some aid

produced lethal toxins.

in diagnosis, but the clinical signs, rapid course and

necropsy findings are similar to those of other diseases,

e.g. anthrax (p. 717), clostridial myositis (p. 723), acute

Aetiology

leptospirosis (p. 735), so that confirmation can only be

The causal organism is Cl. novyi, which like other achieved by isolation and identification of the causal

clostridia is a Gram-positive spore-bearing bacillus,

organism. Pasteurella multocida can be readily isolated widely distributed in the environment, particularly in

from heart blood, spleen, liver and other sites, but

soil. The more pathogenic types, however, are more

identification of the specific serotypes may require

prevalent in those areas where infectious necrotic

submission to specialist laboratories.

hepatitis occurs. After ingestion, spores are transported

to the liver and other locations, where they remain as a *latent infection. On the basis of toxin production a*

Treatment and prevention

number of types are recognized, but infectious necrotic

Pasteurella multocida is sensitive in vitro to a range of hepatitis in cattle is caused by type B, which produces

antimicrobial substances, including oxytetracycline,

large amounts of the lethal alpha toxin.

florfenicol and penicillin/dihydrostreptomycin and, in

The disease occurs in cattle and sheep in those areas

theory, therefore treatment of clinically affected

where liver fluke infection also occurs (p. 276), and it

animals should be feasible. However, the sudden onset

has been demonstrated experimentally in sheep that

and rapid course of the disease are such that treatment

migrating immature liver fluke produce liver damage

during the very early stages only is likely to be suc-

and through this an environment suitable for the

cessful. Even if all the organisms are eliminated, death

activation of the latent infection. It is assumed that

from Pasteurella endotoxaemia may still occur (Jubb et the same sequence of events occurs in cattle, although

al., 1985).

Williams (1964) noted the absence of liver fluke

The only effective method of control is vaccination

damage in some confirmed cases. It has been demon-

of all herds at risk. A dead vaccine in an adjuvant base

strated that the survival of Cl. novyi and Fasciola containing paraffin and lanolin has proved highly effec-hepatica is favoured by the same type of soil environtive when used prophylactically and is also of value in

ment (Bagadi & Sewell, 1973). Other migrating para-

reducing losses if used during an outbreak, immunity

sites, e.g. the intermediate stages of certain canine

persisting for at least 12 months. Persistent subcuta-

cestodes, may also activate latent Cl. novyi infection.

Fig. 44.2

A typical black disease lesion in

the vertical lobe of a bovine liver. Note the

central necrotic area surrounded by a zone

of congestion.

The organism multiplies rapidly in the damaged liver

clear gelatinous fluid in variable amounts is present in

and large amounts of the lethal and necrotizing toxin

the axillary and inguinal regions, and over the brisket.

are formed, which leads to the production of the char-

Fluid, sometimes bloodstained and containing fibrin

acteristic lesion. The toxin is rapidly absorbed, leading

strands, is present in the pleural and peritoneal cavities

to a systemic toxaemic and it is only rarely that the

and in the pericardial sac. Haemorrhages are scattered

organism can be recovered from other organs in the

over the endocardium and sometimes over the epi-

fresh carcass.

cardium, parietal pleura and peritoneum. The mucosa

The disease has been confirmed in most countries

of the abomasum is usually congested and often the

where fascioliosis occurs. Cattle of all ages may be

abomasal wall is distended by a gelatinous oedema. The *affected; Williams (1964) found that in a series of 46*

duodenum and jejunum may show a patchy mucosal

cases, one was in a six-month-old calf, two were in cows

congestion.

over seven years old and the remainder in bullocks and

The pathological changes in the liver are characteris-

heifers between one and two years old. There is little

tic. The organ is a dark brown colour due to venous con-

information on morbidity rates in cattle, but experience

gestion and the gall-bladder is usually distended. One,

in the UK indicates that in most herds only single

two or more sharply demarcated yellowish necrotic

animals succumb. It is likely, however, that the disease

areas up to 8 cm (3 inches) (Fig. 44.2) or more in

is becoming more common in some areas.

diameter may be identified, most frequently on the

surface but also in the depths of the parenchyma, where

they may be missed unless the liver is carefully palpated

Signs

and sectioned with a knife. The necrotic area is sur-

Most cattle with infectious necrotic hepatitis are found *rounded by an obvious zone of deep congestion.*

dead but, in some, illness may last for one to two days

Lesions may be found anywhere in the liver, but the

(Herbert & Hughes, 1956). Affected animals develop

majority tend to be located in the ventral lobe. Evidence

severe depression, are disinclined to move, with a

of liver fluke migration in the form of subcapsular haem-

normal or slightly elevated temperature. Signs of dis-

orrhages and greenish yellow scars (accumulations of

comfort are exhibited on palpation of the liver region.

eosinophils) may be evident near the lesion.

Microscopical examination of sections prepared from

the liver lesions show a central core of necrotic tissue

Pathology

demarcated from the congested parenchyma by a leu-

Because of the acute nature of the disease it is

cocytic barrier (Fig. 44.3). Within the barrier and at the

not possible to carry out ante-mortem laboratory

periphery of the necrotic tissue, large numbers of

examinations.

vegetative clostridia are evident. The hepatic cells

Animals dying from the disease are usually in good

immediately adjacent to the leucocytic barrier show

condition. The subcutaneous vessels are engorged and

degenerative changes.

Fig. 44.3

A section through a black

disease lesion demonstrating the central

necrotic area and the clearly stained leuco-

cyte barrier. (Haematoxylin and eosin, ¥5.)

Diagnosis

Two doses of vaccine at an interval of not less than one

month are required to produce a satisfactory immunity

The post-mortem findings of the characteristic lesions *(see p. 1005). Because of the association with liver fluke*

provide a firm basis for arriving at a diagnosis. Fluo-

infection, control measures should also be adopted for

rescent antibody techniques can be used for the rapid

this parasite. (see p. 278).

identification of Cl. novyi in impression smears made from the periphery of the liver lesion as described by

Batty et al. (1964). Toxins may also be demonstrated in the liver lesions and peritoneal fluid (Williams, 1964),

Pericarditis

although the laboratory tests for these are laborious

and time-consuming. If the post-mortem findings are

Infection of the pericardial sac by micro-organisms

inconclusive and the carcass shows evidence of decom-

results in a purulent or non-purulent pericarditis with

position then the fluorescent antibody and toxin tests

the accumulation of varying amounts of fluid and con-

cannot be reliably used, since Cl. novyi may have mul-sequential masking or muffling of heart sounds, and

tiplied in the liver and other locations after death

may lead to congestive heart failure.

(Bagadi & Sewell, 1974), and some of the strains found

in livers are of low pathogenicity (Williams, 1964) but

Aetiology

are detected by fluorescent antibody techniques.

Other cases of sudden or rapid death have to be

A wide range of micro-organisms are associated

considered in differential diagnosis and these include

with bovine pericarditis and they include A.

anthrax (p. 717), other clostridial infections such as

pyogenes, Haemophilus somnus, Mycobacterium bovis, clostridial myositis (p. 723), lead poisoning (pp. 906,

Mannheimia and Pasteurella species, staphylococci, 944) and metabolic disorders (Chapter 46). It is vital

streptococci and Mycoplasma species.

that blood smears for anthrax diagnosis be examined

Infection with pyogenic bacteria is nearly always

before post-mortem examination is carried out and

primary and frequently associated with traumatic reti-

thereby prevent environmental contamination with

culitis. The organisms are introduced during penetra-

anthrax spores.

tion of the pericardial sac by a foreign body originating

from the reticulum, or infection may be the result of *direct spread from a traumatic mediastinitis. In some*

Treatment and prevention

instances a purulent infection may be superimposed on

There is little opportunity for effective treatment,

an original non-purulent fibrinous pericarditis. Infec-

although in those cattle that are ailing for one to two

tion of the pericardial sac also occurs through the local-

days, the administration of broad-spectrum antibiotics

ization of a blood-borne infection or through the direct

or penicillin and Cl. novyi antiserum may be of value.

extension of a myocarditis or pleurisy.

Effective vaccines have been developed and in areas

During the early stages of a purulent pericarditis

where liver fluke occurs their use should be advocated.

there is a marked hyperaemia and deposition of a fib-

rinous exudate on the epicardium. Varying amounts of

the overall haematological picture depends to some

fluid accumulate within the pericardial sac and, as the

extent on the causal agent and other lesions that may

volume significantly increases, both atria and the right *be present, so that the total white cell count may vary ventricle are compressed to such an extent that their from only marginally above the normal range to more function is impaired and congestive heart failure than 30 000/ml.*

results. A severe toxaemia may also develop. In some The cardiac lesions found at post-mortem examina- instances, however, the volume of exudate is small and tion depend on the type of infection and the duration adhesions develop between the epicardium and peri- of illness. In acute purulent pericarditis the pericardium cardium, which become organized, resulting in com- and epicardium are thickened and covered by a fibri- plete attachment of the epicardium and pericardium, nous deposit, and the pericardial sac distended with impaired cardiac function and congestive heart failure. fluid, which varies from a dirty grey to a yellowish green In non-purulent or fibrinous pericarditis, there is colour with a foul odour. The atria and the right ven- seldom a significant exudation of fluid and therefore no tricle are compressed. When the condition is associated *marked distension of the pericardial sac. The epi-*

with traumatic injury it may be possible to identify a

cardium is hyperaemic and fibrinous deposits appear

foreign body, but should this be wire it may have disin-

at the base of the heart, which subsequently spread

tegrated. Occasionally, a rupture of one of the coronary

over the whole of the epicardium and internal surface

vessels, an atrium, or ventricle may occur in traumatic

of the pericardium. Adhesions develop between the

pericarditis and under such circumstances the pericar-

epicardium and pericardium, but these are not suffi-

dial sac contains a mixture of blood and purulent

ciently dense or strong to impair cardiac movement.

fluid. In more chronic cases, the grossly thickened peri-

cardium and epicardium are closely adherent except for

loculi containing inspissated or thick creamy pus giving

Signs

a 'bread and butter' appearance. Signs indicative of

The early clinical signs of pericarditis are often difficult

congestive heart failure are also identifiable and these

to identify because they are obscured or dominated by *include congested liver and lungs, engorged jugular those of the primary disease, e.g. pleurisy, traumatic veins and subcutaneous oedema of the submandibular reticulitis, and the onset of pericarditis may therefore space, brisket and inguinal region. If the pericarditis is be insidious. Arching of the back, reluctance to move, associated with other conditions, e.g. traumatic reticuli- shallow and rapid abdominal respirations and elevation tis, pneumonia or pleurisy, then lesions attributable to of body temperature to 40–41°C (104–106°F) are the them will also be present.*

initial signs. The pulse rate is increased, and percussion Evidence of a non-purulent or fibrinous pericarditis and palpation over the cardiac area of the thoracic wall is sometimes seen in apparently healthy animals dying elicits a pain response. It may be possible to detect a from other causes. In such animals there is a patchy rough pericardial function sound by auscultation during or diffuse thickening of the pericardium with similarly the early stages, but this is by no means easy and may distributed adhesions to the epicardium, which can be *be missed.*

easily broken down. There is no evidence of interfer-

As the condition progresses, fluid accumulates in the

ence with the cardiac function and the lesions are of no

pericardial sac and the heart sounds become muffled,

pathological significance.

although sometimes a splashing sound may be detected.

The signs of congestive heart failure, engorged jugular

Diagnosis

veins, a jugular pulse and subcutaneous oedema of

the submandibular space, brisket and inguinal region,

The clinical diagnosis of pericarditis is not easy because

develop and most animals die within one or two weeks.

the signs may be dominated or obscured by those of the

Some animals survive the acute phase with antibiotic

primary disease and it may be difficult to recognize the

treatment, and the signs of congestive heart failure

pericardial sounds. The characteristic friction sounds in

abate slowly. However, complete recovery seldom if

the early stages may be confused with those of pleurisy,

ever occurs and recovered animals should be sent for *although the latter is synchronized with the respiratory*

slaughter at the earliest opportunity.

movments. Similarly, the pericardial sounds may

resemble the murmurs (p. 727) produced by valvular

lesions, but unlike the murmurs, they persist for the

Pathology

whole of the cardiac cycle. The heart sounds may also

Blood samples from animals affected with a purulent

be muffled by effusion associated with pleurisy but

pericarditis, especially traumatic pericarditis, show a

under such circumstances there are signs of respiratory

marked leucocytosis and a shift to the left. However,

involvement.

Treatment

and a lowered oxygen tension, immediate growth and

toxin production will occur. However, such conditions

Although long-term therapy with antimicrobial agents

may only be attained after healing at the surface has

is indicated, it seldom results in complete recovery,

occurred, so that multiplication and toxin production *especially when the pericarditis is traumatic in origin.*

may be delayed. Thus the incubation period may vary

Thus Blood and Hutchins (1955) report that only about

from a few days to four weeks or more. In idiopathic

50 per cent of cattle with traumatic pericarditis treated

tetanus it would appear that the neurotoxin is produced

with sulphamezathine and/or penicillin responded

in the rumen (Smith & Holdeman, 1968).

and were sufficiently recovered for salvage. Surgical

From the site of production the neurotoxin reaches

drainage of the pericardial sac either by pericardiocen-

the central nervous system via the peripheral nerve

tesis or pericardiotomy as described by Horney (1960)

trunks. The exact mechanisms of transport are not

may also have to be considered. However, it must be

known, nor are the means by which the toxin exerts its

emphasized that pericardiocentesis offers only tempo-

influence on the nervous system. Smith & Holdeman

rary relief of less than 24 hours duration in most cases.

(1968) state that the neurotoxin can also reach the

There are a number of reports on the successful treat-

central nervous system via lymph and blood.

ment of fibrinous and traumatic pericarditis by pericar-

Individual or small numbers of animals are usually

diotomy (Jennings & McIntyre, 1957; Krishnamurthy et

affected in a herd, but in outbreaks of idiopathic tetanus

al., 1979; Mason, 1979).

many animals may be affected.

Tetanus

Signs

As the incubation period may vary quite considerably

Tetanus has long been recognized as a highly fatal

it is not always possible to relate the onset of clinical

disease of all species of farm livestock. The disease is

disease to specific incidents of injury or surgical inter-

produced by the toxin of Clostridium tetani and is char-ference. The first signs are those of apparent stiffness

acterized by hyperaesthesia, tetany and convulsions.

and reluctance to move, accompanied by muscle

tremors that become more pronounced. Another early

sign in some cattle is prolapse of the third eyelid, which

Aetiology

becomes more prominent with handling of the head.

Clostridium tetani is a spore-bearing organism and is These signs are progressively followed by the appear-considered to be one of the least fastidious clostridia as

ance of a slight but persistent ruminal tympany, eleva-

far as growth requirements are concerned. The spores

tion of the tail, unsteady gait of the hindlimbs, especially

are extremely resistant to environmental conditions.

when turning, and trismus with saliva drooling from the

The organism has two main habitats, namely the soil

mouth. Because of inability to adopt the normal uri-

and gastrointestinal tracts of animals and humans. It

nating posture, urine is retained. Further progression

has been suggested that the main reservoir of infection

leads to generalized muscular tetany with the adoption

for animals is soil. The organism produces a number

of a 'rocking horse'-like posture. Attempts at walking

of toxins, but the neurotoxin is the one of principal

lead to lateral recumbency and an inability to rise.

importance.

Tetanic convulsions and opisthotonus soon develop.

The portal of entry is usually through a deep punc-

Initially, the convulsions are triggered by external

ture, although in cattle introduction into the genital

stimuli, but later these occur spontaneously. The dura-

tract at the time of parturition is also important. The

tion of fatal disease in young cattle is four to five days,

organism may also gain entry into surgical wounds, e.g.

but older cattle may survive for up to 10 days. Non-fatal

after castration, and may be introduced into muscle

cases do occur, but generally these do not progress to

during vaccination and other injections. There are

the convulsive stage and recovery is slow over a period

however outbreaks of disease in cattle in which the

of weeks or sometimes months.

organism has not localized in any tissue site but

remained within the gastrointestinal tract, and such

Pathology

outbreaks are designated as idiopathic tetanus (Wallis,

1963).

There are no tests available for the diagnosis of tetanus

After gaining entry into the tissue, the organism

in the live animal and any tests undertaken would be *remains localized. Multiplication will only occur if*

for the purpose of eliminating those conditions that

optimal conditions develop at the site of infection. If at

produce similar clinical signs. Nor are there any gross

the time of initial injury there is sufficient tissue damage

or microscopic pathological findings that would confirm

tetanus, although attempts should be made to identify

duration. The recommended drugs (Radostits et al.,

the site of infection and culture the organism.

2000) are chlorpromazine (0.4 mg/kg body weight intra-

venously, 1.0 mg/kg body weight intramuscularly) three

to four times daily and acetyl promazine (0.05 mg/kg

Diagnosis

body weight), administered twice daily for eight to ten

Because of the distinctive clinical signs, classical tetanus

days or until the severe clinical signs have disappeared.

is seldom confused with other diseases. Clinical hypo-

Animals that are treated should be kept in dark quiet

magnesaemia (p. 255) in calves and cattle (p. 787) is

surroundings with ample bedding and sufficient space *accompanied by tetany and convulsions, but there is no*

to avoid injuring themselves if convulsions occur.

prolapse of the third eyelid or ruminal tympany, and

On farms where tetanus is a problem, vaccinations

low blood calcium and magnesium levels are diagnos-

should be routinely undertaken (see p. 1005).

tic. Cerebrocortical necrosis (CCN) (polioencephalo-

malacia) (p. 261, 903) may produce a similar clinical

picture, except that again there is no prolapse of the

third eyelid and no ruminal tympany. Also, in CCN the

Leptospirosis (other than Leptospira

erythrocyte transketolase activity is decreased and

hardjo infection)

blood pyruvate and lactate levels are increased, and

classical lesions are obvious at necropsy. Some cases of

Aetiology

lead poisoning (pp. 906, 944) may also show similar clin-

There are many different serotypes of Leptospira

ical signs, but elevated blood and kidney/liver lead

interrogans present in cattle.

values are diagnostic. Strychnine poisoning is extremely *rare in cattle in Great Britain and is usually associated*

with the ingestion of earthworms treated with strych-

nine. Strychnine is used for the destruction of moles,

Aetiology

and can be identified in the abomasal contents. It is used

Many serotypes do occur but probably the most impor-

in other counties, often illegally, to kill wildlife. Bovine

tant are L. interrogans serovar icterohaemorrhagiae spongiform encephalopathy (p. 909) may also need to

and serovar canicola. Leptospira interrogans serovar

be differentiated but the signs usually develop over a

pomona has been found in many countries to be the

longer period than tetanus.

commonest infection of farm animals. It has only

recently been found in Britain and the strain appears to

Treatment and prevention

be different from the one causing abortion in pigs. In

many cases there are carrier animals and often these are

Cattle appear to respond better to treatment than

rodents. The leptospires survive in the environment

horses and sheep, although it is unlikely that fully devel-

if conditions are wet. However, they are inhibited at

oped tetanus will respond and therefore under such

a pH less than 6 or greater than 8. Temperatures

circumstances euthanasia should be considered.

below 7–10°C (44.5–50°F) or above 34–36°C (93–96°F)

When treatment is undertaken it should have three

are detrimental. The organisms can survive over four

objectives: elimination of Cl. tetani, neutralization of months under wet conditions but only 30 minutes when

unfixed neurotoxin and the induction and maintenance

the soil is dried. It often survives in the environment in

of muscle relaxation until all the neurotoxin has been

average conditions for about one and a half months.

destroyed or eliminated.

Most infection is spread via contaminated feed or

Large doses of penicillin administered parenterally is

water. It must be remembered that most serovarieties

the recommended treatment for Cl. tetani infection and are able to infect many species including man.

this should be supplemented by treatment of the

Mortality rate is usually low at about 5 per cent.

infected site (if located) by irrigation and topical appli-

cation of antibiotics. Thus treatment should continue

for at least seven days.

Signs

The administration of antitoxin for the neutralization

of unfixed neurotoxin is considered to be of little value

Acute: The cow is often ill with a pyrexia of 40–41°C

unless administered during the very early stages of the

(104–106°F) with dullness and anorexia. The milk yield

disease. If the site of infection has been identified then

drops and often there are haemorrhages under the

local injection of the antitoxin may be of value.

mucous membranes, and there is often jaundice and

A number of drugs have been used to relieve muscle

haemoglobinuria. In some cases there is synovitis or a

tetany, but because of the need for long-term relaxation

necrotic dermatitis. Occasionally, meningitis has been

some are not suitable because their activity is of short

recorded.

Subacute: In this form the signs are milder with a

Leptospira hardjo infection

temperature of 39–40°C (102–104°F). The animal has a

(flabby bag) *(see p. 580)*

reduced milk yield and is dull. Jaundice occurs in some

cases and there is usually some haemoglobinuria. In

Aetiology

some cases abortion occurs about a month later.

Infection with Leptospira borgpetersenii serovar hardjo (Hardjo bovis) and Leptospira interrogans serovar Chronic: This is not common and results in abortion.

hardjo (Hardjo prajitno), spiral organisms.

These are a common cause of abortion in Britain,

Necropsy

although they have only recently been readily diag-

nosed. Leptospira borgpetersenii sv hardjo appears to Acute: There are often submucosal and subserosal

be better adapted to cattle; it is excreted in

haemorrhages, jaundice, anaemia and haemoglobinuria.

large numbers in urine although it is less fre-

In some animals there is ulceration of the abomasal

quently isolated from aborted fetuses whereas L. inter-

mucosa and emphysema. Histological examination

rogans sv hardjo appears to be less well adapted in often shows an interstitial nephritis as well as cen-cattle (possibly more in sheep), while isolated from *trilobular hepatic necrosis.*

Britain, India, Nigeria, Malaysia and the USA, it has

Subacute or chronic cases are more likely to show a

not been seen in Australia and New Zealand; urine

progressive interstitial nephritis with white foci on the

shedding of organisms is low, but it is more frequently

surface of the renal cortex.

found in aborted fetuses and is relatively more

pathogenic.

Up to 50–60 per cent of British farms may be

Diagnosis

infected. In Northern Ireland 41.6 per cent of randomly

This depends on finding the organism. Otherwise,

selected aborted fetuses were infected (Ellis et al., 1982) paired serum samples can be examined for a rise in

and the level rose to 68.9 per cent of fetuses from farms

Leptospira titres.

with abortion problems. A very common problem in

New Zealand, most cases are in the dairy herd rather

than beef cattle. Humans can be infected but they must

Differential diagnosis

be exposed to concentrated infection, i.e. contact via

urine while milking. Although infection is present in

Any form of haemoglobinuria will need to be elimi-

the milk, it quickly dies off once taken from the

nated, including babesiosis (p. 748), which is usually

udder. Meat does not carry infection. Spread occurs

seen in the summer in tick areas. Kale poisoning (p.

more rapidly in wet seasons in low-lying areas.

941) and postparturient haemoglobinuria (p. 792)

Colostrum-derived protection normally lasts about

should be partly diagnosed by the history and the low

three months. Serological rises in L. hardjo titres fol-plasma phosphorus levels in the latter. Bacillary

lowing infection tend to be short-lived, i.e. a few months

haemoglobinuria (p. 719) will be differentiated by the

to a year or so. It was originally considered to be a

presence of clostridia.

winter disease. However, carriers often stop or reduce

excretion on silage. Most infection now occurs in the

Treatment

summer, often with abortion in the summer or early *autumn. Serology in individual animals is difficult to*

The main therapy is usually antibiotics such as dihy-

interpret because the bacteria are in the lumen of the

drostreptomycin or the tetracyclines. Treatment should

kidney or uterus.

be given as soon as signs develop. Blood transfusion

The spread of infection takes place cow to cow via

often helps. The farmer should be warned of possible

urine, fetuses and uterine discharge, and from bull to

human infection.

cow by infected semen. The source of infection is via

carrier cows or infected calves, which may be chroni-

cally infected, but it may possibly be spread by con-

Control

taminated water or sheep on the farm.

Separate the infected cow. If it is partly due to rodent

build-up, control the rodents. Ensure removal of

brackish water and provide good drainage. Vaccination

Signs

could be used, as with L. interrogans serovar canicola or icterohaemorrhagiae, but as cases are usually spo-There are two main syndromes, the udder form and *radic this does not tend to be used.*

abortion.

Severe udder form: In a cow or heifer the udder signs

diagnosis. It can also be isolated from abortion or post

will not be apparent until the animal has calved. This

calving discharge. Culture of the bacteria can be under-

form occurs soon after the infection enters a herd.

taken. Fetal serology can also be used. Antibodies may

There is a sudden drop in milk yield affecting all four

be detected in post calving discharges and cervical

quarters, with pyrexia usually between 40 and 41.5°C

mucus. Serology of the dam can help but often antibody

(104–107°F). The udder secretion becomes thickened

titres may be static or falling by the time of abortion. It

and clotted, occasionally it is bloody or it can be yellow

is very difficult to detect carrier animals, as up to 25 per

and colostrum-like. The udder itself is not swollen or

cent are serologically negative. Bulk herd milk samples

inflamed but tends to be flaccid. In a six to eight-week

can indicate the presence of infection and also give *period, 30–50 per cent of the herd may be infected.*

some suggestion of infection levels.

The condition usually resolves over seven to ten days

(see p. 580).

Differential diagnosis

Mild udder form: Many cows are infected and show

Other leptospiral infections (p. 734), salmonellosis

only a slight drop in milk yield.

(Chapter 15), foot-and-mouth disease (p. 700), and mas-

titis (Chapter 23) must all be considered in the udder

form. In abortion, (p. 578) salmonellosis, mucosal

Abortion: This usually occurs six to twelve weeks after disease, brucellosis, Neospora carinum infection (pp.

the dam is infected. Abortion can occur on its own or

283, 584) and infectious bovine rhinotracheitis are some

be preceded by the milk drop syndrome. Most cases of

common causes to be differentiated.

abortion occur in the second half of pregnancy. If infec-

tion occurs late in pregnancy then an infected calf may

be born. There may be some apparent infertility in the

Treatment

herd (see p. 580).

Large doses of dihydrostreptomycin (25 mg/kg body

weight) may help remove the organism and prevent

Necropsy

kidney and liver damage. All cattle due to calve should

be vaccinated. In countries where dihydrostreptomycin

Abortion: There are usually no useful macroscopic fea-

is not available, amoxycillin appears to be equally

tures in the aborted fetus.

effective.

Diagnosis

Control

Udder form: History helps in diagnosis, in particular

Vaccination is possible with a killed strain (p.1015). The

the sudden onset of the problem. The signs, sudden loss

vaccines available may contain Hardjobovis or Hard-of milk, flaccid udder, are useful. The Californian Milk

joprajitno strains; there is not always cross-protection Test is positive and there is a high milk white cell count.

between the two strains. Hardjoprajitno vaccines may

Identification and culture of the organisms from urine

produce a longer duration of immunity (G.S. Dhaliwal, *(it can occasionally be isolated from milk and blood in pers. comm.). Both vaccines will control abortion and the acute stages) is a definitive diagnosis. Paired serum improve fertility in endemic herds. Vaccination of samples can be used for the complement fixation test, young stock may also produce benefits. Vaccination microscopic agglutination test and plate agglutination involves two initial doses at least four weeks apart. test. High titres over 1/300 indicate recent exposure to If cattle are young when vaccination commences then infection. Microagglutination titres are found from 10 two doses are required after five months of age. An days after infection; their peak and duration depend on annual booster is recommended but two vaccinations the serotype and route of infection. IgM titres appear a year may be required in herds that calve in the first but peak two to three weeks after infection whilst autumn. It does not affect animals that already have IgG levels appear later and peak 12–30 weeks post milk drop syndrome. Vaccination does help prevent infection (G.S. Dhaliwals, pers. com.). Serum and*

abortion but infected cows may still excrete bacteria.

vaginal mucus antibody tests are also available.

It is therefore advisable to treat all adult cattle with

dihydrostreptomycin before commencing a vaccination

Abortion: Identification of the bacterium in the fetus, programme.

especially in the lungs, kidneys or adrenal glands, by

Any bought-in animals, and especially bulls, should

fluorescent antibody studies, is the main method of

be isolated and treated with antibiotics and vaccine

before entering the herd. Reducing exposure to poten-

Treatment and control

tially contaminated water supplies and to pasture

High doses of intravenous tetracyclines for at least

grazed by sheep is a sensible management control.

three days can be useful. Otherwise ampicillin, amoxy-

cillin, florfenicol, novobiocin, sulphonamides or poten-

Haemophilus somnus infection

tiated sulphonamides can be administered. Once

disease is diagnosed, extra observation must be under-

(see p. 907)

taken of in-contact animals. Control is difficult,

although in North America an aluminium hydroxide

Aetiology

adjuvenated vaccine is now used.

A Gram-negative small rod-shaped organism. Most

strains of the organism are antigenically similar.

Pyaemia

Epidemiology

Pyaemia is defined as a clinical or pathological state

It is seen in North America and Europe. Inapparent

characterized by the formation of multiple secondary

infection occurs more frequently than clinical disease.

abscesses in a number of organs and/or tissues.

Problems occur more frequently in younger animals.

The primary pyogenic infection may occur in a

The portal of entry of infections is often via the respira-

number of sites and the formation of metastatic lesions

tory tract although it is also found in the reproductive

in other organs and tissues follows the entry of organ-

and urinary tracts. Disease is probably a septicaemia

isms into the circulation. Small numbers of organisms *with localization. Single or several cases may occur.*

may intermittently gain entry via the lymphatic

drainage of the primary lesion, to produce a bacter-

Signs

aemia, followed by localization and the formation of

secondary abscesses. More frequently, however, a septic

The peracute form often causes sudden death. The

thrombus is formed within the primary lesion and por-

acute form is often seen as the sleeper syndrome

tions of this become detached to form emboli, which are

or thromboembolic meningoencephalitis (TEME) in

then arrested in the capillary bed of an organ or tissues

growing cattle. The animal is depressed, with closed

to form the metastatic lesions. The most frequent sites

eyes, and recumbent. Usually there is pyrexia (40–42°C,

for secondary abscess formation are the valvular endo-

104–108°F). Nervous signs can be of muscle tremors

cardium, myocardium, lungs and joints, although the

and hyperaesthesia. The animal may be blind with

liver and kidneys may sometimes be involved.

retinal haemorrhage. Other syndromes include synovi-

In cattle, pyaemia is often associated with septic

tis with initial lameness. Pneumonia is a common

metritis and mastitis, and A. pyogenes is the organism finding, particularly in calves, and often associated with

most frequently incriminated. Staphylococcal mastitis

pleurisy (see Chapter 17). Abortion can occur and so

may also lead, in some cases, to pyaemia. On occasions,

can chronic bloat.

hepatic abscesses and foul in the foot caused by

Fusobacterium necrophorum

may also result in

Pathology

pyaemia.

Because pyaemia is a form of generalization of a

There may be focal or diffuse cerebral meningitis

primary infection, the clinical signs, diagnosis and treat-

with characteristic haemorrhagic infarcts in the brain.

ment must be considered in relation to the primary

Haemorrhages can occur in other organs. In the joint

infections referred to above and which are discussed in

form the synovial membranes are oedematous with *the appropriate sections of the text.*

petechial haemorrhages. There is often inflammation of

the pericardium, peritoneum and pleura which may be

serofibrinous or fibrinous. Histologically there is often

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a vasculitis and thrombosis, often with infarcts and

accumulation of neutrophils.

Anthrax

Prognosis

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Chapter 45

Ectoparasites, Tick and Arthropod-borne Diseases

S.M. Taylor, A.G. Hunter and A.H. Andrews

ECTOPARASITES

740

Other problems

775

Insects

740

Tick paralysis

775

Hypodermatosis (warbles)

740

Sweating sickness

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Lice (pediculosis)

741

Mhlosimge

777

Arachnids

742

Magudu

777

Mange

742

Stomatitis–nephrosis syndrome

777

Tick infestations

744

Ixodoidea

744

Fly problems

745

Mosquitoes

745

ECTOPARASITES

Blackflies

745

Midges

745

Insects

Horseflies and deerflies

745

Houseflies

746

Hypodermatosis (warbles) *(see p. 875)*

Bush flies

746

Face fly

746

Hypodermatosis is the term used to describe infection

Head fly

746

with and the lesions caused by the larvae of two species

Stable fly

746

of the fly genus Hypoderma, H. bovis and H. lineatum.

Horn flies and buffalo flies

747

The disease is characterized by damage to dorsal hides,

Horse louse flies

747

oesophagus, central nervous system and occasionally

Tsetse flies

747

death due to anaphylaxis (see p. 927).

Tumbu fly

747

Blow flies and screw-worm flies

747

TICK AND ARTHROPOD-BORNE DISEASES

748

Aetiology and epidemiology

Protozoal diseases

748

Babesiosis (redwater)

748

The adult flies are distributed in the northern hemi-

Theileriosis

750

sphere, excluding the most northerly arctic regions.

Besnoitiosis

756

There are two species, H. bovis and H. lineatum. Hypo-Trypanosomosis

756

derma bovis favours the northern parts of their habitat Rickettsial diseases

761

areas and H. Lineatum the southern and warmer areas,

Anaplasmosis

761

but both species can occur simultaneously. The adult

Tick-borne fever

763

Bovine petechial fever (Ondiri disease, ondiritis)

763

flies have a yellow abdomen characterized by a broad

Heartwater (cowdriosis or malignant rickettsia,

stripe of black hairs. They are active in warm weather,

blacklung)

765

generally in Europe between the months of June and

Jembrana disease (Tabana disease)

766

August. Their presence upsets cattle, which run to avoid

Viral diseases

767

them and in doing so injure themselves on fences or

Bovine ephemeral fever (BEF)

767

other obstacles. The females of H. bovis deposit eggs Lumpy skin disease (LSD)

768

singly on hairs, frequently above the hocks on the hind

Rift Valley fever

769

legs; the eggs of H. lineatum are laid in rows, whence its Tick-borne encephalitides (flavivirus infections)

770

name was derived, usually on the lower part of the body

Tick-borne encephalitides (Near East encephalitis)

771

and in places where both adult and eggs are difficult for

Japanese encephalitis (flavivirus)

771

cattle to dislodge. The eggs adhere strongly to the hairs.

Other arthropod-borne diseases

771

Parasitic diseases

774

They hatch in four to six days and the first stage larvae

Onchocercosis (worm nodule disease)

774

crawl down to the skin, which they penetrate, and

Stephanofilariosis

774

proceed to migrate through soft tissues towards their

Thelaziosis

775

overwintering sites. This movement takes several

740

weeks, and by late autumn H. bovis has reached the

Treatment

epidural fat within the vertebral column and H.
The larvae are susceptible during their migration to
lineatum the submucosa of the oesophagus. The larvae
systemic organophosphorus insecticides and the
remain in these sites during the winter, moulting to their
anthelmintics ivermectin, doramectin, eprinomectin,
second stage of development. At the end of the winter
abamectin and moxidectin. Care should be taken not to
they resume migration both reaching the subdermal
treat cattle when larvae are in their overwintering sites,
tissue along the back in the spring. They make a hole in
as death in situ and subsequent lysis may result in
the overlying skin through which they respire while
anaphylaxis. For that reason statutory eradication po-
developing to the third stage, which reaches a length of
licies have compulsory treatments applied before mid
2–3 cm and is characterized by rows of small spines on
November, coupled where necessary with inspection
the posterior margin of most of its segments and pos-
and further treatments in the following spring.
terior spiracles on a terminal tuberosity. The creamy-

The organophosphorus treatments are normally

white larvae emerge from the back of the animal in

applied dermally as pour-on preparations. A large

April and May and fall to the ground to continue devel-

number are available, the most popular currently being

opment by pupation, eventually emerging as adults

phosmet and crufomate. Mass treatment has resulted

five weeks later. They have a short lifespan as adults,

in eradication from many islands although it has

mating, laying eggs and dying within two weeks of

proved more difficult on large land areas. Avermectins,

emergence.

although highly effective, are not normally used in mass

eradication campaigns since their primary use is as an

Pathogenesis

anthelmintic, although if a single animal in a herd is

found to be infected the entire herd is usually treated

The larvae are most pathogenic during two phases of

with them. Although prophylaxis against adult flies is

their development. The first is during the late autumn

not actively undertaken, slow-release devices such as *and winter, when they are in epidural fat or*

ear tags impregnated with organophosphorus com-

oesophageal wall respectively. If present in large

pounds or synthetic pyrethroids do reduce the possibil-

numbers, or if treated killed in situ, the anaphylactic ity of ovi-position by adults.

reactions may cause damage to the spinal cord that can

result in either spinal paralysis or difficulty in swallow-

ing and eructation, which can lead to bloat. The second

Lice (pediculosis)

is during their pre-emergence development, where they

damage the subdermal tissue and skin of the back and

Lice are ubiquitous parasites of cattle. In large numbers

cause subsequent downgrading of hides and trimming

they cause skin irritation and have been associated with

of carcasses, and cause irritation and loss of growth in

anaemia and may act as vectors of pathogenic organ-

the live animal.

isms (see p. 880).

Signs

Aetiology and epidemiology

In the late autumn and winter, occasionally there can be

Lice are host-specific parasites and are classified into

damage to the spinal cord resulting in paralysis, difficulty

two types: (i) sucking lice and (ii) biting lice. Five

in standing or bloat. In the spring, there are swellings

species infest cattle, four sucking and one biting.

under the skin 55–75 cm either side of the midline

The former are Haematopinus eurysternus and H.

containing pus, a breathing hole and a third stage larva.

quadripertusus, 'short-nosed' sucking lice; Lignognathus vituli, 'long-nosed' and Solenopotes capillatus,

'small blue' sucking lice. The biting species is Damalinia Diagnosis

bovis. As might be construed the sucking lice have

If disease results during their winter development, the

mouthparts adapted for piercing skin and sucking

symptoms have to be differentiated from other causes

blood; the biting lice ingest skin and hair detritus, blood

of spinal or oesophageal paralysis. There is an ELISA

and scabs. Each species has a preferential area on

test available that detects antibody to migrating larvae

animals, but if large numbers are present can be found

and, although originally designed to aid eradication *anywhere on the body surface. Normally, H. euryster-*

programmes, it may be helpful in diagnosis. When

nus and D. bovis are found on the poll, neck and head larvae are in their pre-emergence sites on the back their

and the latter also along the mid dorsal region of the

presence is unmistakeable since no other condition

body. Lignognathus vituli and S. capillatus also favour causes similar lesions, especially if a heavy infection is

the head, neck and frequently the ventral surface of the

present.

neck, dewlap and axillae. Haematopinus quadripertusus

is restricted to subtropical areas and is usually found in

pyrethroids is generally of longer duration. This aspect

the area of the tail and posterior lumbar regions.

is important because for complete removal of all lice

The life cycle of lice is direct. Adults live for approxi-

the activity must not only kill adults but nymphs emerg-

mately one month during which time they lay a few

ing from eggs. The anthelmintics ivermectin, dora-

hundred eggs, which are tightly attached to hair by a

mectin, eprinomectin and abamectin because of their *glue-like substance produced by the louse. The eggs*

long half-life are also extremely effective, removing all

hatch within a few days and the first nymph, which

sucking and more than 98 per cent of biting lice. If used

resembles a small softer adult, emerges. It undergoes

as a pour-on preparation they are even more effective,

three moults to second and third stage nymphs and

and will remove 100 per cent of both species. For pre-

finally adults, each nymphal stage taking one week. The

ventative purposes, housed cattle can be treated at

entire life cycle from egg to adult occupies approxi-

housing, sometimes complemented by removal by elec-

mately three weeks.

tric clippers of a 15 cm band of hair from the poll to the

There are seasonal variations, especially marked in

root of the tail.

temperate areas, in the number of lice found on cattle.

In these areas numbers on susceptible cattle increase

during autumn and early winter, peaking late winter

Arachnids

and early spring. There are two reasons for this: (i) *cattle are frequently housed in autumn and lice are*

Mange

easily transferred from infested to non-infested

Mange is the descriptive term used for infection of

animals, and (ii) climatic conditions favour louse activ-

animals by mites, the smallest arthropods of the order

ity; strong sunlight and high skin temperatures have

Acarina. They are obligate parasites transmitted from

been shown to inhibit lice and the converse occurs in

infected non-infected animals by direct contact. There

winter. Within groups of infested cattle there are always

are four species that parasitize cattle and two others

those that carry heavier burdens than others, and it is

which are facultative parasities of them and other

generally accepted that very large louse populations are

animals (See p. 881).

indicative of stress or intercurrent illness, poorly fed

cattle parasitized by nematodes and trematodes being

frequently and characteristically louse infested.

Aetiology and epidemiology

The pathogenic effects of louse infestation have been

Although of the same order, the mites have different

the subject of much research. It is now considered that

morphologies and habitats, and some are classified as

light or moderate infections have little effect on cattle.

'burrowing' and others as 'non-burrowing'. For these

Heavy infestations lead to skin irritation, scratching and

reasons they are described separately.

rubbing, with resultant damage to hides. Some reports

have indicated that large sucking lice burdens may also

Non-burrowing mites: One species, Chorioptes bovis, is cause anaemia and weight loss, although it has also been

specific to cattle. Psoroptes ovis, although primarily a noted that these effects can be prevented by adequate

parasite of sheep, can become permanently adapted to

high quality nutrition. Lice may also act as vectors for

cattle. Non-specific mites are those species of harvest

blood-borne organisms, and have been implicated in

mites present on pasture, the larvae of which can infest

the transmission of Eperythrozon wenyoni.

many different species of animals: the mite species are

Neotrombicula and Eutrombicula.

Signs and diagnosis

(1)

Chorioptes bovis. The most common mite found

Louse infestations are usually evident by the presence

on cattle. It reaches a length of 0.75 mm and is recog-

of eggs adhering to hairs, on the edge of bald areas and

nizable by its cup-shaped suckers on short unjointed

on parting of hair careful examination of preferential

pedicels. It is seen most frequently during autumn and

niches with a magnifying lens will reveal adults and

winter in housed cattle, frequently on the hind legs but

nymphs.

also on the neck, the head and root of the tail. It is a

surface feeder and produces mild hair loss, lesions

Treatment and control (see p. 1030)

increasing in size only slowly. The lesions are obviously

itchy as affected cattle will rub affected areas on walls,

Lice are fairly easily killed by the application of

doors, etc., incurring damage to the skin and subsequent

organophosphorus, amitraz or synthetic pyrethroid

quality of the hide after death.

preparations, either as sprays, pour-ons or dusting powders, although resistance to the last of these has

(2)

Psoroptes ovis. The mite is normally found on

been reported. The residual activity of synthetic

sheep and is the cause of sheep scab, which is notifiable

and government regulated in many countries. The mite

found in other areas. Early small lesions exhibit hair

is a similar size to C. bovis but is characterized by thinning and slightly thickened scaly skin, but soon the

long jointed pedicels with funnel-shaped suckers on the

irritation and resultant rubbing combined with expan-

legs. Although similar to P. ovis from sheep, which is sion of infected areas result in total loss of hair and

transferrable experimentally both to cattle and rabbits,

thickened, crusted and excoriated skin. Affected

the rarity of cases of mites transferring from sheep to

animals may become so preoccupied with the irritation

cattle and vice versa in nature has led to the conclusion

that they reduce their food intake, leading to loss of

that some adaptation to specific hosts takes place,

weight or milk production, and secondary bacterial *and that infection of sheep by cattle strains does not*

infections may ensue on the most severely rubbed

occur.

lesion.

The mite, although a surface feeder, is much more

(2)

Demodex bovis. This mite is considered to be a

irritant than C. bovis since its mouthparts are adapted normal commensal found on bovine skin; as for all

for piercing skin, causing the formation of serious vesi-

members of the family Demodicidae it becomes path-

cles, which can coalesce and eventually become scabs.

ogenic only when the efficiency of the immune controls

The life cycle is typical for both P. ovis and C. bovis.

of its host is reduced. The mites are characteristically

Female mites lay approximately 90 eggs. The hatching

cigar-shaped, 0.2 mm long, with four pairs of short legs

of eggs and subsequent development from larva to

close to the anterior end. Their preferred niches are in

nymph to adult occupies approximately 10 days. Adult

hair follicles and sebaceous glands and because of this *mites can live for a maximum of six weeks.*

deep location are not transmitted unless prolonged

Affected cattle become restless because of the skin

contact occurs. For this reason it is presumed that the

irritation. The areas commonly affected are the

young become infected shortly after birth during

abdomen, tail root and perineum, and they can become

feeding from their mother, and as a result lesions are

further damaged by scratching. In extreme cases

usually seen in cattle on the muzzle, head, neck and

animals may cease to feed adequately and lose weight.

back. The lesions take the form of small, 0.75 cm diam-

eter nodules and are follicles or glands filled with mites

(3)

Forage mites. The adults and nymphs of the

and caseous pus. In some countries a high proportion

family Trombiculidae are free-living on pasture. Eggs

of hides may be affected, but in the UK the average

are laid on soil, and larvae crawl on to vegetation and

prevalence is 17 per cent (Urquhart et al. , 1987). The to animals that lie on or brush through the foliage. The *lesions do not normally seriously affect cattle and*

larvae are skin-piercers, causing vesicles. Animals

treatment is not usually necessary.

become hypersensitive to their secretions and the sub-

sequent rubbing and scratching increases the damage to

skins.

Diagnosis

All of the mites are too small to be easily seen with the

Burrowing mites:

naked eye, and microscopic examination of skin scrap-

(1)

Sarcoptes scabiei. Mites of this species are host

ings is necessary, as it is for differentiation of most skin

specific although they are morphologically identical to

conditions. Mites are normally most easily found in

those infesting other animal species. The adults are

scrapings taken from the edge of lesions. The scrapings

slightly larger than half the size of P. ovis and C. bovis.

are boiled in sodium or potassium hydroxide and

They are characterized by a rounded shape and the

centrifuged prior to examination of the sediment by *presence of triangular scales on the posterior of the*

microscope.

dorsum. Adult females burrow tunnels in the epidermis.

They lay eggs in tunnels, hatching taking place within a

week. The hatched larvae crawl to the surface and

Treatment and control (see p. 1030)

create further epidermal tunnels in which they moult

Mites are affected by amitraz, some organophosphorus

through the stage of nymphs to become adults. Males

compounds, synthetic pyrethroids and the anthelmintics

and females mate either in tunnels or on the skin

ivermectin, doramectin, eprinomectin and moxidectin.

surface and the cycle resumes, the entire length of which

For topical applications the problem is to ensure that

occupies three weeks.

the chemical can come into contact with the parasite

Sarcoptes scabiei infections cause extreme irritation.

and it may be necessary to remove scabs before appli-

On cattle the preferred sites are the neck and the

cation. The organophosphorus compounds used fre-

lumbar area adjacent to the tail, resulting in the collo-

quently are phosmet, propetamphos and diazinon, and

quial description of 'neck and tail mange', but it can be

the synthetic pyrethroids flumethrin, deltamethrin and

cypermethrin. Organophosphorus compounds and

There are three genera: Argas, Ornithodorus and ivermectin, doramectin and moxidectin should not be

Otobius.

used on dairy cows giving milk for human consumption

unless withdrawal periods are observed. Eprinomectin

is safe to use in such cattle.

Ixodidae family

These have a hardened scutum that covers almost all

the dorsum in adult males but only one-third of the

Tick infestations *(see p. 1030)*

dorsum in unfed larvae, nymphs and adult females. The

mouthparts are visible. There are nymph and larval

In tropical regions ticks play an important role in

stages. All stages including the adult females feed only

causing and spreading disease. Many actively suck

once. Adult males remain on the host and feed often.

blood and can cause death by anaemia. Some ticks

Up to half the engorged weight can be taken in with

cause paralysis, particularly in young animals. The life

one feed.

cycles vary considerably, with some ticks spending all

The family includes one-, two- and three-host ticks

their time on a single host, others are only parasitic at

and there are ten ixodid genera of which seven have

certain stages and some spend each stage of the life

veterinary importance:

Amblyomma,

Boophilus,

cycle on a different host. Those spending all their time

Dermacentor, Haemaphysalis, Hyalomma, Ixodes and on a single host (one-host ticks) are easier to control

Rhipicephalus.

than those on different hosts for each development

stage (three-host ticks)

Control: This can be directed at the ticks on or off the One-host ticks:

Boophilus spp.

host. The latter is easiest to perform, but is ecologically

Two-host ticks:

Hyalomma spp.

damaging as other non-dangerous insects are also

Rhipicephalus bursa

affected. When off-the-host-control is performed it

R. evertsi

includes the use of pasture spraying with anti-tick dips,

Three-host ticks:

Amblyomma spp.

which involves keeping stock off the area for as long as

Argaspersicus spp.

possible to allow death of the ticks. It works best where

Dermacentor spp.

the ticks are short-lived as in warm arid conditions. It

Haemaphysalis spp.

is best performed by treating pastures in rotation. The

Hyalomma spp.

effectiveness of pasture spraying depends on whether

Ixodes spp.

alternative hosts, either domestic or wild, are available.

Rhipicephalus spp.

The practice often means underuse of pasture. However, the overuse or intensification in grazing often increases the tick population. Another method of con-

Ixodoidea

trol often under-rated is that of pasture burning.

In most areas the only effective method of tick

Their life cycle involves egg, larva, nymph and adult.

control is on the host. This is usually done by hand

Almost all ticks at each development stage require a

dressing, spraying or dipping, and in some countries by

blood meal. The unfed stage varies in its ability to

vaccination. Hand dressing is laborious and has to be

survive depending on the amount of moisture present.

done efficiently. It can be done by the use of dusting

The engorged stage drops off the host and then does

powders, creams, pastes or in a liquid form by hand

not move from where it is deposited. The group is

spraying, paint brushing or application by washes. In

divided into two main families, the Argasidae ticks and

large herds sprays or dips are used. In general, dips

the Ixodidae or hard ticks.

provide a more effective overall control. Both effective spray races and dips are expensive to install. The compounds used tend to be organophosphates, synthetic

Argasidae family

pyrethroids and traditional compounds. The last group

These have a cuticle without a hardened dorsal scutum

includes arsenic preparations such as sodium arsenite.

and their mouthparts cannot be seen from above. They

It is cheap but has no residual effect and it can be toxic.

are mainly found in arid or semi-arid areas. When

Resistance to arsenic dips occurs in some areas. Or-

feeding they rapidly engorge with blood. They are able

ganophosphorus dips are effective but have limited re-

to survive for long periods, i.e. months or years, without

sidual activity. They can be toxic, especially when used

the presence of suitable hosts for feeding. The nymphs

by unskilled staff. Organochloride compounds are now

and adults can repeatedly feed, which allows greater

prohibited in most countries because they are persist-

capacity for transfer of infection.

ent for long periods and affect the human food chain.

Synthetic pyrethroids are good and relatively non-toxic

used. Otherwise, for small groups of animals the use of

but some resistance to them is developing, and occurs

mosquito screens will stop contact.

also when ticks are DDT resistant.

The number of dippings depends on several factors

Blackflies

and often means the interval between dippings varies

according to the season of the year. It depends on the

These belong to the family Simuliidae and include

duration of the ixodicide's activity, the toxicity of the

blackflies, buffalo flies and sandflies. They are small

dip, the seasonal activity of the ticks, the time the ticks

(<5 mm long) and black or grey in colour. They occur

spend on the host and whether it is required to control

in most countries and when in large numbers they are

or try to eradicate the parasite. Thus one-host ticks,

an annoyance. It is thought that there may be toxic

which remain on the host for three weeks, are far easier

factors in the saliva. The bites result in vesicles and *to deal with than three-host ticks, which only feed for a these in turn can result in ulcers and secondary infec- day or two. Generally, at its height, dipping will be once tion. The larvae and pupae are attached to reedy stems a week for one-host ticks and twice a week for three- and branches in running water. They take about three host ticks. Such frequent dipping does allow tick selec- to four weeks to pass from egg to adult. They are active tion for resistance. However, often where tick control during the summer months. The flies tend to gather in is not achieved it is more likely due to not dipping fre- swarms and annoy animals. They bite the legs, belly and quently enough or the dip being too weak, improperly head, causing the animals to stamp and kick their legs. mixed or the wrong type or concentration for the stage Occasionally they stampede. Cattle may wallow in mud of the tick to be killed. Where resistance does occur it or kick up dust to keep off the flies. Control depends can be overcome by changing the type of agent in the on attacking the larval stages by spraying breeding dip. Many farmers alternate the type of dip used on a* *sites with insecticide. However, rapid reinfection of the*

routine basis.

areas will occur. Treatment of the adult is difficult but

Vaccination is carried out in Australia and a few other

a repellent such as dimethyl phthalate is helpful.

countries to the one host tick Boophilus microplus. The Regular dipping of cattle for ticks, etc. also reduces fly

vaccine consists of recombinant antigens to the

levels.

microvilli of the tick intestinal epithelium. As a result

ingestion of blood from immunized cattle disrupts the

Midges

digestion of the tick which leads to death or reduced

fertility. After some years of vaccination the local tick

These are extremely small flies (1–3 mm long) of the

population is therefore drastically reduced. Vaccination

family Ceratopogonidae, the important genera being

needs to be repeated at least annually as the immunity

Culicoides and Lasiohelia. These suck the blood of is not boosted by antigens from natural infection.

animals and man. They transmit ephemeral fever, blue-

tongue and other pathogenic viruses. The larvae are *found mainly in swamps, where they live either in*

Fly problems

wet mud or free-standing water. Some occupy more

(see p. 1030)

restricted habitats such as rotting vegetation. Besides

acting as vectors of arboviruses they can cause hyper-

Mosquitoes

sensitivity reactions.

There are many species of mosquito including Aedes

Control is by draining the breeding sites. Otherwise,

spp., Anopheles spp., Culex spp., Mansonia spp. and spraying the areas with oil or DDT gives good results.

Psorophora spp. They can cause problems when in large Repellents, particularly dimethyl phthalate, are effec-numbers due to annoyance of man and animal. Mos-

tive on a short-term basis. Mosquito screens are of no

quitoes cause some loss of blood by feeding as well as

use. Fires at times of biting activity will assist in herd

transmitting diseases such as Rift Valley fever and prob-

protection.

ably other conditions such as lumpy skin disease and

bluetongue. The mosquito life cycle is aquatic for the

Horseflies and deerflies

larva and pupa and takes 5–21 days to reach the adult

stage.

Horseflies are of the Tabanus spp. and are also called Control of the insect over large areas involves

March flies or breeze flies. Deerflies are of the Chrysops drainage of still surface water or by treating water with

spp., Haematopota spp. and Pangonia spp. They are oil, synthetic pyrethroid or other insecticide. Oil is

large, brown, robust flies that bite and suck blood. They

easiest to use and can involve waste engine oil with

act as vectors of diseases such as anthrax, anaplasmosis

kerosene or diesel oil. Applying repellents to cattle

and trypanosomiasis. Haematopota spp. are thought to

tends to be too expensive and self-applicators are often

help transmit summer mastitis. The eggs are laid on the

leaves of plants growing close to or in water. The larval

A repellant such as dimethyl phthalate can be of use.

and pupal stages occur in the water or mud and the life

Synthetic pyrethoids can be successful.

cycle takes about four to five months to complete. The *flies tend to be active during the day in summer months,*

Face fly

particularly when it is hot and sultry, and are mainly

found on the ventral abdomen and legs. Control is dif-

This is Musca autumnalis a small fly resembling, and

ficult but depends on drainage of wet areas. Breeding

slightly bigger than, the housefly, found in Europe, Asia

sites can be treated with oil or insecticide. Otherwise,

and North America. Numbers tend to be greatest in the

repellents such as dimethyl phthalate and g-dimethy-

summer and particularly cattle outside are worried.

tolumide are useful but last only a few days. Some

Fresh cattle faeces are the only fly breeding grounds.

products are available to apply to the cows' udders.

Flies are particularly seen on the face around the nos-

trils and eyes where they feed on the secretions. They

are thought to transmit infectious bovine keratocon-

Houseflies

junctivitis. There are no wholly successful control

measures although plastic insecticide-impregnated ear

The common housefly (Musca domestica) has a world-

tags are useful and powders or cream containing

wide distribution. They cause worry to animals by set-

organophosphorus compounds assist.

tling on them as well as acting as vectors of diseases

such as anthrax, erysipelas, brucellosis and possibly

summer mastitis. They cause aggravation at wounds or

Head fly

other areas where there is blood, exudate, pus, etc. They

The fly Hydrotaea irritans is the same size as the house-cause infections by discharging some of their stomach

fly but has an olive abdomen and yellow wing tips. It is

contents, so-called vomit drop, on to the food to

found in Great Britain and Europe. It is a nuisance fly

moisten it and often they also defaecate. This means

and does not bite although it does feed off exudate

that they are able to transfer many pathogens effec-

around wounds. It occurs in large swarms from July

tively. Eggs are laid on rotting vegetable material or

to September. The life cycle is annual and it involves

faeces. The life cycle involves an egg producing a larva

periods of development in the soil. Sores on animals are *(a maggot), which takes about 10 days to mature,*

made larger due to self-inflicted aggravation because

thereby completing the cycle in about 12–14 days in

of irritation. Hydrotaea irritans is incriminated in the warm weather.

transmission of summer mastitis (see Chapter 24). It is

Control methods include removing all manure and

probably also concerned with infectious bovine kerato-

organic material at least every three days. This can be

conjunctivitis. Control is difficult and involves the use

stacked so as to ferment, ideally in a bunker or pit. Oth-

of parasite sprays and dipping. Plastic insecticide-

erwise, it should be turned over every few days or better

impregnated ear tags are useful.

still treated with insecticide. Faeces can be burnt. Fly

traps (Baber's) can be used to collect flies and larvae.

Buildings should be kept as clean as possible and can

Stable fly

be sprayed with insecticides, or insecticide strips can be

The stable fly, Stomoxys calcitrans, is about the size of placed in areas with little air movement. Electrocutors

the housefly. It is grey in colour, has a sharp proboscis *can be used to which the flies are attracted by an*

and when it settles it sits with its head upwards. It is a

ultraviolet light.

Cattle can have insecticide-

bloodsucker and feeds on the host causing great irrita-

impregnated ear tags but these are not too effective

tion. Wounds often bleed freely after the flies have fed.

against the housefly.

The eggs are laid in faeces, rotting hay or straw and the

life cycle is complete in two to three weeks. The larval

and pupal stages take place in organic matter. Warm

Bush flies

damp environments encourage the flies' growth and

These include Musca sorbens, M. fergusoni, M. ter-survival. They cause considerable nuisance and worry

raeregina and M. hilli. They are found particularly in with reduced milk and meat production and possibly

Australia. They tend to be found all the year round in

anaemia. In cattle there can be a hypersensitivity of the

northern Australia but only in the summer periods in

forelimb skin, which in turn has blisters that coalesce to

the south. The flies often appear in large numbers and form bleeding sores. Stomoxys calcitrans can transmit can be found on the lips, eyelids and other mucous

anthrax. Another species, S. nigra, occurs in South

membranes and by wounds. They are considered to

Africa.

transmit infectious bovine keratoconjunctivitis. Control

Control of the fly involves the frequent removal and

is difficult but involves fly spraying cattle and buildings.

disposal of bedding and faeces from buildings. Destruc-

tion of the flies is difficult because they feed for only a

of environments but are usually found in one of three

short time. It can be helped by the use of insecticide-

terrains: (i) forest, where they inhabit thickly wooded

impregnated plastic ear tags or spraying with suitable

areas with a high humidity; (ii) riverine, where they live

sprays, spraying of walls and shaded areas of pens.

on the edges of forest but by streams, lakes and rivers;

and (iii) savannah grasslands, where the tsetse are the

most important species for spreading animal disease.

Horn flies and buffalo flies

Both the male and female tsetse flies feed on blood

Horn flies include Liperosia or Haematobia irritans, H.

and most of the species are attracted to certain host

minuta and L. or H. exigua. This last is also known as species. In tsetse flies the eggs hatch in the uterus and

the buffalo fly. The flies are greyish, smaller and less

so they are larviparous. The larvae are deposited on

active than stable flies. At rest their wings are com-

shady dry soil and pupate there. One larva is produced

pletely closed but are held away from the body. They

every 10 days and the pupal stage lasts 28–56 days. As

thus spend more time on the host except when laying

the adult female survives three or four months eight to

eggs, etc. Many have a limited geographical range. Thus

twelve larvae are produced.

H. irritans is found in the USA and Hawaii, H. minuta Control depends on surveying an area to determine

in Africa and H. exigua in Australia and south-west

the species of the tsetse fly present and their habitats.

Asia. They are most common on cattle and buffalo

Then the possibility of control can be assessed. Methods

and occur in large numbers, causing much irritation.

of eradication or control are direct using insecticides to
Although bloodsuckers they are not known to transmit
remove adult flies, removal of pupae and use of repel-
diseases. Severe infestations lead to weakness and
lents on cattle. The indirect approach depends on
death. They also produce large sores.
removal of nesting sites and dry weather refuges, and
The eggs are laid in fresh faeces and can only survive
the use of traps. Insecticides including DDT and diel-
with high humidity and warm temperature. They pupate
drin are of long duration but have been considered by
in the soil and the life cycle takes eight days to three
some to cause too much long-term pollution. Shorter
weeks to complete. Control of the flies is difficult but
term insecticides that are biodegradable such as syn-
removal of dung is important. The cattle and buildings
thetic pyrethroids. are now favoured (see p. 760).
should be sprayed frequently with insecticide. If tick
dipping is undertaken this reduces fly numbers. The

Tumbu fly

anthelmintics doramectin, ivermectin and eprinomectin *are effective because of their residual activity, and will*

The tumbu or mango fly is Cordylobia anthropophaga.

protect cattle for periods of up to three weeks. The use

It infests man and animals but rarely cattle. It is about

of plastic insecticide-impregnated ear tags is helpful.

the size of a housefly and lays eggs in the soil or sand.

Otherwise, applying insecticide at regular intervals will

The hatched larva attaches to the skin of a host where

assist.

it produces a painful irritant swelling with a dark central

hole. Once mature the larva passes out to the soil where

it pupates. The adult lives on food and animal excreta.

Horse louse flies

In light infestations each larva can be manually

These include Hippobasum equina, H. rufipes and H.

removed by covering up the airhole with liquid paraf-

maculata. Hippobasum equina is the most common, is fin in Vaseline. The parasite will push its posterior

slightly larger than the housefly and is a reddish-brown,

abdomen out of the hole and it can then be pressed

fast, glossy fly that causes problems to cattle and horses.

out gently. In severe infestations avermectins such as

It feeds on blood and is found on the inside of the hind

doramectin, eprinomectin and ivermectin will control

legs and the perineum. The eggs are laid and develop

infection and insecticides, such as organophosphorus

in dry soil. They can act as mechanical vectors of

compounds, can be applied.

disease. Plastic insecticide-impregnated car tags are of

use in control as are spraying or dipping of cattle.

Blow flies and screw-worm flies

These result in blow fly infection or myiasis. The flies

***Tsetse flies** (see p. 760)*

involved include several genera: Calliphora, Callitroga, The Glossina species are an important African fly that Chrysomyia, Lucilia and Sarcophaga. Cattle are less act as the true vector of trypanosomiasis (p. 756). They

affected than sheep. The flies are really scavengers and

are 6–13.5 mm long, thin-bodied, yellow or brown flies.

mainly live on dead meat. However, true screw-worm

The wings are folded over each other and there is a

flies only lay their eggs in fresh wounds. They are,

slender proboscis. There are 20 species of Glossina and however, attracted to dying flesh on live animals.

all are found in tropical Africa. They occur in a variety

Even the small wounds of ticks attract the flies. The

larvae feed and grow quickly and mature in three to

starts to suck blood. Bloodsucking is not continuous but

five days.

takes place in short periods of activity until the tick

A local dressing of a larvicide and an antiseptic is

becomes fully engorged. Full engorgement for larvae

useful after clipping away the hair. The most effective

requires three to five days, for nymphs five to six days

treatments are the avermectins doramectin, epri-

and for adults seven to ten days. Babesia spp. are not nomectin and ivermectin. They normally promote a

transmitted by infected ticks until the end of the

complete kill in about 12 hours. All wounds should be

engorgement period because the babesial stages in

treated with an antifly preparation. Dipping or spray-

the tick have to develop and move to the salivary gland

ing the animals with insecticides can be helpful. Other-

prior to becoming infective sporozoites. The sporo-

wise, the number of flies can be reduced by trapping and

zoites are injected into the host with saliva and then

quick disposal of carcasses. Chromosomal translocation

invade erythrocytes. They proceed to divide asexually

of males to produce sterile or lethal mutant offspring

in red cells, forming two pear-shaped merozoites. Each

has been tried with some success. The American screw-

erythrocyte ruptures when the merozoites leave to

worm fly Callitroga americana has been controlled by

infect new cells. The reproduction time in erythrocytes

the release of irradiated males. They mate with the

is in the order of 12–15 hours depending on the species.

females, which lay sterile eggs, thereby ultimately

When sufficient multiplication has taken place for par-

reducing or eliminating the fly population.

asites to be visible in very low numbers in blood smears

the animal will show a febrile reaction. The length of

time required is usually approximately one to three

TICK AND ARTHROPOD-BORNE DISEASES

weeks after infection, but depends on the number of

Babesia in the infective inoculum, and in very large

Protozoal diseases

syringe-passed infections may be as short as two to

three days. Thereafter the parasitaemia may build up

Babesiosis (redwater)

and in extreme cases more than 20 per cent of erythro-

cytes may be infected, although the percentage infected

Babesiosis is caused by a intra-erythrocytic protozoan

varies with the species involved, e.g. the parasitaemia of

of the genus Babesia transmitted by hard ticks of the B. bovis is usually less than 1 per cent in venous blood family Ixodidae (see p. 744). Unlike many other para- whereas B. bigemina and B. divergens on average reach sitic diseases, it affects adults more severely than young

3–8 per cent. At this point the affected animal has a

cattle in which infection is frequently subclinical. It

febrile reaction and may exhibit the characteristic

causes fever, haemoglobinaemia, haemoglobinuria,

haemoglobinuria that produced the colloquial term of

anaemia and death.

'redwater' for the disease, and unless treated it may

die. After treatment the animal becomes a carrier of

Aetiology and epidemiology

the organism and may suffer from occasional recrude-

scences of parasitaemia. Ticks become infected by

The four most important species of Babesia that affect feeding on parasitaemic cattle. Infected adult female

cattle are B. bovis, B. bigemina, B. divergens and B.

ticks pass the infection to their eggs, the infection being

major, the first three being much more significant than termed transovarial, and the larvae, nymphs and adults the last. Two are considered 'small' Babesia and two

up to the F2 generation. Some Babesia spp. may remain

'large', and there is one large and one small species for

infected in the absence of feeding on carrier bovines,

both tropical and temperate climatic areas (Table 45.1).

although for B. bovis infection ceases with larvae.

The parasites are transmitted by hard ticks, which are

Transmission from larva to nymph to adult is termed

also affected by their role as intermediate hosts in the

transtadial infection, and is observed with B. bigemina

babesial life cycle. When an infected tick attaches to the

and B. divergens.

skin of cattle its mouthparts penetrate the skin and it

The epidemiology of the Babesia spp. is governed by

the local climate and behaviour of its tick vectors. As a *result they merit separate consideration as tropical or*

Table 45.1

Babesia spp infecting cattle.

non-tropical species.

Species

Size

Climatic preference

Tropical species: B. bovis and B. bigemina. These species are found in Australia,Africa, South and Central

B. bovis

Small

Tropical or subtropical

America, Asia and the very south of Europe. In Aus-

B. bigemina

Large

Tropical or subtropical

tralia and the Americas the tick Boophilus microplus

B. divergens

Small

Temperate

is the sole vector, in Africa other Boophilus and

B. major

Large

Temperate

Rhipicephalus species. Boophilus spp. are one-host

ticks, i.e. all stages of the life cycle take place on one

dark in colour and reduced in quantity. The faeces may

animal, only the engorged female dropping to the

return to normal but less tends to be passed although

ground before laying eggs. Some vectors in Africa, e.g.

there is still spasm of the anus.

R. evertsi, are two-host and R. appendiculatus is a three-host tick.

Late: In another 24–36 hours the rectal temperature

Babesia bovis merozoites in erythrocytes measure

is often subnormal with the animal having blanched

2 ¥ 1.5 mm and those of B. bigemina 4.5 ¥ 2 mm. Para-

mucous membranes, a poor appetite and drinking little.

sitaemia in venous blood is low with B. bovis but it may There is marked constipation and a greatly increased

be high in capillaries and cause sludging of blood, which

heart rate.

if in the brain causes early death. It also produces

Pregnant cows may abort following infection.

enzymes with severe effects on the blood coagulation

system, and is generally considered the most pathogenic

Necropsy

of the bovine Babesia spp.

Babesia bigemina infection results in much higher

The carcass may be very blanched and there is some-

venous parasitaemia but it has few other effects other

times jaundice. The liver is often swollen and pulpy, with

than to cause a febrile reaction and straightforward

the kidneys dark and enlarged. The bladder contains

haemolytic anaemia.

red-brown urine. There are ecchymotic haemorrhages

under the epicardium and endocardium.

Temperate species: B. divergens and B. major. Babesia divergens, the merozoites of which measure 1.5 ¥ 0.4

Diagnosis

mm, is common in areas of permanent pasture in north-

Cattle suffering from babesiosis frequently have a

western Europe and is transmitted by the three-host *history of recent movement to tick-infested pastures*

tick Ixodes ricinus. Babesia major (3.2 = 1.5 mm) is either through grazing management or after purchase,

found only in south-eastern England and on islands

and in Europe may have suffered from tick-borne fever

off the coast of The Netherlands and is transmitted by

a week or so before babesiosis is evident. Examination

Haemaphysalis punctata.

of the cattle, especially the preferential feeding sites of

Babesia divergens behaves rather similarly to B.

the vector ticks, will reveal evidence of recent tick bites

bigemina, i.e. it can cause a high parasitaemia, which or engorging ticks. Clinical babesiosis is unlikely to be

results in fever and severe haemolytic anaemia. It has

observed in cattle less than nine months old; such cattle

little effect on blood coagulation systems in comparison

can be infected and show febrile reactions but the

to B. bovis. Its epidemiology is closely bound to the

resultant parasitaemia remains low and haemoglobin-

ecology of its vector I. ricinus. In Europe, I. ricinus is uria mild. In areas of large tick populations, most cattle

generally active only between May and November, *are infected at an early age and become immune there-*

and in most areas has spring and autumn population

after, the situation being described as enzootic stability.

increases, although in the most northerly climates it

In the early stages of the disease, haemoglobinuria may

may only have one in midsummer. The ticks quest more

not be present and diagnosis requires careful examina-

actively in warm conditions and outbreaks of babesio-

tion of stained blood smears (see Fig. 45.1). Once

sis are frequently observed two weeks after fine

haemoglobinuria is present, the parasitaemia may be

weather. The epidemiology of B. major is still only

more obvious. Differential diagnosis requires elimina-

slightly investigated, but such isolations as have been

tion of other conditions causing haemoglobin uria, e.g.

reported have taken place in May and June.

anaplasmosis (p. 761), eperythrozoonosis, leptospirosis

(p. 734), postparturient (p. 792) and bacillary haemo-

Signs

globinuria (p. 719).

Early: There is slight dullness with a pyrexia often of Treatment and control (see *p. 1029)*

40.5–41°C (105–106°F). The animal shows diarrhoea

and because of spasm of the anal sphincter there is

There are two aspects to treatment: firstly, treatment

a narrow stream of diarrhoea (pipe-stem diarrhoea).

with a babesicide and secondly, the need for supportive

There is also haemoglobinuria. Slight dehydration is

therapy such as blood transfusion and fluid replace-

often seen as a slightly sunken eye.

ment. There are few babesicides now available. The

only treatment now licensed in the UK is imidocarb,

Mid: After 24–36 hours the mucous membranes tend

which is given at a dose rate of 1 mg/kg body weight. It

to become pale and the pulse rate is increased. The

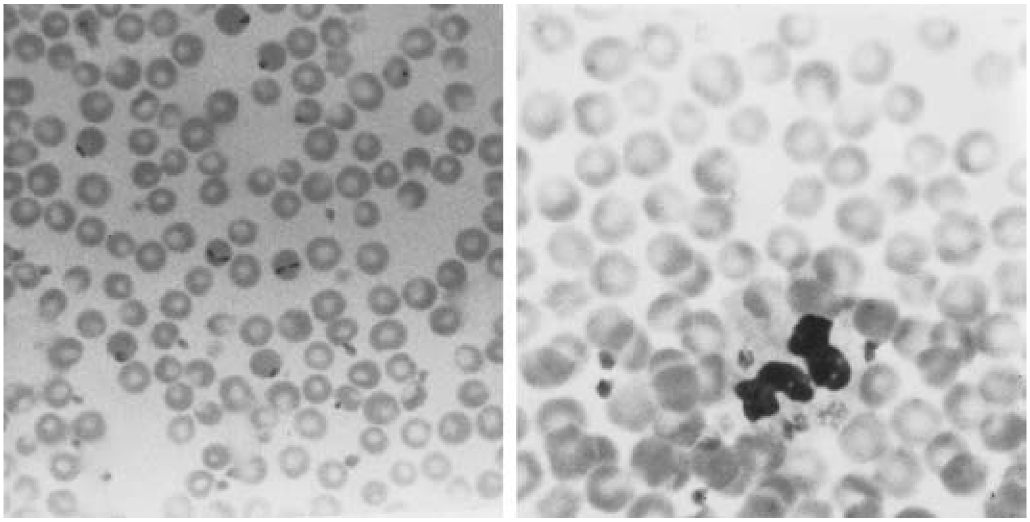
is used widely in South America and other countries. It

animals tend to slow up and there is a reduction in

is highly effective and relatively non-toxic, but does

appetite and thirst. The urine tends to become very

have tissue residues for several weeks after its use.



(a)

(b)

Fig. 45.1

(a) Bovine blood infected with Babesia divergens (¥630). (b) Bovine blood smear showing Ehrlichia phagocytophila in a neutrophil (¥630).

It can also be used at twice the therapeutic dose as a

Table 45.2

Species of the genus Theileria in cattle.

chemoprophylactic, giving protection from infection for

up to six weeks. It is used in this way to administer to

Species

Synonym

Disease

cattle that will be exposed to ticks, or that have been

T. annulata

T. dispar

Mediterranean coast

vaccinated with live Babesia with the hope that cattle T. turkeistomica

infection

will become mildly affected but protected from clinical

T. lawrencei

T. bovis

Corridor disease

illness and immunity to further infection will be

T. mutans

T. orientalis

Benign bovine theileriosis

stimulated.

T. buffeli

Live vaccines for B. bovis and B. bigemina have been T. parva

East Coast fever

available in many countries for many years, notably

T. sergenti

Mediterranean coast fever

Australia and South America. For B. bovis the vaccines (Russian) *consist of live organisms made avirulent by repeated*

rapid syringe-passage through splenectomized calves.

In the case of B. bigemina rapid passage did not reduce

Theileriosis

virulence and vaccines available are either developed

by 'slow' passage from recrudescences of parasitaemia

This comprises a group of infections caused by proto-

or are fully virulent organisms, which are used in

zoan parasites of the genus Theileria (Table 45.2) and schemes involving infection and subsequent treatment.

transmitted by ixodial ticks. They occur in a variety

There are no vaccines currently available for B. diver-

of ruminants and wild animals. Both members of the

gens, although much research is being carried out to

genus Babesia and the genus Theileria occur within red develop inactivated recombinant vaccines for that

blood cells. They are collectively called piroplasms and

species and B. bovis and B. bigemina.

the infections caused by the two are thus sometimes

Blood transfusion is frequently required for severely

known as 'piroplasmosis'.

affected adult cattle and is normally achieved by col-

lection of 5 l of blood from an unaffected healthy cow

East coast fever (ECF) (pp. 73, 753)

into a 22 per cent solution of the anticoagulant acid

citrate dextrose (ACD), the mixture being immediately

The disease is a major constraint for production in

transfused into the recipient animal. Such single trans-

countries where it occurs.

fusions without cross-matching of blood are usually

successful, but repetition can lead to problems of

Aetiology: The cause is a protozoan parasite, Theileria incompatibility of blood antigens.

parva. There is some disagreement about its classifica-

tion. Theileria lawrencei, a parasite of buffalo, causes a delay of three to five days after attachment before this

high mortality in cattle, but if passaged through cattle

occurs. If the tick infects a susceptible animal there is a

it reverts to a parasite indistinguishable from T. parva

period of five days before the parasite can be detected

and producing a syndrome similar to ECF. Thus it

in the local drainage lymph node closest to the tick bite.

has been suggested that the cattle parasite should be

What happens during this period is not known but it is

called T. parva parva and that of the buffalo T. parva likely that sporozoites rapidly enter target lymphocytes.

lawrencei.

By doing this the sporozoites escape the phagocytic,

lytic and immunological defences of the host. Then

Epidemiology: The disease occurs across a large area

there is a transformation of the lymphocyte to lym-

of East and Central Africa and is endemic in Burundi,

phoblast with larger, less dense nuclei and increased

Kenya, Malawi, Sudan, Tanzania, Uganda, Zaire and

cytoplasm caused by the parasite, which in turn differ-

Zambia. It may also occur in Ethiopia and southern

entiates into a macroschizont in the cell cytoplasm. As

Somalia. It is possible to eradicate the disease and this

the disease progresses the macroschizont grows to an

has been done in Mozambique, South Africa, Swaziland

average size of 4.8 mm. The lymphoblasts rapidly pro-

and Zimbabwe, although it can return if preventive

liferate, probably stimulated by the presence of the

measures are not maintained. It is a disease of cattle but *parasite, which becomes aligned along the spindle and*

can infect Indian buffalo (Bubalus bubalis) and African divides by synchrony. As the infected lymphoblast

buffalo (Syncerus caffer). Infection is restricted to coun-divides both daughter cells are infected. Some

tries with a temperature and rainfall suitable to allow

macroschizont-infected cells degenerate releasing free

the survival of Rhipicephalus appendiculatis, a three-

macroschizonts, which invade other uninfected lym-

host tick. The tick is found from sea level to 2135 m

phoid cells. How this occurs is not known but it may be

(7000 feet) provided there is adequate vegetation and

through membrane fusion of cells in close apposition.

a rainfall in excess of 50 cm (20 inches). In many areas

From about day 14 after tick attachment macrosch-

where ECF occurs rainfall is seasonal and disease

izonts differentiate to microschizonts. The mechanism

follows the onset of rain and thus tick activity. In some

of differentiation is not known. Microschizont-infected

highland areas or close to water or sea, where the rain-

cells then rupture and release micromerozoites (1–

fall is more or less constant, tick activity and ECF can

1.5 mm in diameter). The released micromerozoites

occur virtually all the year round. Although R. appen-

enter erythrocytes where they form piroplasms

diculatis is the main arthropod host, eight species of 3–5 mm), which tend to be rod or comma-shaped. The

the genus Rhipicephalus and three species of the genus piroplasm-infected erythrocytes are then available to

Hyalomma can be experimentally infected. In areas

infect ticks feeding on the blood of the cattle host.

where there is a constant challenge then the cattle will

Theileria parva piroplasms rarely divide within ery-

be continually exposed to infection from the tick. If

throcytes, which is different from T. mutans and also challenge is heavy then the calves die. However, those

Babesia spp.

that survive are resistant to further challenge and they

Following feeding on the infected bovine the tick,

can thrive in these areas. In marginal areas where chal-

usually R. appendiculatus, will inject piroplasm-infected lenge is intermittent or seasonal then cattle previously

blood that is around the stage of gametogamy. The tick

exposed may lose or have reduced immunity. Thus if a

is a three-host tick with all three stages (larva, nymph *heavy challenge occurs at the start of the rainy season*

and adult) feeding on separate hosts. Infection is tran-

the cattle are again susceptible and go down with

sitional so an infected larva can transmit infection as

disease. Immunity is only to challenge by a similar

a nymph but not as an adult. There appears to be no

strain. Cattle previously exposed may be partly or

transovarial transmission as occurs with Babesia *spp.*

totally susceptible to infection by other strains. Recov-

Once in the tick gut the erythrocytes lyse releasing the

ered cattle have a sterile immunity, which lasts more

piroplasms, many of which are digested but some of the

than three years. Levels of immunity to piroplasm anti-

many forms develop into male microgametes or female

gens peak often four to six weeks after infection and

microgamonts. Fusion of these by processor anisocyto-

persist for six months.

sis is then thought to occur to produce zygotes, which

invade gut cells and thus differentiate into a motile

Life cycle: The life cycle of T. parva is still not com-kinete of about 19 mm. The kinete breaks out from *pletely understood but most of it is now known or*

the gut cell and enters the haemolymph. The stage of

extrapolated. Firstly, at the stage of introduction of

sporonts is then reached. The kinetes invade the acinar

infection to the cow there is the period of schizogony.

cells (usually type III acinars) of the salivary glands.

Sporozoites from infected ticks are injected with saliva

The kinetes round off and nuclear division occurs to

into the cattle while the tick feeds. There is usually a

produce a sporont or primary fusion body. The sporont

invaginates and forms buds. Further development is

ered by some to be due to a massive infection in par-

delayed until such time as the tick starts to feed in

tially immune cattle.

its next instar. When this occurs primary sporoblasts

develop from the sporont buds and form cystomeres or

Chronic: This is usually seen in animals that are par-

the secondary fission stage. There is hypertrophy of the

tially immune or exposed for long periods to low levels

host cell and the cell nucleus. There is then division of *of infection. It often occurs in calves in endemic areas.*

the primary sporoblasts to produce secondary sporob-

The lymph nodes tend to be enlarged and there is inter-

lasts or the tertiary fission stage and sporozoites (1–

mittent pyrexia, anorexia and loss of condition. These

1.5 mm) are produced. This stage is rapidly completed in

animals frequently recover. In cases of concurrent

three days from the onset of the tick feeding. The sporo-

helminthosis, malnutrition or other disease and a con-

zoites are released into the salivary duct with peak

stant population of T. parva some animals become

sporozoite production by day 5. The host cell and

severely retarded and never reach their full production

nucleus degenerate and the parasite residual bodies

potential.

remain. The sporozoites persist during the whole

period of feeding, which may be up to 10 days for

Pathology: The lesions will depend on the duration of

female ticks and intermittently over a long period for

signs. The most consistent finding is one of hypertrophy

male ticks.

and hyperplasia of the lymph nodes initially, followed

Mortality in susceptible adult cattle is 80–100 per

by lymph node oedema and some haemorrhage and

cent, with an incubation period of 10–15 days.

necrosis later on. There is destruction of lymphocytes

leading to destruction of lymphoid cells. Lymph node

biopsy shows hypertrophy of lymphoid cells and often

Signs

after the 11th day they may show macroschizonts that

Peracute: There is marked pyrexia and death with

increase in number and size. Damaged lymphocytes are

swollen lymph nodes in a few days.

seen with free schizonts. Microschizonts are then

present, either intact or branching out of cells as

micromerozoites. Blood examination reveals a progres-

Acute: Usually the first sign is an enlargement of the sive panleucopenia. A noticeable rapidly developing

lymph nodes for the region draining the area where the

anaemia is only seen in the terminal stages.

infected tick has fed. The preferred feeding sites for R.

The examination reveals froth at the nostrils and *appendiculatus are the ears and so usually the first*

the most striking feature is massive pulmonary oedema,

lymph nodes to swell are the parotids. One to two days

hyperaemia and emphysema. The alveoli, bronchioles,

after the swelling occurs the animal becomes pyrexic

bronchi and trachea are filled with frothy pulmonary

with a temperature rising to 39.5–42°C (103–108°F).

exudate. There can also be pleural and pericardial

The temperature tends to remain high until the animal

exudate. There are excessive haemorrhages and these

either recovers or dies. Other lymph nodes begin to

may be present on most serous and mucous mem-

swell and this tends to become generalized. Some of the

branes. In the abomasum the mucous membrane is red

superficial lymph nodes such as the parotids, prescapu-

and inflamed and there may be ulceration or erosions,

lars and precrurals become very enlarged. Anorexia

especially in the pyloric region. In chronic cases there

gradually develops and there is consequent loss of con-

are ulcers in Peyer's patches. The cortices of the kidneys

dition. In many cases lacrimation and nasal discharge *show haemorrhage and are often congested, and*

occur. The breathing becomes rapid and dyspnoeic, and

nodules of lymphoid tissue projecting from the kidney

there is diarrhoea or dysentery. As the animal deterio-

surface may be seen and are a characteristic feature

rates and approaches death, the temperature falls

when they occur. The spleen may or may not show

and there is severe dyspnoea and recumbency. Nasal

changes and it can be enlarged or shrivelled. The liver

exudate pours out of the nostrils. The animal dies of

is often enlarged with mottled grey areas. Degeneration

asphyxiation from lung oedema. Death is usually about

of the organs is rapid after death.

18–24 days after infection, but occasionally this is

reduced to 14 days. The mortality tends to be near 100

per cent in susceptible animals.

Diagnosis: The signs are relatively specific and infecOccasionally, nervous signs develop and this is known

tion can be confirmed by the presence of piroplasms in

as ‘turning sickness’. Foci of Koch’s blue bodies are

the blood or schizonts in lymph node biopsy smears *found in the cerebral tissue. The animal appears to turn*

stained with Giemsa. There is also panleucopenia and

often rapidly and become giddy with collapse. The less

then anaemia.

severe form involves slower turning and frequent head

Post-mortem findings are helpful but they are similar

pressing. Both nervous forms are fatal and are consid-

to those of malignant catarrhal fever. Differentiation of

T. parva from other Theileria spp. depends on the acute-ing out due to poor immunity or deaths due to vacci-

ness of the disease, the number of piroplasms present

nation. However, animals can be vaccinated with stabi-

in the blood and the number present in lymph nodes.

late produced by freezing down emulsions from

Complement fixation, capillary titre agglutination and

infected blood. After injection of the stabilate long-

indirect haemagglutination tests have all been used in

acting oxytetracycline or buparvaquone is given; other-

diagnosis but are less reliable. The indirect fluorescent

wise short-acting oxytetracycline or paravaquone can *antibody test (IFAT) is considered more reliable. An*

be used. Cattle so treated become resistant to disease

enzyme-linked immunosorbent assay (ELISA) test is

and they show little or no apparent reaction. In some

also being increasingly used.

cases more than one strain of T. parva is introduced, possibly together with a strain of T. lawrencei. A sporozoite vaccine is now being tried.

Treatment (p. 1029): Animals in good condition prior

to infection have lower morbidity. Parvaquone and the

more recently developed buparvaquone are effective if

treatment is not delayed until the animal is too severely

Mediterranean coast fever

affected. Oxytetracycline is effective if given at the

This is in many was similar to East Coast fever but is

same time as infection occurs. It is also able to reduce

caused by a different Theilera species.

the severity of clinical disease and appears most

effective when given by injection. Chlortetracycline

given at any stage of infection at a dose of 10 mg/kg

Aetiology: The cause is a protozoan parasite, Theileria body weight either parenterally or by mouth reduces

annulata. Morphologically, the parasite is similar to T.

the severity of parasitaemia and pyrexia.

parva and the macroschizonts and later microschizonts are found in the lymphoid tissue. Theileria annulata

piroplasms in the erythrocytes tend to be oval or round

Control: In endemic areas indigenous calves have a

in shape. In Russia, there is a similar disease due to T.

high degree of resistance to disease. However, calves of

sergenti, which is different from T. annulata both mor-European breeds are very susceptible to infection and

phologically and immunologically.

often die. Those that survive often succumb to further

attacks. Adult cattle of any breed brought into the areas

are highly susceptible to disease and probable death.

Epidemiology: The condition is found around the

The immunity is more cellular than humoral.

Mediterranean including south-eastern Europe, Russia,

Thus where disease is endemic there is legislation to

the Middle and Far East, India, Sri Lanka, Egypt and

control ticks, to slaughter infected animals, quarantine

Sudan. Both cattle and water buffalo (Bubalus bubalis) cattle and restrict cattle movement. While it has been

are susceptible to the infection. The condition involves

shown in South Africa and Zimbabwe that eradication
a development cycle in ticks of the genus Hyalomma
of ECF is possible, it is expensive and in many coun-
and seven species are known to be vectors. The ticks
tries the legislation is not enacted as rigorously as it
involved are one-host, two-host or three-host ticks. It is
might be. However, individual farmers can do much to
believed that in most tick species there is no transovar-
reduce problems on their own premises by sensible
ian transmission. Thus infection is acquired in the
cattle management and tick control. Efficient and well-
nymph or larval stages and is transmitted in the adult.
maintained fencing will reduce the access of nomadic
When the tick is attached to the host it must feed a con-
cattle or game to the farm. Areas particularly suited to
siderable amount before infective stages of T. annulata
ticks can also be fenced off. Grass burning, rotational
are produced and enter the cattle. Piroplasms appear in
grazing, alternate grazing with other species such as
the erythrocytes shortly after the first detection of sch-
goats or sheep, alternate grazing with immune cattle or

izonts. The intra-erythrocytic form remains in the blood

rotating land between grazing and crop all reduce the

for many years and in natural infections they tend to

problem. Cattle should be quarantined on entry to the

have a ring or oval shape.

farm. Should disease break out its effects can be

The disease is seasonal, depending on the activity of

reduced by slaughtering infected cattle, stopping move-

the ticks, which hide during the winter in crevices

ment of cattle, other animals, people, hay or feed from

between rocks, walls, etc. The result is the infective adult

infected areas and then creating a buffer area between

stage being produced in late spring or early summer.

the infected and clean areas.

Thus infection tends to be seen mainly in the summer

It seems that for effective immunization of cattle

and early autumn. Infection can also be transmitted by

against ECF it is necessary for the infection to be estab-

injecting blood or tissue from ill or recovered animals.

lished in the host. Vaccination is not widely used as it

Intra-uterine transmission has been recorded on occa-

often leads to unpredictable results, with disease break-

sion. Infection of calves in endemic areas usually

produces a mild disease, although up to one-quarter of

Diagnosis: The area, type of animals affected and signs calves can die.

help in diagnosis. Lymph node smears show schizonts.

In the Russian form involving T. sergenti, infection is In some cases a liver biopsy is needed to differentiate.

said to be transmitted by only one species of the genus

Serological tests used for T. annulata include the com-Haemaphysalis.

plement fixation test (CFT), indirect fluorescent anti-

body test (IFAT) and enzyme linked immunosorbent

assay (ELISA).

Signs

Peracute: This occurs in completely susceptible animals Treatment: Many cases of T. annulata infection show entering endemic areas. The animals develop marked

spontaneous recovery. There have been few controlled

pyrexia with anorexia, depression and weakness and

trials of treatment. Both oxytetracycline (by injection)

they die in three or four days.

and chlortetracycline (orally) have been claimed to give *relief. However, buparvaquone is at present the best*

Acute: This is most commonly seen in susceptible

therapy.

animals moved into endemic areas and in marginal

areas of tick activity. The animals develop pyrexia,

Control: Following natural infection there exists a pre-which may persist for several days. It is accompanied

munity that lasts for many years. There is no cross-

by inappetence, lethargy, swelling of the superficial

immunity to other Theileria spp. Immunization is

lymph nodes, oculo-nasal discharge and ruminal stasis.

practised in several countries by taking blood from

This is followed in a few days by anaemia with pale

recently recovered cattle passaged through susceptible

mucous membranes, exercise intolerance and a rapid

cattle. This is continued until no piroplasmic forms of

heart rate. Later on jaundice may become apparent.

the parasite occur. Then citrated blood is injected into

Constipation is common when pyrexia first occurs

susceptible stock, usually calves. Most animals show

but later there is diarrhoea and bloodstained faeces.

only limited reaction to such vaccination, although a

The animals lose condition rapidly and about 90 per

few die. As there are no piroplasms in the blood ticks

cent die over a period of eight to eighteen days after

are not infected. Immunity can then be enhanced by

signs occur.

injecting a virulent strain. It has been possible to culture

schizonts on various tissue culture cell lines and these

Subacute: There is intermittent fever for two to four

have then been used to vaccinate susceptible cattle.

weeks with moderate progressive anaemia and jaun-

They do not produce piroplasms and so the animal

dice. Many of these animals die but some recover over

cannot infect ticks.

a long period. Some of these cases change into a more

Prevention otherwise involves control of the tick and

acute phase and die.

cattle movements. Cattle can be sprayed or dipped with

acaricide. Some walls and buildings can be sprayed to

Chronic: This is often an even more prolonged form of

kill off the overwintering stages. Carrier animals still *the subacute disease. Recovery can occur but is very*

contain infection in their blood and if moved to new

protracted. However, some cases suddenly develop the

farms or countries will take the disease with them to

more acute form and die.

infect local ticks. Thus detection of carriers is of use and

can be done by taking blood from the animal and inject-

Necropsy: There is a pale, anaemic carcass with the

ing into susceptible cattle.

mucous and serosal membranes showing numerous

petechial haemorrhages. The lymph nodes are enlarged,

cystic and oedematous. The liver tends to be pale brown

Corridor disease

or yellow, enlarged and friable with an enlarged friable

This condition is very similar to ECF but it has a

spleen. The kidneys tend to be pale and on occasions

different cause.

show pseudoinfarcts. The abomasum is red, inflamed

and may show haemorrhagic ulceration. There are

epicardial and endocardial haemorrhages and these

Aetiology: It is caused by Theileria lawrencei, which is may be petechial or ecchymotic. The lungs contain

primarily a protozoan parasite of buffaloes. However,

oedema, often red-tinged, and congestion.

it is transmissible to cattle and produces a similar type

A lymph node smear may show schizonts present in

of disease to ECF. The schizonts tend to be smaller and

lymphocytes but they are more common in the liver and

fewer in number and the piroplasms relatively rare in

spleen.

the blood. If T. lawrencei is passaged through cattle it

quickly reverts to a parasite indistinguishable from

A few lymphocytes contain schizonts and there are one

ECF. It has therefore been suggested that T. parva is a or two piroplasms in the erythrocytes.

cattle-adapted strain of T. lawrencei. It has also been proposed that the nomenclature for the two parasites

Diagnosis: The condition is similar to ECF, anaplas-

should be T. parva parva and T. parva lawrencei.

mosis and babesiosis and the peracute form is similar

to heartwater. The signs, and area, help in diagnosis,

Epidemiology: The disease has mainly been described *particularly of those cattle associated with buffalo.*

in South Africa, Zimbabwe and Kenya. It is transmit-

However, where T. parva infection is common then

ted by the three-host tick R. appendiculatus and it is disease caused by T. lawrencei may be missed. A lymph possible that distribution of T. lawrencei is over the node biopsy helps as schizonts in the lymphocytes tend

whole area occupied by the tick. The buffalo (Syncerus

to be few and small in size. Blood samples show only a

caffer) is considered to be the natural host and cattle few erythrocytes to contain piroplasms. There is also no

brought in to the area tend to be susceptible. Those

marked anaemia as in anaplasmosis or babesiosis.

brought up in the region that survive the first few

months are immune but those in marginal areas or

Treatment: Use of oxytetracycline by injection reduces where tick levels have only been partially introduced

the intensity and duration of signs. Similarly, chlortet-

are not. Theileria lawrencei is transmissible from carrier racycline has an effect and can be given by mouth. The

buffaloes via ticks to cattle. It can be passed from cattle

naphthoquinones, parvaquone and buparvaquone are

to cattle via the ticks. The recovered cattle can then act

now successfully used.

as carriers of infection. Morbidity in susceptible cattle

is variable at about 60–80 per cent.

Control: Infection can be controlled by tick dipping,

controlling movement of susceptible cattle, grazing tick

Signs: The signs are similar to those seen with T. parva.

areas with less susceptible species such as sheep or

goats and ensuring no contact occurs between cattle

Peracute: The animal develops pyrexia, lymph node

and buffalo or other game animals. Cattle that are

enlargement and dies in a few days.

exposed to infection and recover are immune.

However, there is not complete cross-immunity with T.

Acute: This is the most common form in susceptible

parva infection, although it does seem that cattle pre-cattle. There is pyrexia and swelling of the lymph node

viously infected with T. parva have a good immunity to closest to the site of the infected tick bite. Other lymph

T. lawrencei. When cattle are initially infected with T.

nodes then start to swell and there is general dullness.

lawrencei there is only limited resistance to T. parva.

There is lacrimation, nasal discharge and oedema

Stabilates of ticks infected with strains of T. parva have occurs, particularly of *the eyelids, face and throat. The*

been injected into cattle followed by treatment with

animal becomes weak and develops diarrhoea contain-

oxytetracycline or parvaquone, which has given some

ing blood and mucus. The respirations become laboured

immunity to T. lawrencei. Some stabilates have included and dyspnoeic.

a T. lawrencei strain.

Mild: In this form there is a mild rise in temperature, Benign bovine thieleriosis

swelling of the lymph nodes and some pyrexia.

This disease tends to be less severe than ECF,

Mediterranean coast fever or Corridor disease.

Pathology: The lymph nodes are swollen and show

hypertrophy and hyperplasia followed by oedema and

haemorrhage. There are extensive haemorrhages on

Aetiology: The cause is a protozoan, Theileria mutans, most of the serosal and mucosal surfaces. The aboma-which is very similar to T. parva.

sum tends to be red, inflamed and with ulcers, especially

in the pyloric region. The spleen may be enlarged. The

Epidemiology: The condition affects cattle as well as

kidney cortex is congested and may show nodules of

the Indian water buffalo (Bubalus bubalis) and the *lymph and tissue raised above the surface. The liver is*

African buffalo (Syncerus caffer). It occurs in most

enlarged and a mottled grey colour. The lungs are grey

parts of the world except countries north of latitude

and contain blood and fluid with froth in the alveoli,

55°N and South America. It is thought that transmis-

bronchi, bronchioles and trachea. Lymph node biopsy

sion is by a wide variety of different ticks but it has been

smears show hypertrophy and hyperplasia of the node.

proved to be so with R. appendiculatus, R. eventsi and

Ambylomma variegatum. Injection of parasitized blood

Besnoitiosis

can produce infection. The disease is maintained by a

This disease was previously known as globidiosis.

premune state of recovered cattle, which allows contin-

ued infection of ticks. Infection often occurs with other

diseases such as anaplasmosis, salmonellosis, heart-

Aetiology

water or babesiosis.

It is due to a protozoan called Besnoitia besnoiti.

Signs

Epidemiology

Acute: This rarely occurs but it has been reported in

It is mainly seen in cattle and horses as intermediate

Australia, India, Japan, Kenya, Korea and South Africa

hosts in south-west Europe and in Africa. Transmission

(where it is known as Tzaneen disease). In this case the

has not been elucidated but is probably via the faeces

disease involves fever with swelling of the lymph node

of infected cats which are the final host. Morbidity can

closest to the infected tick and then more generalized

be up to 10 per cent and recovery is often protracted.

lymph node swelling. There is a progressive anaemia

and some of the cattle die. In Africa there is a cerebral

form of the disease known as turning sickness where the

Signs

animal will tend to walk in circles or head press.

In many animals there are no signs. In the cow there

may be lesions on the teats. There is pyrexia and warm

Subacute: There are very few clinical signs other than swellings develop on the ventral parts of the body *a mild pyrexia with a swelling of the lymph nodes and*

resulting in reduced movement. The lymph nodes are

a mild anaemia.

palpably swollen and there is diarrhoea. Pulse and res-

piratory rates are elevated. Pregnant cattle may abort.

Pathology: In acute cases there is hyperplasia and

There may be excessive lacrimation and increased nasal

oedema of the lymph nodes. There may be haemor-

discharge, which is at first serous and then purulent.

rhages of the serosal and mucosal surfaces. The

There are small, white, raised nodules on the conjunc-

abomasum may be reddened and ulcerated. The

tiva and nasal mucosa. There then follows severe der-

kidney cortex is congested with swollen lymphoid areas.

matitis over most of the body associated with infected

The liver is enlarged and tends to be grey in colour.

cutaneous cysts.

The lungs contain fluid in the bronchioles, bronchi

and trachea. The spleen is swollen.

Diagnosis

Usually in the subacute form there is mild hyperpla-

sia of lymph nodes, which contain a few schizonts.

This is based on clinical signs, especially the cysts on the

Anaemia occurs but is slight. There are only a few piro-

scleral conjunctiva, and on the geographical area and

plasms in the blood and schizonts in lymph node

can be confirmed by the detection of cysts containing

sinuses.

spindle-shaped spores in scrapings of skin lesions or the

conjunctiva.

Diagnosis: Diagnosis is helped by the mild nature of

the signs but is not helped by the presence of only very

Treatment

few piroplasms in the blood or schizonts in lymph node

Nothing specific is available.

biopsies. In addition the schizont is morphologically

similar to T. annulata and T. parva. The best method of differentiation is by serology and the most effective test

Control

at present is IFAT.

A vaccine produced by B. besnoiti grown on tissue

culture is effective.

Treatment: Quinoline drugs such as pamaquin are of

use in the erythrocytic stage.

Trypanosomosis

Control: As the disease is mild, deliberate control or Trypanosomes are blood-borne protozoa with flagellae.

eradication is not usually undertaken. However, control

Infections are widespread in wild and domestic animals

of ticks will result in control of disease. Cattle maintain

and cattle are susceptible to infection with several

immunity by a form of premunity, with piroplasms

species, the most important of which are those cyclically

remaining in small numbers within the blood.

transmitted by tsetse flies (Glossina spp.) throughout

much of subSaharan Africa, namely Trypanosoma

the life cycle and hence nagana is unique to Africa. The

congolense, T. vivax and T. brucei. Trypanosoma vivax one exception of the nagana trypanosomes is T. vivax,

infections also occur in cattle in the absence of the

as mentioned earlier. In Central and South America it

tsetse fly in Central and South America and have been

is assumed that T. vivax is mechanically transmitted by recorded in Mauritius. In *tropical and subtropical areas*

biting flies. This raises the possibility that it may also be

other than subSaharan Africa, cattle are commonly

transmitted mechanically in Africa, and indeed there is

infected asymptomatically with T. evansi.

increasing evidence that this is the case.

Tsetse fly-transmitted trypanosomoses are com-

Infection with T. evansi is also transmitted mechani-

monly grouped together under the name 'nagana' (p.

cally by biting flies. Infection of domestic livestock is

1030). Their distribution lies within the tsetse fly belts

widespread worldwide throughout the tropics and

of Africa, which extend from 14°N to 20°S in south-west

subtropics, but is absent from tsetse-infested areas of

Africa and 29°S in Mozambique, covering an area of 10

Africa. It is an important pathogen of camels, horses,

million km2. Many species of wild animals are symp-

dogs and buffaloes but cattle, although commonly

tomless carriers of nagana trypanosomes and provide

infected, rarely suffer clinical disease. However, they

a sylvatic reservoir of infection in which the try-

may be important reservoirs of infection for other more

panosomes are cyclically transmitted naturally from

susceptible livestock.

host to host by tsetse flies. The principal carriers of

these trypanosomes are wild bovids and suids, e.g. kudu,

Aetiology

giraffe, buffalo, warthog and bushpig. Cattle, other

domestic animals and man are infected when they come

Tsetse-transmitted bovine trypanosomoses are caused

in contact with these wild animal carriers and are bitten

by T. vivax, T. congolense and T. brucei. All are motile, by infected tsetse flies as a result.

extracellular, spindle-shaped, flagellated protozoan

Tsetse flies can be classified as falling into three

parasites ranging from about 10 to 30 mm in length.

groups, namely forest, riverine and savannah. The forest

Trypanosoma vivax and T. congolense are essentially tsetse flies are found in the tropical rainforests of

parasites of plasma, although T. vivax may leave the

Central and West Africa and in scattered areas of East

circulation in small numbers and invade extravas-

Africa. Although they are efficient vectors of try-

cular tissues particularly of the heart (Losos, 1986).

panosomes, they are of least importance as cattle rarely

Trypanosoma congolense has a predilection for the

come in contact with them due to the lack of suitable

microvasculature where it attaches to the endothelium

grazing in the forest regions. Riverine tsetse flies, as

of small blood vessels, particularly the heart and brain

their name implies, infest riverine vegetation, but

(Banks, 1978). Trypanosoma brucei as well as being a

virtually only in river systems draining into the Atlantic

plasma parasite has a predilection for interstitial spaces

Ocean. Their distribution is thus confined to Central

and tissue fluids.

and West Africa, largely overlapping with that of forest

Trypanosoma evansi is related to T. brucei to which flies. Although they are less efficient vectors of try-it is morphologically similar and has a similar infection

panosomes than forest or savannah flies, because they

pattern in the animal host.

infest vegetation near essential water supplies, riverine

flies are important vectors of trypanosomosis of

Pathology

humans (Gambian sleeping sickness) and of domestic

livestock including cattle.

The pathogenesis of bovine trypanosomosis is complex

Savannah tsetse flies are the most important group of

and not fully understood but is characterized by a

flies because they infest large tracts of land potentially

chronic and progressive anaemia. Uncomplicated

suitable for grazing and browsing by domestic livestock.

tsetse-transmitted infection can be considered as

They are also efficient vectors of trypanosomes and so

following a course comprised of three phases (Murray,

when cattle and other livestock encroach into tsetse-

1978).

infested savannah, they are at risk of being bitten by the

fly and contracting infection.

Phase I (fluctuating parasitaemia and fever): Following Tsetse flies become infected when they take a blood

an infected tsetse fly bite, trypanosomes multiply

meal from an infected animal. The trypanosomes then

locally, causing an inflammatory reaction (chancre)

undergo cyclical development within the alimentary *within a few days at the site of the bite. Chancres are a*

system, eventually developing to the infective or meta-

regular feature of experimental infections, but have not

cyclic forms within the fly mouthparts. These infective

been reported in natural infections. About this time, try-

forms are then transmitted to another susceptible

panosomes invade the circulation via the lymphatic

animal host via the saliva during the next fly feed(s).

system, causing reaction and enlargement of locally

The development in the tsetse fly is an essential part of

draining lymph nodes. Trypanosomes then appear in

the bloodstream, the prepatent period following initial

Africa tend to cause a more chronic form of the disease.

infective tsetse bite varying with species thus:

Trypanosoma brucei is the least pathogenic to cattle

and normally regarded as of minor importance.

T. congolense

12–16 days

Although infection with more than one species is

T. vivax

8–10 days

commonly reported in the field, virtually no studies

T. brucei

5–20 days

have been done on mixed infections. Cattle infected

A fluctuating but diminishing parasitaemia then devel-

experimentally with T. congolense and T. brucei, either ops and parasitaemic peaks at approximately 12-day

simultaneously or one year apart, developed cerebral

intervals are associated with febrile responses. Anaemia

trypanosomosis with encephalitis and associated clini-

becomes evident early in infection and is believed to be

cal signs and both species of parasites were isolated

haemolytic in the first instance, but haemolysis

from the cerebrospinal fluid (Masake et al., 1984). The wanes and is superseded by anaemia caused by ery-authors suggested that the higher incidence of cerebral

throphagocytosis due to stimulation and expansion of

trypanosomosis in mixed infections than in single infec-

the mononuclear phagocytic system resulting in

tions suggests an interdependence between T. con-

splenomegaly.

golense and T. brucei in the pathogenesis of cerebral This initial phase of fluctuating parasitaemia and

trypanosomosis, possibly resulting from T. congolense's fever may last from a few weeks to a few months during

predilection for the brain microvasculature facilitating

which cattle lose condition and, depending on the

the entry of parasites into brain parenchymal extravas-

severity of infection, some may die. Cattle that survive

cular spaces. The possibility of such interaction between

this phase enter the second phase.

different species in natural infections merits further

research.

Phase II (low-grade parasitaemia and progressive

anaemia): Over the next few months, infected cattle

Signs

have a low fluctuating parasitaemia during which the

parasites may be difficult to detect. Despite the appar-

The clinical picture of cattle suffering from nagana is

ent reduction in parasites, the erythrophagocytosis and

influenced by several factors, namely breed and health

anaemia continue, although the spleen may return to

status of cattle infected, pathogenicity of infecting *normal size and cattle continue to lose condition.*

trypanosomes, duration of exposure to infection and

level of tsetse fly challenge, which in itself is dictated by

Phase III (apparent aparasitaemia but continuing

several factors. Trypanosoma vivax infections in cattle anaemia): Cattle that survive the second phase suffer

in West Africa are widespread and commonly produce

chronic disease during which the parasites apparently

an acute, rapidly fatal disease in which affected cattle

disappear, although anaemia due to erythrophagocyto-

die during the initial phase of fluctuating parasitaemia

sis continues. Affected animals are cachectic and nor-

and fever. Stephen (1986) describes acute T. vivax

mally die within six to twelve months of initial infection.

infection as resembling septicaemia in which affected

Infection at any stage may lead to congestive heart

animals have body temperatures of 40–41°C

failure and death due to a combination of anaemia,

(104–106°F), depression, dyspnoea, elevated pulse and

circulatory failure and myocardial damage. At autopsy,

respiratory rates and a jugular pulse. Less severe cases *post-mortem findings are not pathognomonic. They*

show signs of anaemia, loss of condition (Fig. 45.2) and

include emaciation, visceral pallor and enlargement of

enlargement of superficial lymph nodes. Abortions and

the heart. Cattle that die early in disease may have

stillbirths may occur in pregnant cows.

enlarged haemorrhagic lymph nodes and splenomegaly

The situation in East Africa and parts of Central

(Stephen, 1986).

Africa is different in that T. congolense tends to be a Despite the large volume of literature on bovine try-more serious pathogen than T. vivax, although this is by panosomosis, good accounts of the pathology of natural

no means absolute as strains of T. vivax are known to disease are scarce and the above account represents a

cause an acute haemorrhagic disease in cattle in the

brief synopsis of the generally accepted picture. Cattle

Coast Province of Kenya (Mwongela et al., 1981). Try-at risk may be infected by several species and strains of

panosoma congolense in East and Central Africa tends

trypanosomes and the pathology and clinical signs will

to produce a chronic disease, although the clinical signs

be influenced by various factors, e.g. the age, breed and

are essentially the same as those of T. vivax infection nutritional status of *infected cattle, the degree of tsetse*

and eventual death is the usual outcome in untreated

challenge and the strains and species of infective try-

animals. In the early stages of infection appetite may be

panosomes. Thus strains of T. vivax in West Africa tend normal between periods of fever, but as the disease

to cause a more acute disease in cattle than those of

progresses the anaemia becomes more severe, cattle

East Africa, whereas strains of T. congolense in East become depressed and lose bodily condition and in the

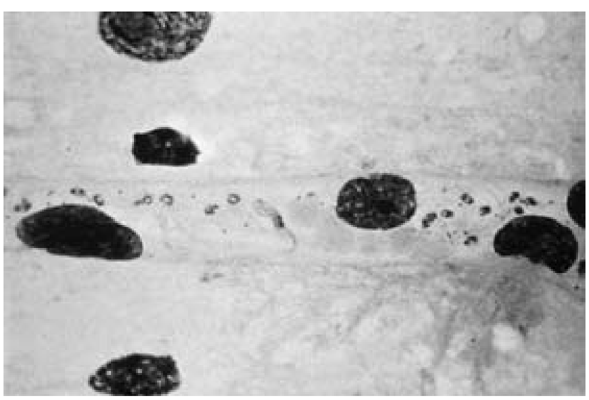


Fig. 45.2

Emaciated cattle suffering from trypanosomosis in

Fig. 45.3

Trypanosoma congolense in ox brain capillary (cour-

northern Botswana (courtesy of A.G. Hunter).

tesy of CTVM Archives) (¥1000).

terminal stages affected cattle are too weak to rise or

chronic wasting condition of cattle in contact with the

eat (Stephen, 1986). Superficial lymph node enlarge-

tsetse fly. Differential diagnoses are babesiosis (p. 748),

ment is not so pronounced as in T. vivax infections.

anaplasmosis (p. 761), helminthosis (Chapter 19) and

Trypanosoma brucei infections of cattle, though

any condition that causes anaemia and emaciation,

common, are generally regarded as of minor signifi-

notably malnutrition. Nagana can be confirmed para-

cance and are usually mixed with the more pathogenic

sitologically by demonstrating parasites in the blood of

T. congolense or T. vivax. Parasitaemias from T. brucei infected animals and various techniques are available

infections are lower than those of T. congolense or T.

(Fig. 45.3). These techniques were reviewed by Paris et

vivax and hence infection can be more difficult to

al. (1982) as follows.

detect, raising the possibility that disease caused by T.

• Microscopic examination of stained thin blood

brucei infection may not always be diagnosed. A few

smears. Different species of trypanosomes can be

reports of meningo-encephalitis have been recorded,

identified by this method.

and experimental infection produces a severe diffuse

• Microscopic examination of wet blood films; this

meningo-encephalitis resulting in depression, unsteady

must be done at the time of sampling and cannot be

gait, head pressing and circling (Morrison et al., 1983).

used to identify different species of trypanosomes.

There is a greater incidence of cerebral trypanosomo-

sis in mixed T. congolense and T. brucei infections as These techniques are not particularly sensitive and may

mentioned earlier and the involvement of the central

not detect animals with low parasitaemias, such as those

nervous system (CNS) in natural bovine trypanosomo-

suffering chronic disease. More sensitive techniques are *sis requires investigation.*

the following:

Trypanosoma vivax infections of cattle are wide-

• Microscopic examination of the buffy coat–plasma

spread in Central and South America and the West

interface of haematocrit-centrifuged blood, either

Indies and were probably introduced with imported

directly through the capillary tube glass or by

cattle from Africa. The importance of T. vivax in the breaking the capillary tube just below the buffy coat

New World is not clear, but epidemics of serious disease

and expressing the contents of the upper part onto

have been recorded in Venezuela and Colombia

a slide for examination by dark-ground or phase-

(Clarkson, 1976). In general, the clinical signs appear to

contrast microscopy.

be the same as chronic forms of T. vivax infection in

• Microscopic examination of stained dehaemoglo-

Africa and the swaying gait of infected emaciated cattle

binized thick blood smears.

may be confused with the clinical signs of rabies.

• Subinoculation of bovine blood into laboratory

Trypanosoma evansi infections of cattle, though

rodents. This is the most sensitive technique for T.

common throughout the tropics and subtropics, rarely

brucei and is usually good for T. congolense, but cause clinical disease.

most strains of T. vivax do not infect laboratory

rodents.

Diagnosis

In practice, many field programmes of monitoring

In tsetse-infested areas of Africa, nagana is well recog-

cattle for infection are based on routine screening of

nized and diagnosis is often based on a history of a

stained thick and thin blood films; thick films are

examined to detect infected animals and thin films to

taining tsetse-free barriers around areas freed of

determine the species of the infecting trypanosomes.

tsetse.

Trypanosoma vivax infections in the New World

• Settlement of land freed of tsetse. Housing, crop-

may have to be differentiated from conditions causing *ping, etc. may alter the vegetation to a form unsuit-*

wasting and anaemia such as anaplasmosis, babesiosis

able for tsetse flies, so preventing reinfestation.

and helminthosis and in addition, as mentioned earlier,

• Destruction of wild animal hosts. This is now unac-

rabies (p. 908; Chapter 70). In general the same tech-

ceptable except in establishing animal-free corri-

niques as described can be used to confirm diagnosis.

dors, possibly in conjunction with the third method,

Serological tests are not in general use for diagnosis

above.

although several are under study. Trypanosomes display

• Release of sterile male tsetse flies to interfere with

the phenomenon of antigenic variation during infection

breeding of wild tsetse populations. Because of the

in the mammalian host in which successive parasitaemic

very low reproductive rate of tsetse flies, only small

populations of trypanosomes have a different antigenic

numbers of flies can be reared in colonies. There-

composition. Thus the host mounts successive immune

fore this method has limited application, usually in *responses to sequences of different antigenic popula-*

conjunction with other methods.

tions and a test developed to detect serum antibodies

to one antigenic population may not detect serum anti-

Thus, the commonest form of prevention is avoidance

bodies against different antigenic populations of the

of the fly by cattle herders who build up local knowl-

same strain of trypanosome. These variable antigens are

edge on when and where pastures are safe to graze.

confined to the surface glycoprotein coat of the para-

Savannah tsetse flies retreat and disperse during the dry

sites and, although tests have been developed based on

and rainy seasons respectively, so that certain pastures

these variable antigens, they are largely confined to

may be tsetse infested for part of the year only. In addi-

research in antigenic variation and have little routine

tion, grazing tends to be safest at midday, when flies are

diagnostic use.

least active, and most dangerous around sunset, when

Tests based on internal common somatic antigens

flies are most active (Pilson & Leggate, 1961).

may have potential diagnostic use as problems of cross-

In the absence of a vaccine cattle can be protected

reactions between species become solved by mono-

prophylactically, although effective prophylactics are

clonal technology (Nantulya et al. , 1987). Of various now limited to one drug, isometamidium chloride.

tests developed, the IFAT and ELISA appear to have

Isometamidium has certain disadvantages. It causes

the greatest potential and the ELISA can be used to

severe reactions at the site of injection, and there is con-

detect circulating trypanosomal antigens as well as anti-

siderable risk of resistance developing to the drug if

bodies (Rae & Luckins, 1984).

cattle are exposed to infection after the active ingredi-

ent in blood has fallen to below a trypanocidal level,

usually three months after injection. Thus where the

Treatment and control (see p. 1029)

risk of infection is constant, injection of the drug must

be repeated at regular intervals to maintain effective

Because of the phenomenon of antigenic variation, no

levels. Despite this, under good management cattle can *vaccine has been developed against trypanosomiasis*

be efficiently reared in tsetse areas under isometamid-

and is unlikely to be in the foreseeable future. In Africa

ium protection, as has been demonstrated on the

this leaves tsetse control as the main method of pre-

Mkwaja Ranch in Tanzania over the last 30 years (Trail

vention. Tsetse control programmes are widespread

et al. , 1985).

throughout Africa but will only be considered in sum-

Treatment against trypanosomosis, in order to be

mary here. Tsetse control is usually under the direction

effective, should be given early in the disease during the

of the veterinary department and requires specialized

initial phase of fluctuating parasitaemia.As no new drugs

expertise. The methods in use are as follows:

have been developed against the disease for nearly 30

• Application of insecticide to tsetse habitat, either

years and some have been withdrawn because of resist-

on the ground by hand or from the air by helicop-

ance, treatment is now essentially limited to two com-

ters or fixed wing aircraft. This is the main method.

pounds, diminazene aceturate and homidium (either

• Use of fly traps. These are used extensively in

chloride or bromide). Resistance has been recorded

francophone West Africa and Zimbabwe.

against both drugs and undoubtedly will be an increasing

• Removal of the tsetse habitat. Tsetse flies have to

problem. As there is little likelihood of pharmaceutical

rest in certain bushes and trees, which can be

companies developing new trypanocides because of

cleared by felling and bulldozing, rendering the

the cost and uncertainty of the market, in many of the

area unsuitable for the fly. This is expensive,

countries concerned the management of the existing

however, and is now largely confined to main-

drugs will require great care in the future.

Trypanosomosis is normally seen as a herd problem

‘trypanotolerant’ breeds was reviewed by Hoste (1987).

and mass chemotherapy is widely used on a herd or

Trypanotolerance has also been identified in Orma

area basis, ideally in conjunction with some form of

Boran cattle of East Africa (Njogu et al. , 1985) and the routine monitoring of blood smears of a percentage of

future prospects of greater utilization of breeds of cattle

cattle to indicate level of infection. Whiteside (1962)

with natural resistance to trypanosomosis are very real.

pointed out that when drugs are used regularly to treat

cattle for trypanosomosis resistance may develop and

when this occurs the drug in use must be changed to

Rickettsial diseases

one against which there is no resistance and that should

cure infections resistant to the first, i.e. a 'sanative'.

Anaplasmosis

Resistance was rarely reported against diminazene,

which consequently was recognized as the best sanative.

This is an infectious and transmissible disease of cattle

The concept of 'sanative pairs' was introduced in

that is seen in most continents of the world. It is non-

which drug usage regimens were devised to alternate

contagious and is transmitted by ticks.

diminazene with another trypanocide to minimize the

development of resistance. Thus the alternative to dim-

inazene was used for treatment of clinical cases for as

Aetiology

long as possible and then changed to diminazene for

The cause of the disease is an intra-erythrocytic

one year to ensure treatment of any resistant infections

parasite, usually Anaplasma marginale. The red blood

in circulation. Thus depending on the level of tsetse

cells contain round inclusion bodies called anaplasma

challenge, the regimen shown in Table 45.3 for treat-

and they are peripheral in location, hence the name

ment using drugs in current use was advocated.

'marginale'. There are three Anaplasma species and of In practice, it is virtually impossible to rear cattle in

the other two, Anaplasma centrale causes a mild condi-areas of very high challenge.

tion in African cattle, as does Anaplasma caudatim.

Because treatment is now limited to diminazene and

Anaplasma marginale, when mature, is 0.3–1.0 mm in

homidium and their use must be managed very care-

diameter and more than one can be present in the same

fully, Whiteside's recommendations are possibly more

erythrocyte. The parasite transfers from cell to cell in *valid today than when first advocated.*

the form of an inclusion body. This is normally oval

Diminazene aceturate is the drug of choice for treat-

in shape and measures 31 mm in diameter and can

ment of T. vivax infections in the New World.

penetrate the red cell envelope.

A member of the genus Paranaplasma, P. caudatum, Use of trypanotolerant breeds of cattle

has been found in a mixed infection with A. marginale

in cattle in the USA state of Oregon. The inclusion

It has long been recognized that dwarf humpless breeds

bodies of A. caudatum can be shown with special stain-of cattle in West Africa have a low susceptibility to try-

ing techniques to have unusual appendages such as

panosomiasis and can survive in tsetse-infested areas

rings, loops or beads in the erythrocytes. However, these

where zebu types or European breeds cannot. Until

are not found when deer erythrocytes are infected.

relatively recently these breeds were regarded as

having poor productivity and were of minor signifi-

cance, however new research indicates this may not be

Epidemiology

the case; their potential is now under extensive investi-

gation and the situation concerning these so-called

The disease is particularly seen in tropical and sub-

tropical parts of the world and it exists in some tem-

perate areas. Africa, North, South and Central America,

Table 45.3

Regimen for treatment of trypanosomosis to mini-

the Far and Middle East, India, Russia and southern

mize development of resistance.

Europe all have the disease present. While mainly a

bovine disease, buffalo, bison, antelope, deer, gnu and

Tsetse challenge

Drug alternatives

wildebeeste can all be infected. All ages of cattle are

susceptible, but calves under six months old show few

Homidium

Diminazene

if any signs. The severity of signs depends on the age

and previous exposure to infection. Generally, the older

Very high

6 months

1 year

the animal at first exposure, the more severe the signs.

High

1 year

1 year

Ticks are the natural hosts of the disease and at least 20

Medium

2 years

1 year

species have been shown to transmit infection. Little is

Low

As long as possible

1 year

known about the developmental life cycle in the tick,

although most infection is transmitted transovarially.

phology alters to include anisocytosis and poikilocyto-

The main genera of ticks concerned are Argas,

sis and leucocytosis is often present.

Boophilus, Dermacentor, Haemaphysalis, Hyalomma, Ixodes and Rhipicephalus. Horseflies (Tabanus spp.) Diagnosis *are experimentally and epizootologically the most*

important insect vector. They directly transmit the

In typical cases the signs presented plus the presence of

disease from an infected to a susceptible animal. Other

anaplasma inclusion bodies in stained peripheral blood

arthropods that can be involved include stable flies

smears are sufficient for diagnosis. Giemsa stain is

(Stomoxys), deer flies (Chrysops), housefly (Musca) and usually used but toluene blue and acridine can also be

mosquitoes (Psorophora). Cattle can be carriers of the helpful. The diagnosis of carrier or chronic cases is more

disease as well as deer. The incubation period is usually

difficult and normally depends on complement fixation,

two to six weeks, but it may be up to 12 weeks.

capillary tube agglutination and agglutination tests.

Signs

Treatment

Peracute: This usually involves cattle over three years The tetracyclines, i.e. tetracycline, chlortetracycline and

old experiencing infection for the first time. It is most

oxytetracycline, are the only approved drugs that are

commonly seen in high-producing purebred dairy cattle *effective in treatment. Administration can be oral or*

and is frequently fatal. There is a pyrexia with rapid

parenteral. Their use in the acute phase slows down the

loss of milk production. Anaemia occurs with very

parasitic life cycle and so reduces the crisis. Latent

pale mucous membranes. The breathing is rapid with

infections can be eliminated by tetracyclines. They act

excessive salivation. Some cattle show nervous signs

more effectively and more quickly when given by injec-

and abnormal behaviour.

tion rather than orally. Experimentally, other com-

pounds of the dithiosemicarbazones have been shown

Acute: This is seen in cattle up to three years old and to be effective. It is also important to provide good

is occasionally found in cattle between one and two.

management for the animals and in valuable animals

Signs often develop unexpectedly. The animal develops

blood transfusions may be necessary.

a progressive pyrexia over a few days, reaching 41°C

(106°F). There is a loss of milk yield with a progressive

Control

anaemia and weakness. In addition there is depression, inappetence, dehydration and laboured breathing.

The main methods of control involve reduction in the

The lymph nodes tend to be enlarged. Some cattle will

vectors of disease, which can be done by ectoparasite

exhibit jaundice, there is frequent micturition of

dipping, but this does not entirely control the problem.

normal-coloured urine and some cows abort. Bulls may

Susceptible cattle can be separated from other carrier

show a temporary loss of fertility. Recovery takes a

cattle and wild animals or carrier cattle can be detected

period of weeks. If death occurs it is within one to four

and eliminated, although the tests used are not

days of the onset of signs.

completely reliable. Otherwise immunization can be undertaken.

Chronic: The signs may follow an acute infection with

It was thought that cattle in indigenous areas do not

gradual emaciation.

normally show signs due to an infection immunity or premunity. However, when there is intercurrent infec-

Mild: This form is mainly present in cattle infected

tion or the animal is stressed in other ways then signs

under one year old. Signs are usually few with a mild

are evident, although it does seem that in premune

pyrexia.

animals there is also a cell-mediated immune response.

Both cell-mediated and humoral responses are required

to provide protective immunity to anaplasmosis. In

Necropsy

addition, continuous antigenic response is dependent

The main signs at post mortem are of an acute anaemia

on a perpetual low-level exposure to infection. Immun-

and there is often jaundice. The spleen is enlarged and

ity using a live, laboratory-attenuated A. marginale

the gallbladder obstructed. The heart is usually pale and

ovine-origin vaccine gives good protection. Inactivated

flabby and petechial haemorrhages may be present on

A. marginale vaccines of bovine and ovine origin

the epicardium and pericardium. The lymph nodes are

require annual boosters. Their protective effect appears

enlarged and oedematous. The blood shows a marked *to be low. Experimentally, a more effective inactivated*

reduction in erythrocytes and haemoglobin. The mor-

vaccine booster has been produced. Recently, a soluble

organism-free cell culture derived from A. marginale

Signs

antigen has been developed.

Affected dairy cattle suffer an abrupt drop in milk pro-

Eradiction is possible where ticks can be removed.

duction, which may last despite treatment for four

Carrier cattle can be detected by a serological test, then

weeks, and beef cattle lose a significant percentage of

the non-infected cattle need to be kept away from

their body weight.

potential domestic or wild animal carriers. Movements

of the cattle need to be controlled and it is necessary to

reduce the level of biting flies. In such circumstances no

Diagnosis

live vaccination programme must be undertaken.

The history is usually similar to that of cattle affected

with B. divergens, i.e. recent purchase or movement to

Tick-borne fever

tick-infested pastures. Diagnosis can be confirmed by

examination of blood smears for the presence of

Tick-borne fever is caused by the rickettsial-like

E. phagocytophila (see Fig. 45.1b).

organism Ehrlichia phagocytophila. It causes a pro-

longed febrile reaction, neutropenia and immunode-

pression in cattle in northern Europe (see Fig. 45.1b).

Treatment and control

Tetracyclines are the antibiotic of choice and long-

Aetiology and epidemiology

acting preparations have proved most successful.

Ehrlichia phagocytophila is transmitted by the tick

Treatment of cattle with pour-on synthetic

Ixodes ricinus during engorgement, but unlike babesio-pyrethroids has been used to prevent tick infestation,

sis, infection takes place almost immediately after

reducing the tick population for two to three weeks. It

ticks start to feed. The circumstances and timing of

has been less successful than when used on sheep, which

infections are dependent on the ecology of the tick and *retain higher concentrations of the pyrethroids on skin*

typically take place most often during spring or autumn

and wool for longer than cattle. The fact that transmis-

tick-activity periods, but can take place at any time

sion of E. phagocytophila occurs early in engorgement, between April and November. Infection in ticks persists

in contrast to B. divergens, has resulted in the observa-transtadially, but not to the following generation of

tion that protection of cattle against tick-borne fever

larvae.

using pyrethroids is less successful than against babesio-

After infection the organism enters or is phagocy-

sis, as accumulation of chemicals is more likely to kill

tosed by white blood cells, usually neutrophils, but

the tick before transmission.

infected eosinophils and monocytes are occasionally

observed. The 'elementary body' can be seen in blood

Bovine petechial fever

smears stained with Giemsa or Leishman stains as a

(Ondiri disease, ondiritis)

pale blue dot in the cytoplasm of neutrophils. It

enlarges to become a morula, after which the neutrophil

This condition is a rickettsial infection of ruminants, but

ruptures and the elementary bodies of which the

is restricted in area of occurrence.

morula is composed infect further cells (Fig. 45.1b). The

disease becomes apparent five to nine days after trans-

Aetiology

mission by infected ticks. The animal develops a high

fever, which can persist for up to 10 days. During this

The cause is a rickettsia-like organism, Cytoecetes

period the continuous destruction of neutrophils leads

(Ehrlichia) ondiri. The infection initiates in the spleen, to a severe neutropenia and for as yet unknown reasons

and there it parasitizes the circulating granulocytes and,

to a reduction of packed cell volume (PCV) of 30 per

more rarely, monocytes. The organisms are pleomor-

cent. As a result of the neutropenia the animal becomes

phic and occur in cytoplasmic vacuoles, particularly in

immunodepressed and susceptible to other infections

neutrophils. The organisms possess a rippled cell wall

such as pneumonia, infectious pododermatitis and

and they can be small (0.2–0.4 mm) or large (1–2 mm) *babesiosis due to B. divergens, which is frequently*

bodies. In some cases there are mixed groups of large

observed in susceptible cattle eight to twelve days

and small bodies.

after tick-borne fever. The 'parasitaemia' subsides but

recrudescences occur periodically thereafter. Immunity

Epidemiology

develops slowly and persists only for a few months as

cattle may be affected, albeit less severely, for some

The disease appears to be confined to the highlands of

years following their infection.

East Africa. It mainly involves cattle exotic to the

region. Very well defined areas are often involved. The

which may be large and distributed throughout the

indigenous cattle and wild ruminants such as the bush-

body. There is oedema and lymphoid hyperplasia.

buck (Tragelaphus) and duiker (Silvicapra spp.) do not Often there is subcutaneous and intramuscular haem-show clinical infection. The vegetation common to all

orrhage and melaena. The heart shows large haemor-

sites is the edge of forest or thick bush. Experimentally,

rhages into the epicardium and endocardium. There are
infection can occur in cattle, sheep, goats, impala, bush-
also haemorrhages and oedema in the respiratory tract
buck, Thomson’s gazelle and wildebeeste. Most of these
and the mucosa and serosa of the alimentary tract. The
develop latent infections. Thus carrier animals are pro-
lymph nodes show hyperplasia and oedema. Both the
duced from which it would seem highly likely infection
liver and spleen may be enlarged and show petechiae.
could be spread by an arthropod vector. However,
Histologically, there is marked evidence of petechia-
as yet, despite intensive investigations, the arthropod
tion. Characteristically, hyperplasia of large areas of the
involved (probably a tick) has not been detected. The
lymphoid sinus are seen. The rickettsiae can be found
incubation period is variable, from four to 14 days, and
in impression smears of that surface of the spleen and
in natural outbreaks disease has occurred 10 days after
liver. There is a characteristic absence of eosinophils,
entering into an infected area. Mortality is around 20
followed by markedly reduced numbers of lymphocytes

per cent and occurs within a few days of onset of signs,

and then neutrophils.

but some animals will die two or three weeks after

disease develops.

Diagnosis

Diagnosis is often difficult as the condition resembles

Signs

anthrax (p. 717), bracken poisoning (p. 946), arsenic

Peracute: These signs are seen in recently imported

poisoning (p. 941), haemorrhagic septicaemia (p. 728),

exotic cattle. They develop marked pyrexia and a

heartwater, acute trypanosomosis (p. 756) and acute

drop in milk yield. The signs usually coincide with a

theileriosis (p. 750). It is usually based on the history

parasitaemia. After two or three days petechial hae-

plus the area where it has occurred. Ehrlichia ondiri can morrhages occur on mucous membranes, and in some

be detected in blood or spleen smears stained with

cases that are fatal there is general congestion, with pul-

Giemsa, where it is particularly seen in granulocytes

monary oedema, dullness, weakness and a staring coat.

and monocytes. Often by the time clinical signs develop

Most of the cattle collapse and die within four days.

the parasitaemia is low or absent. In such cases it may

be necessary to collect blood in EDTA or a suspension

Acute: These types tend to occur over a longer period.

of spleen or lung and inject this intravenously into

The temperature is high but fluctuates. There is

susceptible cattle or sheep. The granulocytes and

inappetence with reduced milk yield and abortion.

monocytes in blood smears from the recipient, stained

Although petechial haemorrhages occur in some

with Giemsa, should be examined daily for 10 days after

animals on the day after the onset of fever, in most

inoculation.

animals they have appeared by three days. The haem-

orrhages disappear to be replaced by fresh ones within

Treatment

seven to ten days. They occur on the vulva, vagina, con-

junctiva, labial surface of the gums and ventral surface

The most effective time to treat is during the incuba-

of the tongue. Any normal discharge and faeces may be *tion period when tetracyclines prevent disease. Once*

bloodstained. In some cases a characteristic ‘poached

overt signs are present, double the usual therapeutic

egg eye’ occurs with a swollen tense eyeball with the

dosage of these antibiotics will reduce clinical signs

aqueous humour containing blood, the conjunctiva

and limit the parasitaemia. A single intravenous dose

swollen and haemorrhagic and the eyelid everted.

of alphaethoxyethylglycoxal dithiosemicarbazone at

5 mg/kg body weight will also reduce signs and the

Subacute: Affected animals show a transient, non-fatal parasitaemia more effectively than tetracyclines.

condition with pyrexia and petechiation of the mucous

membranes.

Prevention and control

Inapparent: No signs are present.

Eradication is impossible because wild animals act as

a reservoir of infection. Clinically infected cattle are

resistant to reinfection for several years, but they prob-

Necropsy

ably carry latent infections of E. ondiri. Losses due to The main findings are usually of an animal in good con-the disease can be reduced by restricting *access to areas*

dition with submucosal and subserosal haemorrhages,

of known infection. Clearing the undergrowth and

scrub aids this. If susceptible animals are to enter

dry season due to reduced tick activity. The incubation

infected areas they should be watched daily and when

period is variable, from 7 to 28 days, with fever starting

infection is present a single dose of dithiosemicar-

on average after 18 days. Mortality can be up to 60 per

bazone may then allow them to recover and become

cent in exotic breeds, but less than 5 per cent in local

immune to infection.

cattle.

Heartwater (cowdriosis or malignant

Signs

rickettsia, blacklung)

Peracute: This occurs in exotic breeds introduced to the This is another rickettsial condition that infects both

region. The animal appears clinically normal, but if

domestic and wild animals.

examined will have a marked pyrexia. It may then

suddenly collapse, go into convulsions and die. Thoracic

auscultation will often reveal oedema in the lungs and

Aetiology

bronchi.

The infection is caused by the rickettsia Cowdria rumi-

nantium and is transmitted by at least five species of Acute: The course of infection is three to six days and Amblyomma ticks. It is first found in reticuloendothe-consists of pyrexia (often over 41°C, 106°F), with

lial cells and then parasitizes vascular endothelial cells.

nervous signs that may include ataxia, circling and

It is seen as close packed colonies consisting of less than

abnormal posture. In other cases signs develop only to

ten to many hundred cocci. The agent is pleomorphic

stimuli and there is then an excessive blink reflex, fre-

but the rickettsia in any one group tend to be of similar

quent tongue protrusion, a haggard, pained expression

size. The organism varies between groups from 0.2 mm

and muscular tremors. Pregnant cows may abort. If the

to greater than 1.5 mm. Division is by binary fission

condition progresses there are convulsions, paddling

and it produces morula-like colonies in the cytoplasm.

movements of the limbs, nystagmus, opisthotonus and

The small granules tend to be coccoid, with larger ones

chewing movements. Often a fetid, profuse diarrhoea is

looking like rings, horseshoes, rods and irregular

present or there may be blood in the faeces. A mild

masses. It has been suggested that differences in the size

cough may be heard. On auscultation hydrothorax,

and shape of the organisms are the result of a growth

hydropericardium and lung oedema are noted.

cycle.

Subacute: The signs are like those of the acute form but they are much less severe with a transient fever and

Epidemiology

sometimes diarrhoea. Disease may last for over a week

The disease has been reported in many African coun-

and the animal usually improves gradually. A few cases

tries south of the Sahara desert. Distribution coincides

progress to collapse and death. ‘This is often the most

with that of the Amblyomma ticks, which require a

severe form seen in indigenous cattle and those previ-

warm humid climate and bushy grass. Experimentally, *ously infected.*

five species of Amblyomma are able to transmit infec-

tion. These are three-host ticks. Transmission usually

Inapparent: These cattle include almost all the

appears to be transtadial and so infected larvae are

indigenous stock as well as some of those introduced to

usually free from disease. Transovarian transmission

the region. In addition they often follow cases of

can occur, but is thought to be very infrequent. Infected

reinfection.

larvae are found on non-susceptible animals, but if they

do become infected it can pass on to both nymph and

Pathology

adult stages. Infected ticks do not transmit infection

immediately; they become attached to the animals, but

The lesions present are very variable and not pathog-

a variable time after they start to feed. In many cases

nomonic. In the peracute form there are few gross

the level of infection is unknown as indigenous domes-

lesions, but in some there is marked lung oedema with

tic and wild animals often show no signs. It is only when *tracheal and bronchial froth. In the acute form there susceptible exotic species are introduced that infection is usually ascites, hydrothorax, hydropericardium and becomes apparent. Besides cattle, sheep, goats, Asian lung oedema. The lymph nodes are often swollen. buffalo, antelopes and deer are susceptible to infection Petechial haemorrhages can occur in the heart, lungs and disease. Indigenous cattle undergo inapparent and gastrointestinal tract. The liver is often engorged, infection. Calves under three weeks old, even from with the gallbladder distended. The spleen is occasion- susceptible stock, are difficult to infect. Heartwater can ally enlarged. There may be congestion of the occur throughout the year, but incidence declines in the meningeal blood vessels.*

Diagnosis

homogenized engorged Amblyomma ticks. The recipi- ent animal is monitored and then treated with tetracy- There is no completely specific method of diagnosis in clines as soon as pyrexia develops. Treatment continues *the living animal. Provisional indication can be from the*

twice a day until the fever subsides. Pregnant cows

history and clinical signs. Lymph node material can be

should not be treated in this way.

aspirated to examine for vacuoles containing organisms

in the cytoplasm of the reticular cells. There is a method

of taking brain cortex so that the capillaries of the brain

Jembrana disease (Tabana disease)

can be examined for rickettsia. Blood can be obtained

Aetiology

and injected into susceptible animals. Eosinophils also

decrease in number during the course of the disease.

The cause of the condition is not known, but it is

Serum can be examined using a capillary flocculation

thought to be a rickettsial infection. Groups of small

test. Diagnosis is easier at post mortem as the organism

coccobacillary organisms have been found in cytoplas-

can be discerned in brain tissue capillaries that have

mic vacuoles present in circulating monocytes and in

been fixed in methyl alcohol and stained with Giemsa.

impression smears of cut organ surfaces. Some consider

Differential diagnosis includes anthrax (p. 717) and

the disease may have a viral aetiology.

acute theileriosis (p. 750) in peracute cases, and in

nervous cases rabies (p. 908), tetanus (p. 733), strych-

nine poisoning, cerebral theileriosis (p. 752), cerebral

Epidemiology

babesiosis (p. 749) and hypomagnesaemia (p. 787).

The disease was first recognized in the Jembrana Dis-

trict of Bali Island, Indonesia, in 1964. Subsequently, the

condition has only been detected in Indonesia. The

Treatment

disease is found in cattle as well as buffalo. Sheep and

Therapy is most effective when carried out early in

goats are infected with no apparent signs, but pigs are

disease. Tetracyclines can be used and do not interfere

refractory to infection. In cattle there is apparent age

with development of immunity.

resistance to infection and cattle over two years old

rarely die from the disease. Animals that recover are

carriers, but the duration of infection is not known.

Control

There is no direct infection from animal to animal and

Disease can be prevented by controlling the vector

so it is not contagious. Boophilus microplus, a pantropi-Amblyomma by dipping cattle at weekly intervals with

cal cattle tick, appears to be the natural vector and it

reliable acaricides. However, the ticks of this genus are

is believed that infection can pass through the egg

less susceptible than those from other genera. As the

phase. The incubation period appears to be about a

tick may transmit infection after a day on the host,

month to six weeks, although it is considerably shorter

better control is obtained by applying acaricide by

after injection of infection. Mortality is about 25 per

dipping or spraying every three days. However, Ambly-

cent and is usually within a week of onset of signs. Some

omma have in some cases shown resistance to

animals relapse with infection at later dates.

organophosphorus and arsenic. Care should also be

taken not to introduce Amblyomma on infected

Signs

animals or in forage to uninfected cows.

In areas where disease is endemic most cattle are

Invariably there is a pyrexia of about 41°C (106°F) with

immune. A carrier state develops after infection and

anorexia, nasal and lacrimal discharge, which can persist

remains for several weeks. Non-infected resistance

for one to nine days. This is soon followed by enlarged

persists a variable time, lasting from a few months to

lymph nodes. Often there is excessive salivation and

several years. After this time reinfection can occur.

erosion of the oral mucosa. Petechial haemorrhages

Ideally, an effective vaccine should be used. However,

may be found on the visible mucous membranes and

at present C. ruminantium is difficult to culture serially haemorrhage is seen within the aqueous humour of the

or to adapt to growth in laboratory animals. One

eye. Blood tends to ooze from the skin (so-called 'blood

method is to inject susceptible stock intravenously with

sweating'). Diarrhoea occurs early on and persists; it is

5–10 ml of blood from an infected animal. As infected

often bloodstained.

animals cannot always be available then infected blood *can be stored in a freezer or liquid nitrogen provided it*

Pathology

is frozen rapidly after addition of dimethyl sulphonate.

The infection can also be retained in deep frozen

There are widespread haemorrhages and oedema.

brain emulsion or, more recently, in a supernatant of

Usually, generalized lymphadenopathy occurs, with the

lymph nodes being hyperplastic and often showing dis-

or South America. The disease is transmitted by vectors

organization. Splenomegaly is common and the blood

from infected host cattle, which explains the seasonal-

vessels show vasculitis and perivasculitis. Surrounding

ity of the condition. If disease enters a new region it can

the blood vessels there is proliferation of lymphore-

cause epizootic infection with a morbidity of about 100

ticular cells in many organs except the liver. Rickettsia-

per cent, but mortality is usually less than 1 per cent. In

like organisms can be detected in impression smears.

the enzootic areas the condition is sporadic, with a mor-

bidity of 5–10 per cent.

The cause of transmission is thought to be midges,

Diagnosis

probably of the Culicoides spp. and Ceratopogonidae This is based on the area and history. Confirmation

family. Transmission is not direct between animals, indi-

depends on the haematological changes, which include

cating the need for maturation in the vector. Spread

a progressive anaemia, thrombocytopenia and transient

mainly depends on the number of insects infected and

leucopenia, which particularly involves the lympho-

the direction of winds. Viral development in the insect

cytes. As the disease progresses 'foamy' monocytes

is suspected to be cyclic. More losses occur in adult

appear and large lymphocytes with coarse nuclei are

cattle, although calves from three months old are sus-

seen. However, confirmation is difficult unless the

ceptible. Often the disease seems to disappear only to

animal dies. It is then dependent on detection of

return again as an epizootic once resistance in the cattle

organisms in impression smears of cut organs and the

population is reduced.

vascular changes. In some cases blood is taken into

EDTA from suspect cases and then injected into sus-

Signs

ceptible cattle.

The incubation period is two to ten days and is followed

Differential diagnosis includes rinderpest (p. 707),

by a marked pyrexia of 40.5–41°C (105–106°F). This is

haemorrhagic septicaemia (p. 728) and plant poisonings

often very transient and so is missed. Other animals

(Chapter 54).

have intermittent pyrexia. There is a drop in milk yield,

which is the main loss caused by the disease, with

Treatment

anaemia, oculo-nasal discharge and increased saliva-

tion. Alimentary signs are variable and can include con-

Tetracycline injections during the course of the disease

stipation or diarrhoea. Within four days locomotory

appear to have little effect on disease severity or dura-

signs appear, including muscular tremors, which then

tion, but they do seem to reduce mortality.

develop into stiffness and weakness. The animal often *becomes lame and the hindlimbs may become stiff.*

Control

Signs may resemble those of acute laminitis. Occasion-

ally, animals show lateral recumbency.

Not enough is known about the disease to initiate

The animal usually starts to show signs of recovery

control measures. Recovered animals are often carriers

after two or three days, with appetite and milk yield

of infection and so resist further challenge.

improving. However, the stiffness and lameness are

likely to take several more days to reduce. Recovery is

uneventful. Mortality is low and is usually the result of

Viral diseases

secondary infection, or following aspiration pneumonia

after regurgitation of ruminal contents or following

Bovine ephemeral fever (BEF)

lateral recumbency. Abortion does not occur, but semen

This is also known as bovine epizootic fever and three-

quality in bulls is often affected for a period.

day sickness. Although signs occur they are quite mild

and seem only to affect cattle. It is caused by a rhab-

Necropsy

dovirus, which can be present in the blood where it

The lesions are not specific. The main sign is enlarge-

appears to be mainly in the leucocyte-platelet fraction

ment and oedema of all the lymph nodes. Congestion

and is transmitted by insect vectors. At present there is

and petechial haemorrhages of the pleural membranes

only a single serological type of the virus, although in

may occur. Other signs are usually the result of com-

Australia several rhabdoviruses with a distinct rela-

plications such as aspiration pneumonia.

tionship to BEF have been isolated.

The condition is present in most of Africa except pos-

Diagnosis

sibly the north. However, the incidence varies widely

between regions and countries. It is also present in Asia,

This depends mainly on the signs of a mild disease with

Australia and New Guinea. It does not occur in North

pyrexia and lameness, limb stiffness and muscle

tremors. There is a leucocytosis with a neutrophilia. A *also be by feeding at troughs or sucking milk from*

fluorescent antibody test will detect virus in blood. An

infected cows. Indigenous cattle are less susceptible

agar gel immunodiffusion test has been successfully

than imported purebreds. Experimentally, giraffe and

used on serum. The virus can be isolated by serial

impala have been infected. All ages of stock are sus-

passage in Vero or BHK cell cultures or by intracere-

ceptible but calves and lactating cows are most likely to

bral injection of sucking mice.

be infected. The duration of immunity is not known and

appears variable. Reports suggest it to be from 11

months to five years, or even lifelong.

Treatment

Morbidity rates are very variable, from 5 to 80 per

Treatment is symptomatic but can include antibiotics

cent, with less than 2 per cent mortality. There can be a

for secondary complications, with the use of non-

rapid spread of the disease.

steroidal anti-inflammatory agents such as phenylbuta-

zone or flunixin meglumine for muscle stiffness. It is

Signs

best not to drench animals because of the high risk of

aspiration pneumonia. Recumbent animals should be

The incubation period lasts from two to five weeks in

provided with adequate shade and water.

natural infection but four to fourteen days with exper-

imental infection and is followed by a rise in tempera-

ture, which may fluctuate. In severe cases there tends to

Control

be anorexia, lacrimation and salivation. There is a clear

Control of the insect vectors has not been successful.

nasal discharge, which later becomes purulent. There is

Immunity is long lasting after natural infection and has

then the sudden appearance of nodules, varying in

led to the development of vaccines, which are available

number from a few to many hundred. The nodules are

in Japan and South Africa. Experimentally, live cell

firm, raised areas within the skin and vary in diameter

culture vaccines in an adjuvant base have been used

from a few millimetres to 4–5 cm. These larger areas

with success, but give rise to fears of vector transmis-

often have erect hair over them that exaggerates their

sion between vaccinated and non-vaccinated stock.

appearance. The nodules are usually of a uniform size

Control can also be achieved by dipping cows twice

on individual animals and they occur over the whole

weekly during the peak period of infection when con-

body, although they are mainly found on the back, neck,

ditions are wet, hot and humid.

brisket, legs, thighs, scrotum, udder and round the muz-

zle and eyes. Those on the mucosae of the muzzle, vulva,

prepuce, nostrils, eyes and mouth are yellow-grey in

Lumpy skin disease (LSD) *(see also p. 887)*

colour and soft, and if rubbed off there is an ulcer or

The disease, also called Knopvelsiekte, results in many

erosion. When the eye is affected there is keratitis and

pox-like skin lesions and has been associated with a

conjunctivitis. Respiratory lesions lead to dyspnoea and

virus that is serologically related to sheep pox and on

oral ones to salivation.

tissue culture produces three different groups of virus.

The associated lymph nodes tend to be enlarged. In

One, an orphan virus (group I), is generally present on
some cases oedema develops. This can be of the lower
the skin of normal cattle but does not appear to cause
limbs, brisket, udder, vulva or scrotum. The enlarged
the disease. The ‘Allerton’ virus (group II) causes a
skin nodules can later ulcerate. These can then persist
condition of a mild nature and is isolated from skin
for several years or develop a dry surface that is lost.
nodules, saliva, nasal secretions and semen. This form
This becomes a deep pit, which heals by second inten-
appears to be identical with the bovine herpes virus 2
tion. These wounds can become secondarily infected.
of bovine mammillitis. It has often given rise to the
This secondary infection can then spread to associated
name of pseudo-lumpy skin disease (p. 888). The severe
lymph nodes, the lungs, liver, kidney, etc. The areas
disease is caused by a ‘Neethling’ virus (group III) and
of superficial oedema also remain a long time and
is found in blood, mucus, saliva and semen.
can then slough, causing suppurative areas. Involve-
The disease is seen in most parts of Africa and is

ment of the lung can lead to cicatrization and rupture

endemic in southern Africa. The virus is present on the

of the tracheal rings several months after onset of the

skin even when hides are salted, in blood and in saliva

disease.

and all can transmit infection.

The disease results in a chronic loss of condition and

The method of transmission has not been completely

milk yield. Secondary infection can lead to mastitis,

established, but it is believed to be by insects, particu-

abortion and sterility in bulls.

larly mosquitoes, as spread can occur without direct or

The 'Allerton' mild or pseudo-lumpy skin form of the

indirect contact. Virus has been isolated from Stomoxys

disease is less severe and only lasts a few weeks. There

and Biomyia flies. As the saliva is infected, spread can is a mild pyrexia followed by nodule formation mainly

on the head, neck and perineum. The nodules are char-

Rift Valley fever

acteristic with a hard, raised, rounded mass with a flat

This condition, also known as enzootic hepatitis, is a

surface and a pit at the centre. Sometimes the skin

zoonosis but mainly affects sheep and cattle. Camels

lesions coalesce. Only the epidermis is affected, unlike

can be infected and also goats to a limited extent. It is

the 'Neethling' form. The problem area develops into a

notifiable in many countries. It is caused by an insect-

hard, dry, necrotic lesion after a week to nine days. This

borne RNA virus of one main antigenic strain of

is then lost over the next 10–14 days leaving a hairless

the family Bunyaviridae, and genus phlebovirus. The

area. Hair will grow again.

condition is transmitted between animals by insect

vectors, usually mosquitoes. The disease was first iden-

Necropsy

tified in the East African Rift Valley, which gave rise to

its name.

'Neethling' lesions include the whole depth of the skin,

The condition is only found in Africa, particularly the

producing a hard white-grey mass. The skeletal muscle

central and southern regions, but the mosquitoes that *may contain grey nodules. Oedema of this is seen as*

are responsible for transmission occur on other conti-

yellow jelly-like liquid. If the oral mucosa is affected it

nents. Thus there is a possibility of spread. Disease is

contains soft grey-yellow nodules with necrotic epithe-

transmitted by various types of mosquito including

lium. Necrotic ulcers with surrounding inflammation

Aedes spp. Other biting arthropods would also cause

can occur in the nasal cavities. In the lungs there are

spread.

firm grey nodules and the whole tract may show ero-

Man can be infected by contact with infected animals,

sions and ulcers. Pulmonary lesions may lead to oedema

such as when undertaking necropsies. Infection may

and a purulent pneumonia. When lymphadenitis is

enter skin abrasions. The signs are of an influenza-like

present the nodules are swollen, pale and oedematous.

disease with pyrexia, severe headache, nausea, joint

The rumen and abomasal wall can show ulcers and ero-

pains, flushing of the face, sometimes epistaxis and per-

sions. Microscopically, the stratum papillomis, stratum *manently impaired vision due to retinal haemorrhage.*

reticulis and subcutis are involved. Secondarily, the

Death is rare, but in some instances complications such

surface epithelium, hair follicles and their associated

as sight impairment can occur.

glands are infected. In the subcutaneous tissues there is

Usually, an epizootic outbreak occurs in cattle fol-

oedema, fibroplasia and perivascular inflammation with

lowed by long periods, often of five years, between out-

mononuclear cells, which usually results in thrombosis

breaks. The persistence of infection between epizootics

and overlying necrosis.

is unknown, but as cattle at the edge of and within

forests tend to seroconvert consistently it is considered

Diagnosis

disease is maintained in wild fauna.

Disease is more common in warm wet seasons. Young

The rapid spread of the disease and the sudden appear-

animals are more severely afflicted than the adults.

ance of skin nodules after pyrexia are relatively char-

Mortality tends to be high in young calves, often reach-

acteristic signs. However, a biopsy can be taken and

ing 70 per cent. In the adult, a mortality of 10 per cent

inclusion bodies can be found in skin lesions and the

can occur but the main problem is abortion.

virus can be cultured. Other diseases that may be con-

fused are the 'Allerton' form, urticaria (p. 883), der-

matophilosis (p. 886), demodicosis (pp. 743, 881),

Signs

onchocercosis (p. 774), besnoitiosis (p. 756) and severe

tick and insect bites.

The signs that develop depend partly on the age of the

animals. They tend to be most severe in the calf, where

the incubation period varies from 12 hours to three

Treatment

days. Occasionally, death occurs within 24 hours with

There is no specific treatment but secondary infection

few characteristic signs other than collapse and colic.

may require the use of antibiotics or sulphonamides.

Others show high fever, incoordination and collapse.

The rare renal form is acute and can occasionally occur

in adult cattle. In this type there is pyrexia, a profuse

Control

mucopurulent discharge, vomiting and prostration. Up

Quarantine has generally not proved to be successful.

to 70 per cent of affected cattle can die.

In some countries a sheep pox virus tissue culture

In adult cattle abortion is more common than the

vaccine has been found to be of use. Otherwise, a

acute form. However, up to 10 per cent can develop

vaccine produced from attenuated 'Neethling' virus on

marked pyrexia and die. Other lesions can include

kidney tissue culture has been used successfully.

erosion of the oral mucosa and dry thickening of the

unpigmented areas of the teats, udder and scrotum.

and fever (Chapter 51). The causes are included within

Hyperaemia of the coronets also occurs.

a complex of flaviviruses. The infections tend to be con-

tained in various geographical areas. As a result there

are a number of diseases that are identified by the area

Pathology

where the disease occurs. Thus, in Europe there is

The main lesion is one of hepatic necrosis with white or Russian spring-summer encephalitis, Omsk haemor- grey foci in the subcapsular area. Other lesions are rhagic fever and Central European encephalitis. Tropi- typical of septicaemia with subserous haemorrhages of cal problems include Kyasamar Forest fever in India the pleura, pericardium, endocardium, lymph nodes and and Lanyot in Malaysia.

gut. There is often also oedema, congestion or haemor-

In almost all cases the viruses maintain their presence rhages of the gallbladder. Microscopically, there is focal in ticks, small rodents and insectivores. In the endemic or diffuse necrosis of the liver.

cases infection of wild and domestic ruminants is inap- parent. However, the introduction of new ruminants can result in disease. As yet the infections of Kyasamar

Diagnosis

Forest fever, which have been found in man and horses, The history of an outbreak is helpful in that it is in a have not resulted in disease in native domestic cattle. mosquito area, there is an abortion storm plus calves

Infection in cattle would be via ixodial ticks. Man can

becoming ill with many of them dying. Post-mortem

be infected by ticks or, more commonly, via drinking

examination of calves may show typical hepatic necro-

infected goat's or sheep's milk. Infections from ma-

sis. There may also be evidence of human infection and

terial submitted for laboratory diagnosis also occur.

if sheep are present then again in lambs there is disease

Immunity following infection is good and lifelong.

of high fever, incoordination, collapse and high mortal-

Colostrum results in passive immunity being conferred

ity, with abortion in ewes. There is usually a severe

to the young calf.

leucopenia. Serological confirmation is by means of a

serum neutralization or complement fixation test.

Signs

Disease is almost always only apparent in animals intro-

Treatment

duced to the tick area. The incubation period is one

There is no known successful treatment, although inter-

or two weeks. Pyrexia suddenly occurs and is usually *feron is effective in vitro and may eventually become diphasic. It is not until the second period of tempera-available.*

ture rise that nervous signs appear. There is then inco-

ordination, muscle tremors, ataxia, photophobia and

hypersensitivity. The nervous signs become progres-

Control

sively worse. There can then be a flaccid paralysis, with

The passage from country to country is difficult to

death within a week. Those animals that recover are

control without the exclusion of susceptible animal

often subsequently debilitated.

species. Control of the insect vectors would be uneco-

nomic and impracticable. It is possible that humans

Necropsy

could act as carriers. A vaccine from neurotrophic virus

passage through mouse brain has been used success-

There are few gross lesions. On histological examina-

fully. However, it can cause abortion. In consequence,

tion there is necrosis of the neurones, particularly in the

a killed vaccine produced on BHK cells has been devel-

Purkinje layer of the motor nuclei, vestibular nuclei, *oped (p. 1018). This involves two injections to produce*

cerebellum and ventral nerves of the spinal cord.

adequate immunity. Good immunity has been produced

Perivascular inflammation occurs throughout the white

in sheep and humans by virus grown in rhesus kidney

matter.

cell cultures and then inactivated by formaldehyde. A

human vaccine is now available from virus raised in

Diagnosis

diploid fetal lung cells and inactivated with formalin.

The diagnosis is based on the area, presence of ticks,

signs and lesions. The virus can be isolated from the

Tick-borne encephalitides

central nervous system, particularly the brain stem and

(flavivirus infections)

spinal cord. Differential diagnoses include bovine

There are a series of diseases of animals resulting from

spongiform encephalopathy (p. 909), rabies (p. 908;

tick-borne infection and characterized by nervous signs

Chaptre 70),

neuromycotoxins,

plant poisoning

(Chapter 54), tetanus, hypocalcaemia (p. 781) and

Diagnosis

hypomagnesaemia (p. 787).

The signs and post-mortem picture are not specific.

However, cerebral injection of infected brain tissue into

Treatment

rabbits will aid virus identification. The major disease

to be differentiated is rabies (p. 908).

There is no effective form of treatment.

Control

Treatment

There is no effective form of treatment, only sympto-

Cattle should not be introduced to endemic areas

matic.

unless they are vaccinated. The vaccines available

provide protection for at least a year. Control of ticks

by improving grazing and reducing bracken, etc., is

Control

useful.

There are no suitable control measures that can at present be suggested.

Tick-borne encephalitides

(Near East encephalitis)

Japanese encephalitis (flavivirus)

This condition is still not fully elucidated. However, there are several diseases that have been recognized for This is mainly a disease of man and has been given many years. The disease is endemic in some countries several local names, including Japanese B encephalitis, including Syria, Lebanon, Israel and Egypt and a similar Russian autumnal encephalitis and summer encephali- condition is recorded in India and Russia. tis. Infection of animals is often from the human source. In most cases the accidental infection of ruminants Most disease is seen as encephalitis in horses, followed results in few cases of disease. Usually, the virus cycles by pigs. Mosquitoes are the natural vectors. Usually, inapparently within birds and ticks. Most clinical disease infection in cattle and other ruminants is inapparent is in Equidae, but occasionally problems have been *and of little overall significance.*

recorded in sheep and cattle. The tick vector of Near

East encephalitis is Hyalomma anatolicum. Infection

Other arthropod-borne diseases

passes through all stages of tick life including the egg.

All infection is tick mediated and it cannot be trans-

There are well over 300 diseases that are arthropod

mitted directly between animals. Immunity follows

transmitted. Many are of limited geographical distribu-

infection in cattle but its duration is unknown.

tion. Frequently areas do not produce overt disease.

However, where signs do occur, they can be non-

specific with malaise and pyrexia. Often indigenous

Signs

animals and wild animals develop inapparent disease

The incubation period for the disease is unknown, but

that does not cause them any hazards or reduce pro-

may be four weeks. The severity of signs is variable and

duction. However, the introduction of new animals will

in the acute form there is a drowsiness and a pyrexia of

frequently result in overt disease, which can reach a *about 40°C (104°F). However, in a few horses there are*

high morbidity level.

epileptiform fits with a progressive paralysis. Collapse

and death can soon occur. In the subacute form pyrexia

Akabane virus (Asian virus)

is usually transient and mild. Nervous signs are slight,

but in some cases they can persist. Inapparent infec-

This bunyavirus is mosquito borne and related to Simbu

tions are common.

virus. It is recorded in the Far East as well as Kenya and

Australia. The condition in cattle is thought to produce

arthrogryposis and hydrocephalus as well as abortion.

Necropsy

The alimentary and urogenital tract of the body show

Bhanja virus (African virus)

mucosal congestion, but there is meningeal blood vessel

congestion. On histological examination there is dif-

This is mainly an infection of goats but it has occasion-

fuse lymphocytic infiltration, perivascular infiltration,

ally been isolated in cattle, particularly in southern

microglial proliferation and neuronophagia and occa-

Nigeria, and has also been reported in India. Infection

sional rarefaction of tissues.

has been found in Haemaphysalis ticks. Experimentally,

calves injected with Bhanja virus have developed a

infected experimentally and show a short-lasting

viraemia for several days and leucopenia.

viraemia.

Bunyamwera virus (African virus)

Germiston virus (African virus)

This is mainly a condition of goats, but serological evi-

This is a bunyavirus and is transmitted by mosquitoes.

dence has been found in cattle and sheep. The infection

The virus causes infection in humans, usually in labora-

occurs throughout Africa and is considered to be mos-

tories, but in cattle there are usually no signs but sero-

quito borne.

conversion. The condition is present in cattle, egrets and

herons.

Cache Valley virus (American virus)

This is found in mosquitoes in Central and North

Harana virus (Asian virus)

America. Disease has not been recorded but sera of

The virus is transmitted by Hyalomma ticks and spread cattle are often positive.

to other animals by migrating birds. This virus resem-

bles, and may be identical to, Azo virus. It results in a

California encephalitis virus (American virus)

severe infection of humans, often with haemorrhages

and fever. It can be fatal. In cattle the disease is

In America there is a high incidence of antibody in the

transient and usually results in anorexia, pyrexia and

sera of cattle. Evidence of infection can also be found

depression.

in deer and horses. It is a bunyavirus transmitted by

mosquitoes. The virus is the most common cause of

human viral encephalitis in the USA.

Ibaraki virus (Asian virus)

It is thought to be arthropod borne and is a double-

Calovovirus (European virus)

stranded RNA virus. Antibody surveys show the infec-

tion to be widespread in South East Asia and the Far

This is a bunyavirus that is mosquito borne. It results in

East. The condition is very similar to that of bluetongue.

cattle infection.

Disease is severe and only recorded in Japan. Signs

include pyrexia with oedema and haemorrhaging in

Congo virus (African virus)

the mouth, abomasum and around the horn/skin

junction. Degeneration of the muscles follows. There is

This is a disease of humans and also affects goats and

then dehydration and emaciation due to difficulty in

cattle resulting in anaemia, depression and pyrexia. The

swallowing. Death is commonly due to inhalation

virus is transmitted by Hyalomma ticks and infection

pneumonia.

between countries is probably accomplished by migrat-

ing birds. It is likely that the condition is related to

Hazna virus and others in Europe and Asia. The disease

Jos virus (African virus)

is severe in horses and is often fatal. However, in cattle

and goats indigenous to Africa it results in a short

This unclassified virus is transmitted by Amblyomma

period of illness that may be seen as anorexia, fever and *variegatum ticks. The disease signs are not really known depression.*

but the virus has been isolated from indigenous

Nigerian cattle.

Corriparta virus (Australian virus)

Kodam virus (African virus)

The virus is mosquito borne, particularly by Culex spp.

The disease level is unknown but antibodies are found

This flavivirus is found in Rhipicephalus parvus ticks.

in the sera of cattle, horses and man as well as kanga-

The signs of disease are unknown but antibody is found

roos and wallabies.

in cattle.

Dughe virus (African virus)

Kokobera (Australian virus)

The virus appears to be spread by Amblyomma varie-

The virus has been found in mosquitoes in Queensland.

gatum ticks, Culicoides and mosquitoes. It is the most It is a flavivirus. Antibodies have been detected in sera

frequently isolated arthropod-borne virus in Nigeria. In

from cattle and horses, although there is no indication

most cases there are no signs in cattle, but calves can be *that the virus is a pathogen.*

Kowanyama virus, Mapputta virus, Trubanaman

spread by mosquitoes. The virus appears to be related

virus (Australian viruses)

to Rwamba virus.

These are all found in tropical Australia and can be iso-

lated from the Anopheles mosquito. Their pathogenic-

Rwamba virus (African virus)

ity is not known but antibodies are found in the sera

Cattle sera will show antibodies to this virus but disease

of cattle, sheep and pigs as well as kangaroos and

is not apparent. The name also applies to infection in

wallabies.

humans, donkeys, goats and sheep. The condition is

spread by mosquitoes. The virus appears to be related

Kunjin virus (Australian virus)

to Pongola virus.

This is a flavivirus found in mosquitoes in tropical

Australia. There is serological evidence of infection in

Sabo virus (African virus)

humans, horses, cattle and poultry. In calves experi-

This virus is found in Culicoides in Nigeria. It is also mentally infected a mild, non-purulent encephalitis

frequently isolated from Nigerian cattle and has been

develops.

isolated from goats. There is a transient fever and

listlessness following infection. The virus is a member

Kotonkan virus (African virus)

of the Simbu group of bunyaviruses.

This is a rhabdovirus found in Culicoides. The disease resembles ephemeral fever virus. The infection is par-Sango virus (African virus)

ticularly present in Nigeria.

This virus is found in Culicoides in Nigeria. It is also frequently isolated from Nigerian cattle. There is a tran-

Lokern virus (American virus)

sient fever and listlessness following infection. The virus

is a member of the Simbu group of bunyaviruses.

Antibodies to the bunyavirus have been found in cattle,

horses and sheep. The infection is found in Californian

sandflies and mosquitoes.

Shamondu virus (African virus)

This virus is found in Culicoides in Nigeria. It is also fre-Middelburg virus (African virus) *quently isolated from Nigerian cattle. There is a tran-*

sient fever and listlessness following infection. The virus

While antibodies can be found in domestic cattle in

is a member of the Simbu group of bunyaviruses.

South Africa, disease has not been recorded. Man is not

affected. The virus is spread by Aedes mosquitoes.

Shuni virus (African virus)

Murray Valley encephalitis virus (Australian virus)

This virus is found in Culicoides in Nigeria. It is also frequently isolated from Nigerian cattle and has been

This is a flavivirus found in mosquitoes and wild birds.

isolated from sheep. There is a transient fever and

It can produce epidemics of human encephalitis in

listlessness following infection. The virus is a member

Australia and New Guinea. The infection can be

of the Simbu group of bunyaviruses.

detected serologically in cattle, horses, pigs and dogs.

When calves are experimentally infected the disease is

symptomless.

Sindbis virus (African, Asian and Australian virus)

The life cycle is believed to involve Culicoides, mos-

quitoes and wild birds. In most cases cattle exhibit no

Obodhiang virus (African virus)

signs but they do develop antibody titres. Infection

This is a rhabdovirus found in Culicoides. The disease of humans results in illness. It is a species of the

resembles ephemeral fever. It is found in mosquitoes in

alphaviruses.

Sudan and the pathogenicity is not known.

Thogoto virus (African and European virus)

Pongola virus (African virus)

The virus is found in ticks in Nigeria and in Boophilus

Cattle sera will show antibodies to this virus but disease

decoloratus ticks in Kenya. It has also been isolated in is not apparent. The name also applies to infection in

the tick Rhipicephalus bursa in Sicily. The infection can humans, donkeys, goats and sheep. The condition is

also involve humans and sheep. Calves, when experi-

mentally infected, show viraemia and leucopenia but

Treatment

usually there are no other signs.

There is no specific treatment but diethylcarbamazine *citrate 4 mg/kg in the food can be helpful, otherwise*

PARASITIC DISEASES

ivermectin, doramectin and eprinomectin can be used.

Onchocercosis (worm nodule disease)

Control

Aetiology

The control of insect vectors is not practicable.

This is a filarial infection of the genus Onchocerca. In cattle, Onchocerca gibsoni affects the subcutaneous

tissues, particularly the brisket and lower limbs; O.

Stephanofilariosis

liendis (synonyms O. gutturosa, O. bovis) is found in the Aetiology

ligamentum nuchae, other ligaments and stifle joints; O.

ochengi causes a dermatitis and O. armillata is found This is caused by parasites of the genus Stephanofilaria.

in the aortic wall. The worms are thread-like and

These include S. assamensis, which occurs in India

often measure 6 cm long with microfilariae 200–400 mm

and Pakistan, S. kaeli, found on the legs of cattle in long.

Malaysia, S. stilesi, affecting the ventral surface of the body and found in many parts of Asia, and S. dedosi,

which occurs in Indonesia affecting the head and neck.

Epidemiology

The parasites are small (2–9 mm long) and filariform in

The condition occurs worldwide, but is more common

shape.

in the tropics and subtropics. The life cycle is indirect.

Transmission is by midges (Culicoides spp.), sandflies and blackflies (Simulium spp.), which ingest microfilaria Epidemiology

in the skin and subcutaneous tissue. They develop to

The parasite occurs in cattle and buffalo in many parts

the infective larval stage and then infect the final host

of South East Asia as well as the tropics. The life cycle

when the vector again feeds. The larvae migrate to

is indirect and involves anthomyid flies as intermediate

the predilection site where O. gibsoni develops into

hosts. Open skin lesions develop from which the flies

nodules and the others become enclosed in a fibrous

feed and ingest the microfilariae. In the fly they develop

cyst. The females produce microfilariae that remain in

to the infective larval stage and are then transmitted to

the skin or subcutaneous tissue.

the final host when the fly feeds. There appear to be *more flies when conditions are moist either due to rain*

Signs

or presence of rivers, streams or irrigation.

There are few clinical signs except for the presence of

nodules up to 3 cm diameter under the skin, particularly

Signs

in the brisket. In O. liendis infections there are few signs in the ligamentum nuchae but the stifle joint may be

There are only superficial lesions, seen initially as a

swollen. Disability can occur due to the supporting lig-

papular dermatitis. There is then exudate and haemor-

aments being affected. Infestation with O. gibsoni can rhage lasting many months with the skin becoming

result in nodules.

thickened and dry.

Pathology

Diagnosis

There are nodules present. Onchocerca armillata is

This is based on the lesions and recent wet weather.

present in nodules in the wall of the thrombic aorta; O.

Scrapings or smears from skin lesions reveal adult

liendis is found in the ligamentum nuchae, ligaments, worms and microfilariae.

stifle, the omentum, splenic ligament and capsule.

Diagnosis

Treatment

The presence of infection can be detected by examin-

Topical application of organophosphorus compounds

ing skin biopsies. Differentiation from skin tuberculo-

is effective, including trichlorphan 6 per cent and

sis (p. 743) and demodectic mange (p. 781) is necessary.

coumaphos 2 per cent.

Control

Control

There is no effective control but in some cases fly repel-

The condition is not usually severe and so control is not

lents are used. However, these are expensive for routine

normally undertaken particularly because of the ubiq-

use. In adult animals that have been repeatedly infected

uitous nature of the vector.

with S. stilesi there is evidence that further infestation is reduced or stops.

Other problems

Thelaziosis

Tick paralysis

Aetiology

Aetiology

Disease is caused by infestation with spirurid nema-

todes of the genus Thelazia, in cattle by T. rhodesii. The This occurs with a number of different ticks and results

worms are thin, white and can be up to 20 mm long.

in an ascending flaccid paralysis either due to acetyl-

choline failure at neuromuscular sites or a lack of

conduction within the nerve fibres.

Epidemiology

It occurs in the conjunctival sac of mammals in many

parts of the world. In the species that have been studied

Epidemiology

the worms are viviparous and produce first-stage

This is seen in ticks in Australia (Ixodes holocyclus), larvae that are infective for various Diptera, including

North America (Dermacentor andersoni, D. acciden-

Musca spp. The flies act as the intermediate hosts where talis) and South Africa (I. pilosus, I. rubicundus, the parasite develops to a third-stage infective larva,

Haemaphysalis punctata). Most cases coincide with the

which is transferred to the final host when the flies *peak tick populations and particularly at maximum*

feed.

adult activity. At times only one feeding tick may cause

the problem.

Signs

There are often no signs, otherwise there may be

Signs

lacrimation that can be unilateral or bilateral and is

The signs involve a change in temperament followed

often purulent. There can be conjunctivitis, keratitis,

by slight incoordination. Then the animal starts to drag

corneal opacity, ulceration, protrusion of the eyeball

its hindlimbs and as the forelimbs are progressively

and photophobia. Abscesses may develop on the

involved it becomes recumbent. There is respiratory

eyelids.

distress and then the animal dies of respiratory failure.

Pathology

Necropsy

There may be conjunctivitis, keratitis and corneal ulcer-

ation and scarring.

There are no characteristic signs at post mortem.

Diagnosis

Diagnosis

This depends on the signs and finding the worms.

If the ticks are removed the animal makes a recovery.

Treatment

Treatment

The most effective treatments are the avermectins iver-

Remove as many ticks as possible by hand, then treat

mectin, doramectin and eprinomectin at 200 mg/kg. Lev-

with an ixodicide.

amisole can be given orally at 5 mg/kg body weight or

as a 1 per cent eye lotion. Otherwise, local anaesthetic

can be used and the helminths removed manually. Irri-

Control

gation of the unanaesthetized eye can be undertaken

with 1 in 8000 aqueous iodine or 2 per cent boric acid,

Although susceptibility decreases with age, immunity

3 per cent piperazine adipate or 0.2 per cent diethyl

varies from a few weeks to years. Prevention really

carbamazine.

involves the proper use of dips, sprays, etc.

Sweating sickness (sweetsiekte,

Inapparent: These animals show few signs but there is

notkalersiekte, vuursiekte,

a form of residual immunity to the problem.

schwitzkrankheit, la dyhydrose tropicale,

foma, ol macheri)

Pathology

This appears to be a toxicosis with a dermatotrophic

toxin related to tick infestations. Removal of the ticks

The lesions depend on the duration of the condition

results in a rapid clinical recovery. The problem is not

and any concurrent disease. There is a disseminated

transferred from animal to animal by the introduction

intravascular coagulopathy with microthrombi (Van

of blood, saliva or tissue from ill animals. Animals

Amstel et al. , 1987). The oral mucous membranes show

appear to be susceptible or non-susceptible. In the

ecchymotic dermatitis, inflammation and superficial

former case cattle become ill with each exposure and *necrosis. The nasal cavity, pharynx, larynx, oesophagus*

can die. Only certain strains of the tick Hyalomma trun-

and omasum show white pseudomembranes. In the

catum, known as the boat-legged tick, are implicated.

thorax there is hydrothorax, hydropericarditis with

The disease is seen in Central, East and South Africa.

oedema and emphysema. The liver displays fatty degen-

Although cattle are involved, particularly calves, sheep,

eration and the abomasal, small and large intestine

goats, pigs and dogs are also affected. The signs vary

mucous membranes show hyperaemia.

according to individual susceptibility, age of the animal

and the number of the correct strain of tick present. The

Diagnosis

inactive period is about six days, but varies from four to

eleven. The morbidity of the condition is very variable

This is dependent on the area and local history of the

and mortality ranges from 30 to 70 per cent. Immedi-

disease and presence of H. truncatum ticks on the

ately following recovery from sweating sickness immu-

animal. Pathological signs are helpful and there is an *nity persists for well over a year and in some cases lasts*

increased prothrombin clotting time. Peracute cases

up to four years. There appears to be no passive trans-

could be confused with anthrax (p. 717), babesiosis

fer of immunity to calves in colostrum.

(p. 748), anaplasmosis (p. 761), heartwater (p. 765) and

poisonings (Chapter 54).

Signs

Treatment

Peracute: This is fatal in 48–72 hours, with a sudden rise in rectal temperature, hyperaemia, anorexia, dyspnoea,

There is no specific drug that will affect sweating sick-

hyperaesthesia of the visible mucous membranes and

ness, but hyperimmune serum is useful in treatment.

muscle tremors. There tends to be excessive lacrimation

The inflammatory nature of the disease suggests the

and nasal discharge.

use of anti-inflammatory agents, but corticosteroids

are probably contraindicated as there are often high

circulating cortisol levels in affected cattle. The use

Acute: This only occurs in animals under a year old and of antibiotics is indicated because of the likely *presents as a sudden rise in temperature to 40–41°C*

immunosuppression that can occur in the presence of

(104–106°F) for a period of up to eight days. The

high cortisol levels. As there is severe intravascular

pyrexia may be continuous or intermittent and lasts

coagulation the use of heparin at 10–20 iu/kg body

longer in the latter case. The mucous membranes

weight may be helpful. The liver is often affected and

become hyperaemic and there is lacrimation, salivation

so multivitamin injections, particularly containing

and nasal discharge. The hair is in poor condition and

cyanocobalamin, choline and methionine, may be of

wet eczematous areas develop involving the head, par-

use.

ticularly the cheeks under the eyes, nose, ears, then the

neck, abdomen and flanks, and especially the groin. In

some cases the whole body may be affected and accom-

Control and prevention

panying the eczema there is hyperaesthesia, discharge

Effective control of the ticks responsible with acaricides

and loss of the surface epithelium. Many badly affected *is helpful. Eradication is usually not feasible and so aca-*

calves show total hair loss.

ricide regimens should be designed to clear short-term

infestation with the ticks, insufficient to produce dis-

Subacute: The signs are a sudden rise in temperature,

tress but of long enough duration to allow immunity to

but to a lesser extent and lasting only two or three days,

develop. As the tick needs to be attached to the animal

and the mucous membranes show slight hyperaemia, as

for at least 7–10 days to produce disease, weekly

can the skin.

dipping normally produces reasonable control.

Mhlosimge

dromes in dogs and cattle resulting from severe tissue

*damage. Contributions to Microbiology and Immunology, **7**, This is a less important toxicosis that is transmitted by*

103–19.

certain strains of Hyalomma truncatum. It affects cattle, Murray, M. (1978) Anaemia of bovine African trypanosomia-sheep and pigs. The signs are usually milder than sweat-

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between sweating sickness and Mhlosimge.

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This is also a less important toxicosis transmitted by

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non-fatal and can affect cattle, sheep and pigs. The signs

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sonal study of the feeding activity of Glossina palli-

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Adult Cattle

Metabolic Problems

Chapter 46

Major Metabolic Disorders

R.G. Eddy

Milk fever (parturient paresis, hypocalcaemia, eclampsia)

781

Breed: The Jersey and, to a lesser extent, the Guernsey Hypomagnesaemia (grass tetany, grass staggers, lactation

are particularly susceptible to milk fever. This would

tetany, Hereford disease)

787

indicate a genetic predilection for this disease and is

Hypophosphataemia

791

probably related to the relatively high production level

Postparturient haemoglobinuria

792

for a small breed.

Acetonaemia (ketosis, slow fever)

793

Pregnancy toxaemia

796

Age: It is rare for milk fever to occur at the first calving The downer cow

797

Fatty liver syndrome

801

and relatively uncommon at the second. The incidence

does appear to increase with age and incidence levels

of 20 per cent or more are common at the sixth calving

Milk fever (parturient paresis,

and beyond. The reason is thought to be that the re-

hypocalcaemia, eclampsia)

quirement for calcium at parturition increases as milk

yield rises with each lactation and the ability to mobi-

lize calcium quickly from the body reserves, i.e. bone,

Milk fever or hypocalcaemia is probably the most *decreases with age.*

common metabolic disorder affecting cattle. It is nor-

mally associated with parturition occurring just before,

Seasonal factors: The incidence in the UK is highest in during or immediately after calving although it has

the months of August to October and at its lowest in

been reported in dry cows and, increasingly, during mid

the winter months of December, January and February.

lactation. The incidence of milk fever is higher in dairy

However, this is more likely to be a result of differing

cows than beef cows and increases with age and yield.

feeding regimens of dry cows than a seasonal effect. In

Milk fever undoubtedly increased in incidence during

countries where there is little change in dry-cow nutri-

the 1970s and 1980s when levels of around 9 per cent

tion during the year, e.g. Israel, there appears to be no

per annum were being reported. More recent studies

seasonal differences in the occurrence of milk fever.

would suggest that the incidence has fallen to around

5–6 per cent, in spite of increased milk yields, and prob-

Nutritional factors: The wide range of incidence of milk ably the result of improved nutrition of dry cows. The *fever observed between seasons, within a season and*

incidence does vary considerably between seasons as

between farms in the UK is due to the variation of

well as between farms. In some years the incidence in

nutritional input given to dry cows. Dry cows that are

September and October in the UK can be as high as

fed a diet of hay or silage only, which is now common-

60 per cent on some farms, whereas during the winter

place in the UK, will have a low incidence of milk fever

months when dry cows are housed 0–6 per cent would

at calving. However, if feeds containing high calcium

be frequently reported. The disease does appear to be

levels are included in the diet, e.g. sugar beet pulp or

more common when dry cows are fed grass rather than

high calcium minerals, the incidence will increase.

conserved fodder. Milk fever is a common cause of

The incidence of milk fever in cows at grass varies

death and is probably the most common cause of appar-

considerably with the season. In dry weather the inci-

ent sudden death in dairy cows. It is also a common

dence is low, but during long wet spells the level is high.

cause of dystokia and hence stillborn calves.

A diet of grass with a low dry matter (DM), whether in

the spring or autumn, can predispose to high incidences

Predisposing factors

of milk fever. There is more than one reason for this.

There are several important predisposing factors that

One is that such a diet leads to diarrhoea, which prob-

influence the occurrence of milk fever and these

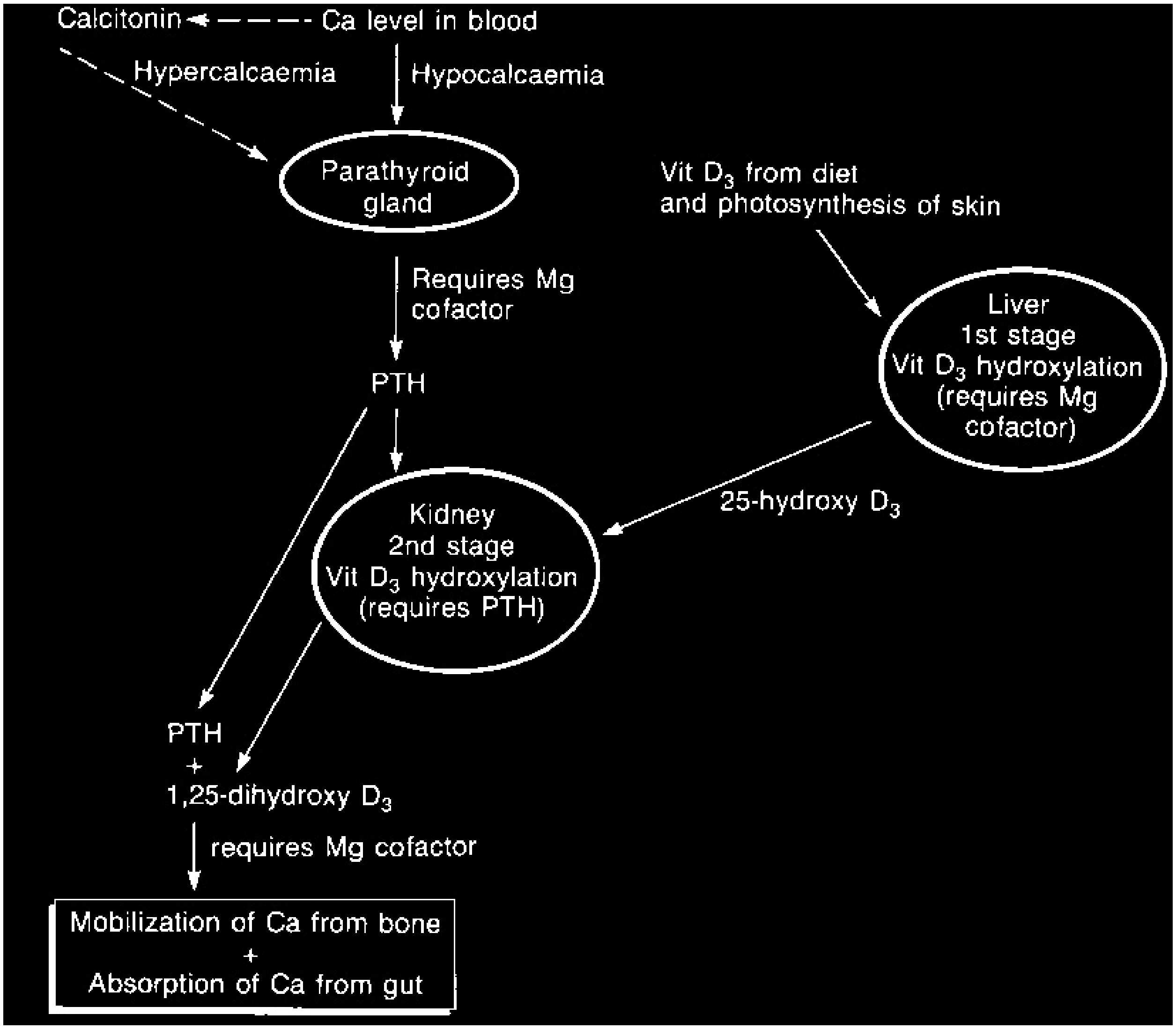
ably reduces the calcium available for absorption. The

account for the wide variation of incidence observed in

calcium level of wet grass, particularly in the autumn,

the UK and other countries worldwide.

can be excessively high, often as high as 1 per cent of



DM. Potassium levels may also be high. It has been

calcium is required for each litre of colostrum pro-

shown that low magnesium levels in the diet restrict the

duced, so the requirement is increased two- or three-

cow's ability to absorb calcium (Sansom et al. , 1983) and fold in a very short period. In order to meet this

the high levels of milk fever found in the spring and *enlarged demand and to avoid hypocalcaemia, calcium*

autumn in the UK are often due to low magnesium

absorption from the gut is increased and further

levels in the grass.

calcium is available from mobilization of the calcium

reserves in bone. This explains why mild hypocalcaemia

occurs in all cows at parturition. If the cow does not

Aetiology

respond quickly to the sudden increase in calcium

requirement the hypocalcaemia deepens and signs of

Some degree of hypocalcaemia occurs in all cows at

milk fever become apparent.

parturition, but only when this becomes severe do

In the normal cow this adaptation process at parturi-

clinical signs develop. Frequently, hypophosphataemia

tion is under the hormonal control of the parathyroid

and hypermagnesaemia accompany the hypocalcaemia,

hormone (PTH). Hypocalcaemia stimulates the secre-

although when milk fever is due to low magnesium

tion of PTH, which in turn stimulates the production of

intake the blood levels of magnesium will also be *a hydroxylase enzyme in the kidney that is able to syn-*

depressed. The normal concentration of calcium in

thesize 1,25-dihydroxycholecalciferol (1,25(OH)

plasma lies within the range 2.2–2.6 mmol/l (8.8–

2D3),

which is produced from vitamin D

10.4 mg/100 ml), but will fall to 1.5 mmol/l (6.0 mg/

3. The 1,25(OH)2D3

stimulates increased gut absorption of calcium and pro-

100 ml) in most cows at parturition without milk fever

bably the mobilization of calcium from bone (Fig. 46.1).

signs occurring. Usually, when milk fever is present the

Several factors affect the speed of response to this

plasma level will be in the range 0.75–1.5 mmol/l

adaptation process:

(3.0–6.0 mg/100 ml).

The predisposing factor in the aetiology of hypocal-

• Age of the cow, as already mentioned. Older

caemia at parturition is the sudden increase in the

cows are less able to mobilize calcium from the

requirement of calcium for the production of *skeleton.*

colostrum. The daily calcium requirement of a 600 kg

• Oestrogens also inhibit calcium mobilization and as

cow in late pregnancy is approximately 28–30 g; this

oestrogen levels rise at parturition this will have a

comprises 13–15 g required for endogenous loss in

negative effect on the adaptation process to main-

faeces and urine and 15 g to maintain the growing fetus.

tain calcium levels. Milk fever does occasionally

At the onset of lactation, approximately 1–1.5 g of

occur during lactation, usually in association with

Fig. 46.1

System for mobilizing calcium in cattle.

PTH, parathyroid hormone (Kelly, 1988).

oestrus. This again would be due to the inhibitory

tympany and total absence of the pupillary light reflex

effect of oestrogens.

until the cow dies. Death can be due to paralysis of the

• Food intake is often depressed at or around partu-

respiratory muscles, but more often death occurs from *rition so the total available calcium in the diet will*

bloat. Many cows with milk fever are found in ditches

be reduced. This is particularly the case if diets low

or streams, having fallen in during the incoordination

in calcium, e.g. straw or cereal-based diets, are fed

phase of the disease. In these situations death can be

over the parturition period.

due to drowning.

• The calcium intake during the dry period. If high

The length of time for the disease to progress from

levels of calcium are present in the diet the reduced

first signs of inappetance to death varies from 10 to 24

PTH output that occurs reduces the rate of absorp-

hours. Many cows are found dead or near to death by

tion from the gut, so that when the demand for cal-

the stockworker at the time of morning milking, having

cium suddenly increases and the cow's appetite is

been quite normal the previous evening at 7.00 pm.

generally reduced absorption does not satisfy the

If hypocalcaemia occurs at the onset of calving the

body requirement (Fig. 46.1).

parturition process will cease due to lack of myometrial

• A low magnesium intake in the diet reduces by

contractions. A considerable number of cases of dys-

various mechanisms the ability of the gut to allow

tokia due to uterine inertia are the result of hypocal-

calcium absorption. Therefore, diets that are

caemia and, if not treated, will result in a stillborn calf

deficient in magnesium will predispose to hypo-

or even death of the cow before the calf is born. It is

calcaemia by reducing calcium absorption.

common for the stockworker to find a cow in lateral

Hypomagnesaemia also inhibits mobilization of

recumbency in the early morning with the calf pre-

calcium from bone (Fig. 46.1).

sented in the birth canal or even with the head present

• Problems associated with digestion, e.g. acidosis and

at the vulva. Frequently, the calf will be dead and occa-

profuse diarrhoea, will reduce the amount of

sionally even partially eaten by foxes or other wildlife.

calcium in the gut available for absorption. This

could also explain cases of hypocalcaemia that occur

Clinical pathology

at times other than parturition or oestrus.

The concentration of calcium in plasma is usually below

1.5 mmol/l (6 mg/100 ml) in cows with clinical hypocal-

Signs

caemia and will fall to as low as 0.25 mmol/l (1.0 mg/

The clinical signs of milk fever are progressive. In the

100 ml). Phosphorus levels also fall to 1.0 mmol/l from

first stage there is a loss of appetite, lethargy and the

the normal range of 1.4–2.5 mmol/l (4.3–7.8 mg/100 ml).

rectal temperature is reduced by 0.5°C (1°F). This pro-

Magnesium levels usually increase to around 1.25

gresses to a stage where the cow stands with the hocks

mmol/l (3.0 mg/100 ml), except where the cause of milk

straight and sways laterally, particularly when moving.

fever is related to low magnesium diets when hypo-

Constipation is normally seen at this stage. Muscle

magnesaemia may be present. Hyperglycaemia is also

tremors may be present about the head and limbs.

usual during milk fever, but this is frequently seen in

Hyperaesthesia is also often evident at this stage and *normal cows at parturition.*

the cow becomes apprehensive. The lateral swaying

In fatal cases of milk fever there are no gross or his-

develops into incoordination and ataxia and the cow

tological lesions characteristic of the disease. Bruising

will fall over sideways and rise with increasing difficulty

of subcutaneous tissue and muscles due to localized

until she becomes permanently recumbent.

trauma may be apparent. The liver is occasionally dis-

The recumbent stage is the one most commonly seen

tended and infiltrated with fat, resulting in a yellow

by veterinarians in practice. The cow will be sitting in

discoloration. Cows with such a fatty liver are thought

sternal recumbency, often with a noticeable S bend

to be more prone to milk fever, but fatty liver is not

in the neck, progressing to the stage where the head

pathognomonic of milk fever.

will be resting on her shoulder. The heart rate will be

slightly raised but rarely exceeds 90/minute. The pupils

Diagnosis

will be dilated and the pupillary light reflex will be

reduced or even absent. The gut stasis that character-
The diagnosis of milk fever is made on the signs
izes this stage of the disease further reduces the avail-
described above and the history of recent or imminent
ability of calcium for absorption and the disease will
calving. Although blood biochemistry may be consid-
progress to the comatose stage. The rumen ceases to
ered useful, in practical situations there is not the time
function and often becomes tympanic and the cow
available to obtain a result. A cowside test for calcium
appears severely depressed. The comatose stage is
is now available in some countries but its value is prob-
characterized by lateral recumbency, increased rumen
ably limited to differential diagnosis of the downer cow

syndrome or cows failing to respond to treatment for
slipping on ice or slippery concrete or even a collision
milk fever. The most valuable diagnostic aid available
with a vehicle such as a tractor.
is, once the differential diagnoses have been eliminated,
the response to treatment. Intravenous treatment with

Hypomagnesaemia: This can occur at any time of lac-

calcium borogluconate will produce a clinical response

tation during the spring or autumn but is sometimes

within minutes. The cow will become more alert, defae-

present as a complication of milk fever, particularly

cate and eructate, often before the full dose of calcium

during the two seasonal risk periods of spring and

has been administered.

autumn. Hyperaesthesia is the main differentiating sign

of hypomagnesaemia.

Differential diagnosis

Downer cow syndrome: Initially, this may be difficult to differentiate from milk fever but response to therapy

Although milk fever is an extremely common disease it

and clinical biochemistry will he helpful. This will be

is essential that a full clinical examination be made for

discussed in full later in the chapter (see p. 797).

every case. It is common for the new veterinary gradu-

ate to diagnose and treat a recumbent cow for milk

Inanition: Any condition producing severe weight loss

fever when the cause of the recumbency is toxic masti-

will result in recumbency, particularly in pregnant cows,

tis. The clinical examination must therefore include

the most common of which is probably starvation. In

examination of milk from all four teats, the heart rate

seasons where insufficient conserved food is available,

and the mucous membranes. Misdiagnosis is now more

recumbency due to starvation is common. Body condi-

common as farmers treat their own cases of milk fever

tion is the obvious differentiating feature. However, any

and frequently confuse the disease with other causes of

disease that causes considerable weight loss will have

recumbency.

the same effect, e.g. liver fluke (p. 276). In seasons when

The differential diagnoses of milk fever are:

liver fluke prevalence is high, this disease can result in

• Acute toxic mastitis (Chapter 23);

extreme weight loss and anaemia and recumbency prior

• Calving paralysis (p. 438);

to parturition is common. Weight loss, red cell count

• Physical injury (p. 446);

and presence of fluke ova in faeces would be the dif-

• Hypomagnesaemia (p. 787);

ferentiating features.

• Downer cow syndrome (pp. 439, 789);

• Inanition and other disease (p. 150);

Pregnancy toxaemia: This can occur, particularly in

• Pregnancy toxaemia (p. 796);

beef cows, in the last two or three months of pregnancy.

• Acidosis (p. 829);

The sweet smell of acetone on the breath, poor condi-

• Hypothermia (p. 930);

tion or excessive fat and a history of unavailability of

• Bovine spongiform encephalopathy (BSE) (p. 909).

food should distinguish this problem. The rumen will

also be functioning in the early stages of this condition.

Acute toxic mastitis: In acute toxic mastitis from

whatever cause the temperature may be raised but is

Acidosis: Acute acidosis as a result of the sudden inges-sometimes subnormal, the pulse may be in excess

tion of large amounts of carbohydrate material, usually

of 120/minute, the eyes are often sunken, the mucous

cereal-based concentrates, will result in recumbency, *membranes injected and, in acute coliform mastitis,*

although hypocalcaemia is often a feature of acidosis.

they are frequently a purple colour. Abnormal milk

Here the history will help and usually acidosis is accom-

secretion will be found in one or more teats, although

panied by diarrhoea.

in acute coliform mastitis this change in milk character

may be less than obvious.

Hypothermia: Mild hypothermia (reduction of 0.5°C or

1°F) is a normal feature of milk fever. However, severe

Calving paralysis: The history of dystokia due to fetal hypothermia (reduction of 3–4°C or 5–7°F) occurs in

oversize and recumbency since calving help in the dif-

cows that have been recumbent all night in winter out

ferential diagnosis, but many cases are not clear-cut.

of doors. Although these cows have some other primary

Intravenous calcium together with the response noted

disease, e.g. milk fever or mastitis, treatment will be un-

is probably the best aid to differential diagnosis.

successful unless steps are taken to raise body temper-

ature as rapidly as possible.

Other physical injury: This can occur at any time of lacIn summary, there are many diseases and conditions

tation or the dry period and can include fractured limbs,

that result in recumbency of the cow. However, careful

pelvic damage and severe muscle damage. These can

history taking and a thorough clinical examination will

be the result of excess riding behaviour during oestrus,

eliminate most differential diagnoses and if one is still

not sure of the diagnosis, response to intravenous

of the downer cow syndrome in recent years. Following

calcium will always be a useful indicator.

intravenous therapy plasma calcium rises rapidly and

falls to around 2 mmol/l (8 mg/100 ml) 5–6 hours after

treatment. Following subcutaneous therapy, the plasma

Treatment

calcium levels may take 3–4 hours to reach 2 mmol/l

The treatment for milk fever is the slow intravenous

(8 mg/100 ml). Furthermore, in severe cases of milk

infusion of 8–12 g of calcium as soon as possible after

fever the peripheral blood circulation will be impaired, *the onset of clinical signs.*

which will inhibit the absorption of any fluid material

A number of licensed preparations are available

administered subcutaneously. In practice one is often

for the treatment of milk fever and most are based on

called to attend cases of milk fever that have not

calcium borogluconate (CBG) at 20 per cent, 30 per

responded to subcutaneous treatment administered by

cent or 40 per cent strength (see Table 46.1). It has been

the farmer several hours before and the whole of the

shown that 400 ml of 30 per cent CBG is adequate to

treatment solution is still present at the injection site.

treat milk fever in average size cattle and will provide

As already stated approximately 85 per cent of cows

9 g of calcium. However, the most commonly used

will respond to one treatment. If response is not evident

product in the UK is 400 ml of 40 per cent CBG, which

by 5–6 hours, then the cow should be re-examined,

will provide 12 g of calcium. During cold weather the

the diagnosis reassessed and if necessary a further in-

CBG solution should be warmed to body temperature.

travenous infusion of 8–12 g of calcium administered.
Approximately 85 per cent of cases will respond to one
Some practitioners advocate 400 ml of CBG intra-
treatment. In many cases cows recumbent from milk
venously plus 400 ml subcutaneously to prevent
fever will rise within 10 minutes of treatment and others
relapses. Relapse of milk fever occurs in 25 per cent of
will get up 2–4 hours later.
cases treated and this figure is not affected by additional
Following the intravenous infusion, which itself
subcutaneous administration. Blood levels of calcium
should take five minutes, it is essential to sit the cow in
six hours after intravenous or subcutaneous infusions
a sternal recumbency position and turn her so that
are similar and by 12 hours after administration all the
she is lying on the side opposite to the one on which
calcium administered, whether by the iv or sc route, has
she was found. Many cases will eructate and defaecate
been eliminated from the body.
during the treatment. If the cow does not rise immedi-
Treatment of milk fever should also be accompanied

ately she should be turned to lie on the opposite side by removal of the calf and advice to the farmer not to every two hours. Following intravenous treatment, milk milk the cow for 24 hours except to check for the pres- fever cows should be able to sit comfortably in the ence of mastitis. As already stated, relapses occur in sternal recumbent position without the aid of support 25 per cent of cases treated and the likelihood of such as bales of straw. If the cow keeps returning to relapse will be reduced if milk is not drawn from the lateral recumbency following treatment the diagnosis udder during this 24-hour period. The 8–12 g of calcium should be reassessed as it is unlikely to be milk fever. given is only a small proportion of the daily calcium The use of intravenous treatment cannot be overem- requirement, so the treatment is only a holding opera- phasized as it is essential that the blood calcium levels tion until the normal adaptation process is in full oper- return to normal as quickly as possible to avoid the ation. Cases of relapse usually occur at 18–24-hour complications resulting in the downer cow syndrome.

intervals and should be treated in the same way, i.e. by

Farmers treating their own cases of milk fever com-

the intravenous infusion of 8–12 g of calcium. Occa-

monly use subcutaneous injections of CBG. This is

sionally cows, particularly Jerseys, have been known to

undoubtedly a factor that has increased the incidence

relapse on up to seven occasions.

There is a tendency amongst farmers to give two

bottles of 40 per cent CBG, which would amount to

Table 46.1

Licensed products available for the treatment of

24 g of calcium. Such a procedure is probably counter-

milk fever in the UK.

productive, as there is some evidence to suggest that

too high levels of calcium administration will slow up

Product

Pack size Available

Dose required for

the adaptation process and actually increase the

(ml)

calcium (g)

600 kg cow (ml)

number of cows that relapse.

Some proprietary CBG preparations also contain

CBG 20%

400

6

600–800

magnesium (1.0 g) and phosphorus (2.6 g) in addition to

CBG 30%

400

9

400

calcium. If hypomagnesaemia is a complicating factor

CBG 40%

400

12

400

Maxacala

100

4.17

200

of milk fever then the addition of the magnesium may

be helpful. However, in cases of clinical hypomagne-

a C-Vet Veterinary Products.

saemia more than 1.0 g of magnesium will be required.

The presence of the phosphorus has no doubt been

magnesium chloride to the drinking water is a practical

added because of the finding that the blood levels of

and effective way to supply magnesium to cows; 40 g

phosphorus in cases of milk fever are also depressed.

daily of magnesium chloride crystals can be added to

However, clinical evidence would suggest that the

drinking water if large enough troughs are available.

addition of phosphorus has no effect on the percentage

Trough size should be 20 l/cow. If trough size is limited,

of cases that recover or relapse. In fact, it has been

magnesium acetate can be added to the water supply

shown that plasma phosphorus levels return to normal

using a water proportioner plumbed into the water

within a few hours after successful treatment with CBG

supply pipe.

without the addition of phosphorus.

If the plasma levels of the dry cows are normal then

Historically, the treatment of milk fever was by udder

diets restricting calcium intake may be considered, par-

insufflation. This has the effect of slowing down milk

ticularly if the plasma calcium levels are at the high end

production. Plasma calcium levels do rise following

of the normal range. To be certain to prevent milk fever,

udder insufflation and will reach 2.5 mmol/l (10.0 mg/

dry-cow diets should contain less than 30 g/day of

100 ml) by 4–5 hours after treatment. However, the effi-

calcium. However, in practice, diets producing less than

cacy of CBG intravenously and the danger of mastitis

50 g/day of calcium will prevent most cases of milk

following insufflation have now rendered this mode of

fever. Autumn grass in the UK often contains 8–10 g/kg

treatment almost extinct except that some clinicians

DM calcium. Thus with daily intakes of 12–14 kg DM,

have been known to use the technique in cows that

90–140 g/day of calcium will be available in the diet. It

persistently relapse.

is impossible appreciably to reduce this level of intake

without removing the cows from grass and substituting

a diet based on maize silage, hay or straw. However,

Prevention

some farmers are prepared to do this to reduce the risk

Much milk fever can and should be prevented (see

of milk fever and incidence levels of 5 per cent or less

Table 46.2). If an outbreak occurs in any season where

are possible. It should be appreciated that if low

more than 10 per cent of cows are needing milk fever

calcium diets are advocated for dry-cow use, just before

treatment the first action the clinician should consider

parturition a diet containing more calcium should be

is to blood test a group of six or seven dry cows to

administered to ensure adequate calcium being avail-

measure the concentration of calcium and magnesium.

able over the risk period. This can be achieved by

If the magnesium levels are low, i.e. below 0.85 mmol/l

feeding cattle concentrate or feeds that are high in

(1.8 mg/100 ml), this should be seriously considered as

calcium, e.g. sugar beet pulp (see Table 46.3).

interfering with calcium absorption, in which case sup-

Other methods of milk fever prevention involve

plemental magnesium should be administered to all

dealing with individual cows. Maintenance of appetite

dry cows within three weeks of calving. Approximately

is essential and, in the past, appetite stimulation by the

10–12 g of magnesium administered daily to dry cows

use of anabolic steroids has been suggested, but the use

will be sufficient to produce normal plasma levels of

of these products is now illegal in Europe. Maintaining

magnesium and to allow normal calcium absorption.

adequate calcium intake by drenching cows daily with

However, this is often difficult to achieve because of the

150 g/day of calcium chloride on the day before calving

problem of giving supplemental feeds to grazing cows.

and for four days thereafter has had some success in

A supplement of 25 g daily of calcined magnesite mixed

with cereal (1 kg/cow) or silage will produce the desired

effect, but many farmers are reluctant to give supple-

Table 46.3

Approximate calcium, phosphorus and magnesium *mental feeds to dry cows. Recent experience in the UK*

contents (g/kg DM) of some common feedstuffs.

has shown that the addition of magnesium acetate or

Ca

P

Mg

Barley

0.6

3.8

1.4

Table 46.2

Approximate requirements of 600 kg cows for

Wheat

0.5

3.5

0.6

dietary calcium, phosphorus and magnesium (g/day). Source:

Maize

0.2

2.7

1.0

ARC (1980), reproduced with permission of CABI International.

Sugar beet pulp

10.4

0.9

1.4

Brewers grains

5.0

6.0

1.8

Ca

P

Mg

Maize silage

3.7

3.2

3.0

Grass and grass silage

3.0–10.0

1.5–4.5

1.0–3.0

Maintenance (non-pregnant)

15

13

9

(range)

Maintenance + late pregnancy

28

22

12

Grass and grass silage

5.9

3.9

1.5

Lactation (g/kg milk)

1.65

1.55

0.74

(average)

preventing milk fever and might be considered in cows

tating or dry cows in the spring or autumn and is usually

with a known history of milk fever.

not accompanied by clinical signs. It usually affects the

The use of vitamin D3 and its metabolites given by

whole herd. Lactating cows will suffer a slight reduction

injection has been advocated in preventing milk fever.

in milk yield and may have a slight nervous disposition,

The administration of 10 million iu of vitamin D3 given

e.g. reluctance to enter the milking parlour. Dry cows

eight to two days before calving will considerably

will be more prone to milk fever at parturition. If the

reduce the incidence of milk fever but the practical

herd is affected with subclinical hypomagnesaemia

problem remains of accurately predicting the time of

some individuals will develop grass staggers, particu-

calving, which in practice has proven more difficult than

larly if stressed. Milk tetany occurs in calves fed pre-

expected. More recently, the analogue of the vitamin D3

dominantly milk, particularly calves suckling cows that

metabolite 1a-hydroxycholecalciferol (1a(OH)D3) has

are subclinically hypomagnesaemic (see p. 253). The

been used in trials to prevent milk fever. Doses of

incidence of hypomagnesaemia varies considerably

350 mg given at least 24 hours and not more than five

from region to region. Some areas of the UK are par-

days before calving do reduce the incidence of milk

ticularly high in the incidence of the disease in both

fever, but once again the problem remains of accurately

beef and dairy cows. Overall, the annual incidence in

predicting the time of calving. Recently, workers in

UK dairy herds is approaching 1 per cent.

Israel (Sachs, 1988) have suggested that a single dose of

The clinical disease is most common around peak lac-

700 mg of 1a(OH)D3 given eight to seven days before

tation, presumably reflecting the secretion of magne-

expected calving is more effective and that the accuracy

sium in the milk. It is also a common cause of sudden

of calving date prediction is less important.

death. In 1984 in the UK it was estimated that 0.8 per

Vitamin D3 or 1a(OH)D3 will not be effective if the

cent of the dairy cow population died from the disease

diet is deficient in magnesium. Before recommending

(Whitaker et al. , 1984). This was following the intro-their use the magnesium status of the herd should be

duction of milk quotas in Europe and a dramatic

assessed by blood testing six or seven dry cows.

reduction in the use of concentrate feeds for dairy

It has been found that there is less milk fever when

cows, particularly during the summer months.

diets are acidic. This is the basis of the dietary cationic–

anionic balance (DCAB). It is the balance between

Aetiology

cations (Na^+ and K^+) and the anions (Cl^- and S^{2-})

present in the diet. Their levels affect the acid–base

As there are no readily available body stores for mag-

balance and thus calcium metabolism. Some diets in the

nesium, the main factors involved in the aetiology of

dry period are anionic and the reduction of the balance

hypomagnesaemia are the reduction of the amount of

in favour of a negative balance assists. This is achieved

magnesium available in the food, and hence available

by increasing the feeding of Cl^- and/or S^{2-}, by reducing

for absorption from the gut, accompanied by a high

the amount of Na^+ and/or K^+ present or by feeding

physiological demand for magnesium. Magnesium is *maize silage. The target is to achieve in the last two*

lost from the body in milk, urine and faeces. The

weeks before calving -200 mEq/kg DM. This can be

endogenous loss in faeces has been calculated to be

done by using 200–250 g of anionic salts. Practically this

approximately 1.8 g/day (ARC, 1980). Milk contains

is often achieved by the addition of 100 g NH_4Cl and

0.12 g/l of magnesium so a cow producing 30 kg of milk

100 mg of $MgCl_2$. However, such diets should only be

would lose 3.6 g daily in the milk. Any excess magne-

used where there is adequate calcium provision. The

sium absorbed will be excreted via the urine, this being

system is complex and should only be used on farms

the mechanism for stabilizing plasma magnesium

with good quality management.

levels. If the plasma magnesium levels rise much above

0.8 mmol/l (2.0 mg/100 ml) the excess will be excreted.

If magnesium intake levels are excessive, up to 5.0 g/day

Hypomagnesaemia (grass tetany,

may be excreted in the urine. However, if magnesium

grass staggers, lactation tetany,

intake falls to the level to maintain homeostasis or

Hereford disease)

below there will no magnesium identifiable in the urine.

To maintain magnesium homeostasis the absorption

Hypomagnesaemia is a common feature of a group of

of magnesium must be continuous so a constant supply

syndromes dominated by hyperaesthesia, incoordina-

is necessary in the diet. Feeds vary considerably in both

tion, tetany and convulsions that can occur in all rumi-

the content and the availability of magnesium so the

nants of all ages. Grass tetany or grass staggers is the

choice of pasture is important. Clovers have higher

name given to the syndrome affecting lactating cattle

magnesium content than grasses and grasses themselves

(beef or dairy cows) when grazing grass in the spring or

vary. Fast-growing Italian ryegrasses have lower levels

autumn. Subclinical hypomagnesaemia can occur in lac-

than perennial grasses. Many broad-leaf plants, such as

buttercups (Ranunculus spp.), plantains and nettles,

two to four-month-old calf is denied feed supplemenhave considerably higher magnesium levels than

tation other than cow’s milk, magnesium absorption

grasses, which probably accounts to some extent for

will decline to less than requirements and clinical signs

the increasing incidence of hypomagnesaemia seen in

will appear. This is seen in suckler calves or veal calves

recent years in the UK as old permanent pastures have

reared on milk or milk substitute that has not been sup-

been replaced with ryegrass leys.

plemented with magnesium (see p. 253).

Some soils are known to be deficient in magnesium

but also the uptake of magnesium by plants may be

Signs

influenced by cations such as calcium and potassium in

the soil. It has been shown that fertilizers containing

The signs of grass staggers may be classified as sub-

potassium applied to grazing areas in late winter or

acute, acute or peracute. In the subacute form cows will

early spring will reduce the absorption of magnesium

be apprehensive and hyperaesthetic. The head will be

by plants, and soils containing high levels of potassium *held high and tremors may be seen around the head*

are particularly prone to producing hypomagnesaemia

(particularly the eyelids), over the shoulder and on the

in grazing ruminants.

flank. These tremors will be exaggerated if the animal

Although historically this disease has been one

is touched or the skin pinched. The legs may become

related to spring grass, in recent years it has become

stiff and a staggering gait may be evident. Cows can

increasingly common throughout the whole grazing

remain in the subacute phase for several hours or

season from April to October. The occurrence during

progress to the acute or peracute form, particularly in

winter has also increased in the UK; this can be attrib-

response to noise or some other stimulus such as

uted to the increasing use of grass silage made from

attempting to herd them. The peracute cases will

young leafy grass low in magnesium during May.

stagger for a few steps and fall over with tetanic spasms

Another important factor in the aetiology of the

of the head, neck and legs followed by clonic convul-

disease is the energy intake of the animals. This is par-

sions. The legs will paddle furiously, the eyes roll and

ticularly the case in beef suckler cows grazing inade-

there is frothing at the mouth. The heart will pound fast

quate pastures, particularly during times of inclement

and furious and death can occur at any time. Cows have

weather. Experiments have shown that reduced energy

been known to be grazing one minute and, in response

intake will interfere with the magnesium available for

to noise from a vehicle or other stimulus, to stagger, fall

absorption. The availability of magnesium for absorp-

over in convulsions and die in two or three minutes.

tion from the gut is thought to range from 4 to 35 per

The signs in the acute case will be similar but may

cent. Calcium, potassium and ammonium (nitrogen)

last for up to an hour or more. In these cases a period

ions are all thought to interfere with body uptake of

of convulsions will be followed by a quiescent period in

magnesium.

which the cow may attempt to rise, only to walk a few

It is possible to find animals with low plasma magne-

steps and fall over again followed by convulsions. The sium levels but yet clinically normal. It would appear rectal temperature, if taken, will be elevated by 1 or 2°C that the critical factor influencing the onset of clinical (2– 4°F). Cows are often found dead with obvious signs disease is the level of magnesium in the cerebrospinal that the limbs had been paddling prior to death, thus fluid (CSF). The speed at which magnesium levels fall disturbing the soil around the feet.

also influences the onset of clinical signs. In the spring, In the subclinical form the majority of the herd are magnesium levels fall rapidly and clinical disease may usually affected even if acute cases have not been diag- become apparent at blood levels at which in the nosed. If acute cases are present it can be assumed that autumn, when the fall is more gradual, the cows remain the majority of the herd will be affected subclinically. clinically normal.

The cows may be slightly nervous, reluctant to enter the The role of calcium in the onset of clinical hypomag- milking parlour or be unwilling to be herded. The milk *nesaemia is also unclear. Approximately 80 per cent of*

yield will be depressed slightly.

cows with grass staggers have low plasma calcium

The signs of milk tetany in calves (p. 255) are much

levels. It has been shown that cows will develop clinical

the same as for cows with subacute, acute and peracute

disease within 24 hours after a fall in plasma calcium

cases occurring. Often in peracute cases the animals are

levels although they have been hypomagnesaemic for

found dead.

several days.

Milk tetany occurs in calves two to four months old

Clinical pathology

reared on whole milk diets without the addition of mag-

nesium supplementation. In young calves absorption of

Healthy normal cows should possess plasma magne-

magnesium is good. However, as the calf grows older

sium levels over 0.85 mmol/l (2.0 mg/100 ml). Any levels

the ability to absorb magnesium declines. Thus, if the

below this must be considered a risk and indicative of *subclinical hypomagnesaemia, although in acute cases*

cow group and testing for magnesium is the most useful

the plasma levels will generally be below 0.4 mmol/l

indicator. Testing urine for magnesium levels has been

(1.0 mg/100 ml). Magnesium levels in the CSF in acute

advocated, absence of magnesium indicating the sub-

tetany will generally be below 0.6 mmol/l (1.4 mg/

clinical state. Urine test strips are available in some

100 ml). Hypocalcaemia is present in at least 80 per cent

countries. However, there are real practical problems in

of acute tetany cases and hyperkalaemia is common.

getting a number of cows to micturate on demand.

Following tetany or in recovered cases aspartate amino-

transferase (AST) and creatine kinase (CK) levels will

Differential diagnosis

rise to relatively high levels but return to normal quite

soon after recovery.

Acute lead poisoning: In lead poisoning (see pp. 906,

At post mortem there are no pathognomonic signs.

944) there may be excitement and occasional convul-

Haemorrhages may be present on the heart muscle and *sions. Hyperaesthesia, as measured by observing muscle*

occasionally along the aorta. Regurgitation and aspira-

tremors in response to pinching the skin, will be absent

tion of rumen contents may sometimes be seen. The

and blindness is usually a feature of lead poisoning.

CSF levels of magnesium will be low and magnesium

will be absent from the urine, although the bladder is

Milk fever (p. 783): Some cows in the early stage of

nearly always empty at post mortem.

milk fever may exhibit hyperaesthetic signs. The history

of being close to parturition is the most helpful aid to

this differential diagnosis. Many cows are hypocal-

Diagnosis

caemic as well as hypomagnesaemic and so treatment

The diagnosis of grass staggers is made on the signs

involves calcium administration; thus being able accu-

described above. The time of year and type of grazing

rately to differentially diagnose the two conditions is

may help in forming a diagnosis. As there is little or no

not important in practice.

time in acute cases to conduct blood biochemistry, *response to treatment will also confirm a diagnosis. It*

Acetonaemia (p. 740): Some cows with acute aceton-

may be useful for the clinician to take a blood sample

aemia will have hyperaesthetic signs and appear

before treatment so that analysis can be performed at

nervous and apprehensive. However, the depraved

a later stage should this prove necessary. If animals are

actions of these cows, such as licking the walls and floor

found dead then diagnosis must be differentiated from

or biting at gates, will usually distinguish this disease

other causes of death. Diagnosis at post mortem is dif-

from hypomagnesaemia, as will a Rothera's test on a

ficult because of the absence of obvious lesions. If quan-

sample of milk.

tities of soil have been gouged out of the ground by

each of the four feet during the paddling phase this is

Listeriosis (p. 904): Acute listeriosis may be confused strongly indicative of acute grass staggers. Absence of

with acute grass staggers, but the high rectal tempera-

magnesium from urine would be a useful indicator, but

ture and absence of true hyperaesthesia in listeriosis *the bladder is generally empty. Blood and tissues are of*

cases should be enough to distinguish this disease.

no value at post mortem because magnesium levels rise

rapidly after death. Levels in CSF may be helpful and

Bovine spongiform encephalopathy (p. 909): The emer-

recently it has been suggested that magnesium levels in

gence of BSE in the UK in 1986 has sometimes made

aqueous humour taken after death will be depressed in

the differential diagnosis of the subacute form of hypo-

cows that have died from grass staggers. If a cow is

magnesaemia more difficult. The ataxia, apprehension

found dead and grass staggers suspected from the

and mild hyperaesthesia found in BSE are similar to

history and absence of other lesions at post mortem,

that found in subacute hypomagnesaemia. Diagnosis is

the wise clinician will blood sample six to seven cows in

usually confirmed by response to treatment and blood

the group and test for magnesium levels. It is important

biochemistry, a sample being taken before treatment. If

to make a diagnosis to be able to offer preventive

there is any doubt in the clinician's mind it would be *advice for the remainder of the herd.*

wise, in cases of suspected BSE, to take a blood sample

Diagnosis of death due to milk tetany in calves is pos-

to eliminate subacute hypomagnesaemia before notify-

sible by measuring the calcium and magnesium levels

ing the suspicion to the authorities.

in bone. A rib or coccygeal bone is usually used for this

purpose. A calcium/magnesium ratio in bone of 70 : 1 is

Others: Lightning strike (p. 930) as a cause of sudden considered normal and 90 : 1 considered an indication

death, some plant poisonings, and in particular

of severe magnesium depletion.

Paspalum staggers (Claviceps paspali poisoning), are

To diagnose subclinical hypomagnesaemia blood

differential diagnoses but can usually be distinguished

sampling seven cows each from a lactating and a dry-

on grounds of history alone. Rabies (p. 908; Chapter 70)

may cause problems in countries where it occurs, but

raised into sternal recumbency and left for a further 30

such animals usually are hyperactive, bellowing and *minutes before attempting to stimulate the animal to*

riding other cattle.

rise.

Treatment is successful, if early, in 80 per cent of acute

Suboptimal production: If production is below expec-

recumbent cases and nearly 100 per cent in acute stand-

tations, particularly in seasons associated with hypo-

ing cases. If the recumbent case is not able to rise within

magnesaemia,

then subclinical hypomagnesaemia

two hours of treatment the likelihood of success is

could be present. Blood biochemistry in the form of a

extremely poor and slaughter should be considered.

metabolic profile that includes magnesium should be

Subacute grass staggers should be treated in the same

considered (see p. 813).

way and success is usually near to 100 per cent.

Relapses are considered normal unless preventative

measures are taken. Blood magnesium falls to pre-

Treatment

treatment levels within six hours of intravenous

Acute cases of grass staggers must be treated promptly.
administration, although the subcutaneous injection has
During the course of treatment the operators should be
a more prolonged effect. Daily subcutaneous injections
as quiet and gentle as possible as any sudden stimulus
of 200–400 ml of 25 per cent magnesium sulphate for
will initiate a bout of convulsions. Hence, actually
five days following treatment have been recommended
restraining a staggering acute case will often be difficult
or the oral administration of four magnesium bullets,
and when attempting to place a rope or halter on
which are composed of an alloy of 86 per cent magne-
the animal it will sometimes collapse into a fit of
sium, 12 per cent aluminium and 2 per cent copper
convulsions and may even die before treatment has
weighted with iron shot (Rumbul bullets, Agrimin Ltd),
been administered. The success of treatment is
immediately following the intravenous and subcuta-
also related to the length of time signs have been
neous treatment.
present in the recumbent acute case. The longer the cow

An individual cow suffering from grass staggers is

has been showing convulsions, the less likely it will be

one of a herd and many cows in the herd could be at

to recover.

risk, of or at least suffering from, subclinical hypomag-

Intravenous infusions of magnesium salts, e.g. mag-

nesaemia. It is important therefore that a group of six

nesium sulphate, are sometimes recommended for

to seven cows be blood tested to ascertain the herd

treatment but this procedure is not without its dangers.

magnesium status, and if the blood levels are below

Intravenous magnesium sulphate may cause cardiac

0.8 mmol/l (2.0 mg/100 ml) herd supplementation with

embarrassment or even respiratory failure. If magne-

magnesium must be instituted.

sium sulphate is administered intravenously the con-

The treatment of milk tetany in calves is generally

centration should be no more than 6 per cent and

academic, as most cases are found dead. However, very

must be administered very slowly with the heart being

slow intravenous infusion of 100 ml of 20 per cent CBG *auscultated. However, it is also essential to administer*

with the addition of 20 ml of 25 per cent magnesium

calcium in the form of CBG because most cases of grass

sulphate followed by 60 ml of 25 per cent magnesium

staggers are also hypocalcaemic.

sulphate subcutaneously would be the regimen of

The treatment protocol favoured by the author is to

choice. Oral supplementation of magnesium must also

discard 100 ml of fluid from a 400 ml bottle of 40 per

follow if the calf recovers. Suggested daily doses of

cent CBG, which also contains magnesium 0.2 per cent

magnesium oxide would be 1, 2 and 3 g for calves up to

and phosphorus 0.5 per cent, and replace this with

five weeks, five to ten weeks and ten to fifteen weeks

100 ml of 25 per cent magnesium sulphate solution. The

old, respectively.

mixture, which then contains 9 g of calcium and approxi-

mately 6 g of magnesium, is infused intravenously very

Prevention

slowly, taking 8–10 minutes. The remaining 300 ml of

the original 400 ml 25 per cent magnesium sulphate is

The simplest method of prevention of hypomagne-

injected subcutaneously. If during the infusion, or

saemia is to add calcined magnesite (magnesium oxide)

immediately after, the convulsions get worse 10 ml of

to cattle concentrate that is being fed to the cows.

pentobarbitone sodium 200 mg/ml (euthanasia solu-

However, the main risk periods in northern Europe for

tion) can be administered intravenously and this will

hypomagnesaemia are times when concentrate food is

often reduce or even eliminate the convulsions. Fol-

not being fed, e.g. spring grazing and autumn grazing

lowing this treatment regimen, if the cow is recumbent,

for dry cows. In Australia, New Zealand and Ireland

it is important to remain quiet for a further 10 minutes

very little concentrates are fed, and in many beef

as stimulation even immediately after treatment may

suckler herds other ingenious methods must be devised.

initiate convulsions. The recumbent cow should then be

The magnesium bullets mentioned above will give

protection for four to six weeks. However, although two *growing in the pasture may not only be aesthetically*

bullets are recommended, in severe hypomagnesaemic

acceptable but may reduce the incidence of hypomag-

areas experience has shown that four bullets are

nesaemia in grazing animals.

required to prevent problems.

The prevention of milk tetany in calves can be

Dusting the pastures with magnesium oxide has been

achieved by ensuring magnesium supplementation.

attempted using 50 g/cow per day of magnesium oxide,

Proprietary milk substitute powders are adequately

or 0.5 kg/week applied in the early morning when the

supplied with magnesium. If whole milk is used mag-

dew is on the grass. This works best when cows are strip

nesium oxide at the rates given above should be added

grazed and the magnesium oxide is applied every

to the daily diet (see p. 790).

morning. Weekly applications are effective in dry

weather, but must be reapplied following rain.

However, grass staggers is more common in wet than

Hypophosphataemia

dry weather.

The increasing practice in recent years in the UK of

Hypophosphataemia is the result of a primary defi-

buffer feeding, where a silage supplement is fed to cows

ciency of phosphorus in the diet (see also p. 792).

during the grazing season, has meant that magnesium

oxide at the rate of 50 g/cow per day can be mixed with

Occurrence

or sprinkled on top of the silage and increases feed

passage time.

Dietary deficiencies of phosphorus are widespread

Supplementation of water supplies using magnesium

under natural conditions. There is a distinct geographi-

acetate via a water proportioner is effective but

cal distribution where large land masses are identified

expensive. The proportioner has to be adjusted daily

as being deficient in phosphorus and livestock cannot

to allow for the variation in water intake that occurs

be supported without phosphorus supplementation.

under different weather conditions. The expense and

These areas will be deficient because of the underlying *management input required have been a disincentive*

rock formation. Large areas of southern Africa and

for this method of prevention to become widespread.

Australia are well identified as being deficient in phos-

The addition of magnesium chloride crystals to

phorus. Such areas, however, are unknown or rare in

the drinking water has increased in popularity in the

northern Europe and, if they exist at all, will be local-

UK in recent years. It is relatively inexpensive but, to

ized. Although there are areas of Europe where the

be effective, the trough sizes must be large enough

underlying rock formation contains no phosphorus,

for all cows to drink the medicated water. The addition

continuous application of fertilizers containing phos-

of 40 g/cow per day of magnesium chloride to the

phorus and cultivation techniques have improved the

drinking water has been shown to give reasonable

soil structure and nutritive value. In consequence,

protection. Addition of magnesium salts to the drink-

primary phosphorus deficiency is probably a rare occur-

ing water will depress water intake if the concentration *rence in Europe.*

is too high. Troughs with a volume of 20 l/cow are

required for this method of control to work effectively.

Aetiology

Mineral licks and powders containing high levels of

magnesium are relatively useless in preventing hypo-

Phosphorus deficiency is usually primary, although a

magnesaemia because of the uncertainty of all cows

severe deficiency of vitamin D (p. 253) may exacerbate

consuming enough material to give them protection

the problem. It was once considered that excess calcium

when it is required.

would also reduce the availability of phosphorus in the

When discussing the long-term strategies for con-

diet and cause deficiencies of phosphorus. Although the

trolling hypomagnesaemia, fertilizer policy should be

calcium : phosphorus ratio in the diet is important in

included. All potassium-containing fertilizers should

monogastric animals, it is probably of less significance

be avoided on soils with high potassium levels and on

in cattle. The maintenance requirements for adult and other soils, if potassium-containing fertilizers are used,

growing cattle would be approximately 15 g of phos-

they should be applied at low levels in the autumn. If

phorus daily. The lactating cow requires approximately

necessary, they can be applied later in the grazing

0.75 g/kg of milk produced, so a cow yielding 30 kg of

season.

milk will require 40 g of phosphorus daily. This level of

Perhaps plant species should also be considered in

requirement is considerably less than that currently

long-term control strategies. Clover/grass mixtures

being recommended in the UK by the Agricultural

should be favoured ahead of grass alone, but perhaps

Development and Advisory Service, but nevertheless is

above all the use of selective weedkillers should be

supported by experimental evidence from the Agricul-

discouraged. A few buttercups and other wild plants

tural Research Council (ARC, 1980).

Signs

Control

In young cattle phosphorus deficiency results in slow
Under range conditions, where phosphorus deficiency
growth and rickets. In adult cattle the principal signs are
is the most common, supplementation of the diet with
reduced milk yield, weight loss and depraved appetite.
phosphorus is often impractical. Bone meal, dicalcium
Osteomalacia will result from prolonged dietary defi-
phosphate or disodium phosphate may be provided in
ciency of phosphorus. The depraved appetite or pica
feed supplements or free access mineral mixtures. The
results in cows eating earth, licking rocks and, where
dietary intake of phosphorus should be at least 15 g/day.
bones are available, osteophagia. The osteophagia fre-
Top dressing pastures with superphosphate fertilizers
quently results in a high incidence of botulism (p. 721)
will correct any underlying deficiency and have the
and in some areas of southern Africa and Australia
added advantage of increasing the yield and protein
death from botulism is the most important consequence
content of the pasture. However, this is often impracti-
of phosphorus deficiency. Reduced fertility has been

cal in areas where the problem exists.

considered a feature of severe phosphorus deficiency,

In acute cases where phosphorus therapy is urgent,

but experimental work has demonstrated that fertil-

e.g. postparturient haemoglobinuria, the intravenous

ity is independent of either calcium or phosphorus

administration of sodium acid phosphate (30 g in 200 ml

intakes. Reduced fertility is a feature of malnutrition

distilled water) is advocated (see below).

and frequently animals that are deficient in phospho-

rus are also suffering from malnutrition. Low energy

Postparturient haemoglobinuria

intake in such animals is much more likely to be the

cause of reduced fertility than any specific mineral

One specific syndrome associated with phosphorus

deficiency.

deficiency is postparturient haemoglobinuria. This is

Cows in late pregnancy often become recumbent,

a disease of cows one to four weeks after calving.

particularly in drought seasons. This recumbency is

Haemolytic anaemia and hypophosphataemia are con-

probably a result of general malnutrition rather than a

sistent features.

specific phosphorus deficiency.

Hypophosphataemia nearly always accompanies

hypocalcaemia in cows with milk fever, but this is not

Occurrence

thought to be of any significance. Phosphorus levels

Postparturient haemoglobinuria was first described in

rarely fall to the levels of 0.3 mmol/l (1 mg/100 ml) seen

Scotland in 1853 and has been reported from many

in severe clinical cases and in any case calcium therapy

countries including Australia, USA and most of

will result in the blood phosphorus levels quickly

Europe. The occurrence is sporadic and when it does

reverting to normal.

arise it usually only affects one or two cows within a

herd. In recent years its occurrence in the UK has been

extremely rare. In Scotland it has been associated with

Diagnosis

the feeding of beets and turnips, in Holland with the

The presence of rickets or osteomalacia and/or pica will *feeding of lush spring grass and occasionally it has been*

indicate a dietary deficiency of phosphorus, which can

reported to accompany the feeding of sugar beet

be confirmed by analysis of serum and the diet for the

byproducts and alfalfa.

presence of phosphorus. The normal blood level is

1.3–1.6 mmol/l (4–5 mg/100 ml). Levels of 0.5–1.1 mmol/l

Aetiology

(1.5–3.5 mg/100 ml), falling as low as 0.3 mmol/l (1 mg/

100 ml) of serum in severe clinical cases, will be found

Diets low in phosphorus are incriminated in the cause

in hypophosphataemic animals.

of postparturient haemoglobinuria. However, it is

Most pastures in northern Europe contain 1.5–

probable that there is some additional factor that pre-

4.5 g/kg DM of phosphorus and at these levels phospho-

cipitates the problem in hypophosphataemic cattle. This

rus deficiency will not occur. Osteophagia will occur with

is likely to be a haemolytic factor present in sugar beet

pasture levels of 0.2 g/kg DM of phosphorus and rickets

leaves, alfalfa, kale and other Brassica spp. plants.

and osteomalacia at pasture levels of 0.1 g/kg DM.

The only commonly used feedstuffs in the UK that

Signs

are deficient in phosphorus are sugar beet pulp at

0.9 g/kg DM, kale and other Brassica spp. crops. These The principal clinical signs are those associated with

are rarely used at a proportion of the diet high enough

anaemia. The cow may be weak and staggering, with

to significantly reduce the phosphorus intake to dan-

mucous membranes pale and heart rate raised. Haemo-

gerous levels.

globinuria will be a consistent feature. The faeces are

firm and dry. If left untreated the cow will finally

ally, nervous signs. Ketone bodies, e.g. acetoacetate, b-

become recumbent and may die within two to five days.

hydroxybutyrate or acetone, are present in all body

Less severely affected cases may recover, albeit slowly,

fluids. Hypoglycaemia together with increased plasma

in three or four weeks. Pica is frequently observed

free fatty acids and liver fat and decreased liver glyco-

during the recovery period.

gen are also a feature of this disease. These changes are

associated with an inadequate supply of the energy that

is necessary to sustain high levels of milk production in

Clinical pathology

early lactation. Pregnancy toxaemia, a common disease

Serum phosphorus levels are low, usually 0.15–

of pregnant sheep and characterized by hypoglycaemia

1.0 mmol/l (0.5–3.0 mg/100 ml). Low phosphorus levels

and hyperketonaemia, can also occasionally affect

will be encountered in other cows in the herd. Red cell

pregnant cows particularly when carrying twins (see p.

counts, packed cell volume and haemoglobin are all

796).

dramatically reduced. Serum bilirubin will increase in

Historically clinical acetonaemia was more common

the later stages of the disease.

in the winter when cows were housed and being fed con-

At post mortem the liver will be swollen and infil-

served forage of dubious quality. The annual incidence

trated with fat. The carcass is jaundiced and anaemic *in dairy herds is around 0.5 per cent and recent reports*

and red or red/brown coloured urine will be found in

have indicated an all year round occurrence with a

the bladder.

higher incidence in June, July and August than in the

winter months. Cows of any age can be affected and

Channel Island breeds, particularly the Jersey, appear to

Diagnosis

be more susceptible than the Friesian or Holstein. Ace-

Postparturient haemoglobinuria must be suspected in

tonaemia is less common in the UK now than it was 20

any cow that is weak, anaemic and exhibiting haemo-

to 30 years ago. This is probably due to higher quality

globinuria within four weeks of parturition. The haemo-

feeds being available although the preponderance of the

globinuria must be distinguished from babesiosis (p.

Friesian breed may have some effect on the disease inci-

748) and copper poisoning (p. 948). A history of feeding

dence. Outbreaks are usually restricted to one or two

large quantities of kale, beet tops or alfalfa will also be

cows but varying numbers of cows in the herd may be

a helpful aid to diagnosis. The diagnosis should be con-
affected. If the incidence of the disease is high it can
firmed by demonstrating hypophosphataemia and
become a severe economic problem due to depressed
haemoglobinuria.
milk production. The disease usually occurs three to six
weeks after calving, when the cow is at her peak milk
production but her appetite or DM intake has not yet
Treatment
reached its peak. During early lactation the dairy cow is
Intravenous therapy with 30 g of sodium acid phosphate
in negative energy balance. The energy intake in feed is
in 200 ml of distilled water followed by the provision of
insufficient to meet the energy output in milk. This
calcium phosphate in the diet is the first line of treat-
results in the mobilization of fat reserves to meet the
ment. In extremely anaemic cases blood transfusion
energy deficit and a consequent loss in body weight. This
with 5–10 l of blood should be considered. Supportive
should be considered a normal metabolic situation in
therapy with large doses of vitamin C intravenously and

high-yielding dairy cows. Such cows will have slightly

iron dextran injections will aid the recovery.

raised blood ketone levels and may even excrete ketones

in urine and possibly in milk. The cow in early lactation

is therefore in a delicate metabolic balance and any

Prevention

stress that causes a reduction of feed intake can disturb

If brassicas have to be fed to cattle in early lactation

this balance and result in the onset of clinical ketosis.

their intake should be limited to a maximum of 20 kg

Factors that can influence the occurrence of the disease

wet matter/day. This limitation and an adequate phos-

include excessive feeding of silage that has a high

phorus intake will prevent the occurrence of postpar-

content of butyric acid, a deterioration in forage quality,

turient haemoglobinuria.

sudden changes in types of food on offer and excessive

fatness at calving. In the UK the butyric acid content of

grass silage is of considerable importance in the aetiol-

Acetonaemia (ketosis, slow fever)

ogy of this disease because wet conditions, so frequently *encountered during silage making, predispose to butyric*

Acetonaemia or ketosis is a metabolic disorder of high-

fermentation of the silage. The role of such silage in the

yielding lactating cows characterized by reduced milk

aetiology of acetonaemia is probably two-fold. Firstly,

yield, loss of body weight, inappetance and, occasion-

there is the direct effect of the presence of butyric acid

and secondly there is the reduced dietary intake that

acetyl-CoA is converted into the ketone bodies ace-

accompanies such silage. Cows that are too fat at calving

toacetate and b-hydroxybutyrate and, to a small extent,

have lower DM intakes in early lactation and are there-

acetone. Tissues other than liver can utilize ketone

fore more likely to suffer acetonaemia.

bodies but, if their production exceeds the rate they are

Acetonaemia is diagnosed in grazing cattle if the

used by muscle and other tissues, they accumulate and

grass has a high moisture content and/or when the

ketosis is the result. Ketone bodies are excreted in milk

energy intake is insufficient. Cobalt is required for *and urine.*

rumen microbial synthesis of vitamin B12 and is also

The reduction of propionic acid production by the

essential for adequate utilization of propionic acid. In

rumen is usually a feature of underfeeding or a reduced

areas of cobalt deficiency acetonaemia will be com-

feed intake caused by inappetance. Cobalt deficiency, as

monly diagnosed in grazing cows (p. 295).

mentioned above, will also have the effect of reducing

Secondary ketosis is common, if not more common,

propionic acid production. Butyrate is a precursor of

than primary ketosis and can result from any disease

acetyl-CoA and is therefore ketogenic. An increase in

that causes a reduction in appetite in early lactation.

butyrate uptake from the rumen will therefore be keto-

Displaced abomasum (see p. 839) and traumatic retic-

genic. This explains why silage high in butyric acid will

ulitis (p. 837) are two common problems frequently

induce ketosis in apparently normal cows.

associated with secondary ketosis.

Signs

Aetiology

Hypoglycaemia is the major factor involved in the onset
To understand the aetiology of acetonaemia one must
and development of the clinical signs of acetonaemia.
realize the precarious metabolic balance that exists in
There will have been a gradual loss of body condition
all cows in early lactation. To satisfy the requirements
over several days or even weeks. There is also a mod-
of milk production the cow can draw on two sources of
erate decline in milk yield over two to four days before
nutrients, food intake and her body reserves. In the first
the onset of the obvious clinical signs, which are refusal
two months of lactation a cow producing up to 45 kg of
to eat grain and concentrate feeds and a more sudden
milk daily will use up to 2 kg of body fat and up to 350
drop in milk output. At this stage a sweet smell (as in
g of body protein per day. As far as the dietary supply
pear drops) of acetone is apparent on the breath and
of nutrients is concerned 80 per cent of the ingested car-
the discerning stockworker will even detect the same
bohydrates are fermented by the rumen microflora into

acetone smell in the milk. Once appetite is decreased

the volatile fatty acids, acetic, propionic and butyric

weight loss is accelerated due to utilization of body

acids, which are themselves absorbed. Acetate may be

stores. Rectal temperature, pulse rates and respiratory

oxidized by various tissues or incorporated into milk fat

rates are normal in the early stages of the disease, as are

by the mammary gland.

ruminal movements. Faeces will usually be firm with a

Glucose is synthesized in the liver and renal cortex

dark 'waxy' appearance.

by the gluconeogenic pathway. Approximately half of

A small number of cows with acute acetonaemia

the cow's glucose requirement is derived from dietary

exhibit nervous signs, which include excessive saliva-

propionic acid, which is incorporated into the tricar-

tion, abnormal chewing movements and licking walls,

boxylic acid (TCA) cycle and converted to glucose by

gates or metal bars. Incoordination with apparent

gluconeogenesis. Glucogenic amino acids, lactic acid

blindness will also be a feature. Some cows will even *and glycerol can be converted into glucose by this*

show a degree of aggression and will sometimes charge

process. Reduced production of propionic acid in the

into walls, occasionally injuring themselves. The other

rumen will result in inadequate glucose production and

signs observed above are also present. The nervous

a consequent hypoglycaemia. Hypoglycaemia leads

signs often only last for a few hours with the animals

to a mobilization of free fatty acids and glycerol from

showing more normal behaviour in between.

the fat stores. Hormones such as adrenaline, gluca-

gon, adrenocorticotrophic hormone, glucocorticoids and

Clinical pathology

thyroid hormones all influence this mobilization from

the body fat stores. Skeletal muscle and heart can utilize

Hypoglycaemia, hyperketonaemia and the presence of

fatty acids for energy production when glucose is short.

ketones in the urine and milk are the features of this

However, the liver has a limited ability to oxidize fatty

disease. Cowside diagnosis is obtained by the detection

acids because acetyl-CoA, which is the end product of *of ketones in milk and urine using the Rothera's test*

fatty acid oxidation, cannot be adequately incorporated

reaction. A drop of milk or urine is added to a small

into the TCA cycle when levels of oxaloacetate, the

quantity (which consists of sodium nitroprusside 3 g,

result of active gluconeogenesis, are low. The excess

sodium carbonate 3 g and ammonium sulphate 100 g) of

Rothera's reagent on a white tile or piece of white card.

Treatment

A pink to purple coloration of the reagent confirms the

There are three main components of successful

presence of ketones. Urine normally contains low levels

treatment:

of ketones so a diagnosis is only positive when the milk

is also positive.

(1)

To restore blood glucose levels as quickly as

Blood glucose levels are reduced to below 1.4 mmol/l

possible.

(25 mg/100 ml). Total blood ketone levels are raised

(2)

To replenish oxaloacetate, an essential intermedi-

to over 5 mmol/l (30 mg/100 ml). The plasma glycerol

ate in the TCA cycle in the liver, so that fatty acids

and free fatty acid levels (non-esterified fatty acid,

mobilized from the fat deposits are completely

NEFA) are also elevated. Subclinical ketosis has

oxidized. This will reduce the rate of production

become more important in recent years with the intro-

of ketone bodies.

duction of the laboratory test for b-hydroxybutyrate

(3)

To increase the availability of dietary glucogenic

(bHB). The level of bHB is frequently used on a herd

precursors, notably propionic acid.

basis as a measure of energy balance in both lactating

and dry cows. Herds with subclinical ketosis have been

An intravenous infusion of 500 ml of 40 per cent

identified using this test. Serum levels of bHB in excess

glucose will cause a transient rise in blood glucose levels

of 1.75 mmol/l (10 mg/100 ml) will indicate a severe *that lasts approximately two hours. This should be*

energy deficit in the diet (see p. 807).

accompanied by oral administration of glucose precur-

Although mortality is not normally a feature of ace-

sors such as propylene glycol (150 ml, twice daily).

tonaemia, affected cows do possess fatty infiltration and

Propylene glycol is preferred to propionate or glycerol

degeneration of the liver.

because propionate is fermented in the rumen and may

cause digestive disturbances and glycerol is converted

to ketogenic acids as well as propionic acid in the

Diagnosis

rumen. Cobalt salts are frequently added to the pro-

The diagnosis is made on the history of a cow in early

pylene glycol and in cobalt-deficient areas at least

lactation with a sudden fall in milk yield, some weight

100 mg/day of cobalt should be administered.

loss, refusing to eat concentrates, with normal tempera-

Glucocorticoid drugs are the most commonly used

ture, pulse and respiratory rates and normal rumen

therapy for acetonaemia, either used alone or in com-

movements. Many astute stockworkers will recognize bination with glucose therapy or when followed by oral the acetone odour on the breath or in the milk and administration of glucose precursors. Glucocorticoid report this to the attending veterinarian. The diagnosis therapy results in a reduction of ketone body formation is confirmed by a positive Rothera's reaction on milk due to utilization of the acetyl-CoA derived from fatty and urine and, if this is not conclusive, a blood sample acid oxidation and raises blood glucose levels due to a can be analysed for glucose and ketone levels. It is greater availability of glucose precursors in the liver. important to differentiate between primary and sec- The commonly used glucocorticoids are dexametha- ondary ketosis so a complete clinical examination must sone, betamethasone and flumethasone and all are be performed. Many cases presented by the farmer as effective. Frequently, a single dose is administered but acetonaemia are in fact suffering from displaced abo- this does often result in relapses two to three days after masum (p. 839). Some cows with hypocalcaemia (p.

the treatment, when the injection can be repeated.

783) may also show acetonaemia.

There is one disadvantage of repeated glucocorticoid

The differential diagnosis of the nervous form of ace-

therapy and that is that appetite and milk yield are

tonaemia can be sometimes confusing. The behavioural

reduced.

changes are similar to listeriosis (p. 904), but usually

For successful treatment in most cases of aceton-

with listeriosis pyrexia will be present. Hypomagne-

aemia the following regimen is to be recommended:

saemia (p. 788) should be distinguishable by the pres-

• 500ml of 40 per cent glucose intravenously, fol-

ence of hyperaesthesia, particularly the tremors of the

lowed by

eye-lids and muscle tremors over the shoulders and the

• One dose of glucocorticoid, followed by

presence of tetanic convulsions. Bovine spongiform

• Oral treatment twice daily with 150g of propylene

encephalopathy (p. 909) may also be confused with ace-

glycol containing cobalt for three to four days.

tonaemia because of weight loss. However, the appre-

hension, kicking and progressive nature of BSE should

Anabolic steroids are also a useful treatment for ace-

be distinguishing features, besides which blood glucose,

tonaemia and were used in Europe before their use was

magnesium and ketone levels will be normal in BSE.

prohibited under the EC hormone ban. They are effec-

Rabies (p. 908; Chapter 70) is characterized by mania,

tive by increasing the levels of the intermediates of the

ascending paralysis and is always fatal.

TCA cycle in the liver. They also stimulate appetite,

which ensures an increased supply of the glucogenic

cattle in late pregnancy. The problem is best described

precursors. They do not directly raise blood glucose

as starvation, but the aetiology and pathogenesis are

levels. It is important that the cow's appetite returns to

similar to acetonaemia in that an energy deficit in

normal as soon as possible after treatment so access to

the diet leads to massive mobilization of fat reserves,

good quality fodder is a prerequisite to successful treat-

resulting in hypoglycaemia and hyperketonaemia. The

ment. If butyric silage is implicated in the cause of the

problem is most common in beef cattle grazing mar-

problem this should be removed from the diet and only

ginal land, but has been seen in dairy cattle in late

well-fermented silage or good quality hay offered.

winter in seasons where there has been a shortage of

If acetonaemia is affecting a high proportion of the

conserved forage. Cows of all ages are affected, but

herd it would be wise to obtain a supply of ground

overfat animals and those carrying twins are the most

maize, as it has been shown that ground maize is readily

susceptible. Beef cows often have access to good pas-

digested in the small intestine and results in a rapid rise

tures in the summer months and can get overfat. If the

in blood glucose levels.

same cows do not have access to good quality forage

during the winter months, when they are in late preg-

Prevention

nancy they will succumb to ketosis because of the deficit

in energy intake. In dairy cows the problem can occur

The prevention of acetonaemia starts before calving.

at or around calving and is again the result of insuffi-

Cows should not be too fat at calving, a condition score

cient energy intake in excessively fat animals.

of 2.5–3.0 would be optimum and anything higher

would be considered too fat. Access to a plentiful

supply of long coarse fibre to promote good rumen

Signs

digestion is also important during the dry period. Con-

centrates used during lactation should be introduced in

The severity of the clinical signs and their speed of

small quantities (1–2 kg/day) two weeks before calving

onset are associated with the stage of pregnancy and the

to allow adjustments in the rumen microflora. Changes

degree of nutritional stress. Affected cows are usually

to diet in early lactation should be made gradually.

seven to nine months pregnant and show the same clin-

Forage containing ketogenic substances such as

ical signs as cows with acetonaemia. They become

butyric acid should be avoided in early lactation.

increasingly dull and depressed and the smell of

Roughage should comprise at least 40 per cent of the acetone can be detected on the breath. Many cows diet. In cobalt-deficient areas measures should be taken become recumbent fairly quickly, within a few days of to ensure adequate cobalt intake, e.g. by spreading the onset of hyperketonaemia. Often in poorly super-cobalt sulphate on to pastures. The concentrates used vised herds recumbency is the first sign noticed by the need to be of good quality. This statement may seem stockworker. Recumbent cows are severely depressed, obvious but unfortunately some concentrate manufac-have an increased respiratory rate and faeces are scanty, turers, under pressure from farmers, will produce sub-hard and covered in mucus. Some cows develop blood-standard concentrates at a lower than normal price. By stained or fetid diarrhoea in the terminal stages. Most and large the quality of a concentrate food is reflected cows die three to fourteen days after recumbency, in its price.

having fallen into lateral recumbency. This often occurs The use of metabolic profiles (Chapter 47) measur-

two to five days after sternal recumbency. Cows

ing blood glucose and BHB levels in groups of dry cows

affected close to parturition often die during

and cows in early lactation can be useful in the hands

parturition.

of the experienced veterinarian. This will often indicate

an energy-deficient diet and one that could predispose

to subclinical if not clinical acetonaemia.

Clinical pathology

As already stated, acetonaemia is less common now

Hypoglycaemia, hyperketonaemia and ketonuria are

than in previous years. This is due mainly to improve-

consistent findings. In recumbent cases the blood levels

ments in forage conservation techniques and the use of

of bHB are much higher than in acetonaemia; levels

mixed forages, especially maize silage. Thus cows are

up to 22 mmol/l (125 mg/100 ml) may be found. Cows

fed better quality feeds and there is increased aware-

affected close to parturition have hypocalcaemia and

ness that optimum output comes as a result of optimum

occasionally hypomagnesaemia. Recumbent cows in *input.*

the terminal stages have hyperphosphataemia (up to

6.5 mmol/l; 20 mg/100 ml), hyperglycaemia (up to

Pregnancy toxaemia

9.0 mmol/l; 160 mg/100 ml) and raised AST levels. At

post mortem the most consistent findings are an

Pregnancy toxaemia, although primarily considered a

enlarged, yellow, fatty liver with fatty changes in the

disease of sheep, does also affect cattle, particularly beef

kidney and adrenal cortex.

Diagnosis

(1)

How long has the cow been recumbent?

(2)

When did she calve and was calving difficult?

Often several cows are affected before veterinary atten-

(3)

Did she rise after calving?

tion is sought. The usual stimulus to seek veterinary

(4)

Has she been treated for milk fever, and if so how

help is when one or two cows are dead or close to death.

often and how much CBG has been used?

The history, stage of pregnancy and the nutritional

(5)

Has the cow moved recently, either spontaneously

status will usually be enough to enable a tentative diag-

or with help from the farmer?

nosis. Raised blood or urine ketone levels and low

(6)

Where did the cow go down, e.g. concrete, ice, in

blood glucose (plus low calcium in cows close to

field, in a ditch, and was this likely to affect the

calving) will usually confirm the diagnosis.

pathogenesis?

(7)

Is there adequate bedding?

Treatment

Examination

Treatment as described under acetonaemia (see p. 795)

would normally be indicated. However, so severely

The first superficial examination will be the position of

affected are the majority of these cows that medical

the animal, position of the legs and degree of alertness.

treatments almost invariably fail to succeed. Immediate

Lateral recumbency, if not due to hypocalcaemia, hypo-

removal of the calf by Caesarean section (p. 1115) may

magnesaemia or bloat, is indicative of a terminal state

save a valuable cow. This should be followed by the full

and slaughter should be advised as soon as possible.

course of treatment described under acetonaemia.

This includes cows which, although they will sit in the

sternal recumbency position for short periods with the

aid of supports such as hay bales, revert to the lateral

Prevention

recumbent position when they struggle free of the

Although the problem is more common in fat cows it is

supports.

essentially the result of starvation and is predominant

The position of the legs is a useful aid to prognosis.

in years when insufficient conserved fodder has been

If the hindlimbs are in the normal position and the cow *made. To prevent further cases developing and becom-*

attempts to rise the prognosis is guarded to hopeful. If

ing recumbent a supply of good quality forage is essen-

the hindlimbs are rigidly extended forwards so the feet

tial, even if the farmer has to sell a proportion of his

are touching the elbows of the front legs this indicates

herd to obtain fodder for the remainder.

severe sciatic nerve damage, upper hindlimb muscle

degeneration or hip problems, e.g. fracture or disloca-

tion, and the prognosis is hopeless. If both the hindlimbs

are spread laterally, with lateral flexion at the stifle, the

The downer cow

cow has probably 'done the splits' and again the prog-

nosis is hopeless. If one hindlimb is in this position then

Attending the recumbent cow is one of the more chal-

the prognosis is guarded and careful nursing may

lenging problems encountered by the bovine practi-

succeed. If both hindlimbs are extended behind the

tioner (see also p. 439). Often, accurate diagnosis is not

animal, and when the position is corrected they return

possible but prognosis is extremely important and prob-

to the original position when the cow attempts to move,

ably more important than accurate diagnosis. It must be

again the prognosis is hopeless as this indicates severe

remembered that recumbency is the normal course in

muscle degeneration.

the terminal stages of any disease so a full clinical exam-

The full clinical examination will then be conducted

ination is essential in every case plus a thorough history,

(see Fig. 46.2) and may well reveal other diseases

often supported by biochemical examination of blood.

present, e.g. mastitis, metritis (vaginal examination is

Many workers have offered definitions of the downer

essential), torn vagina, ruptured uterus, pneumonia,

cow, but the most useful in practice and the one to be

septicaemia, hypothermia or abdominal catastrophe. It

used here is: a cow that has been recumbent for 24

is essential that a rectal examination be performed.

hours or more, is in sternal recumbency and is not suf-

Assuming there is no abnormality in rectal tempera-

fering from hypocalcaemia or hypomagnesaemia, mas-

ture, respiratory rate, mucous membranes and the heart *titis or any obvious injury to the limbs or spine.*

rate is below 80/minute, then ischaemic necrosis of the

hindlimb muscles or, as it is more commonly referred

to, pressure syndrome should be considered.

History

It is important that the clinician obtains an accurate

Pressure syndrome (ischaemic necrosis): Experimental

history of the case and the following questions must be

work (Cox, 1982) has demonstrated that if a cow is lying

asked:

in the same position for six hours or more there will be

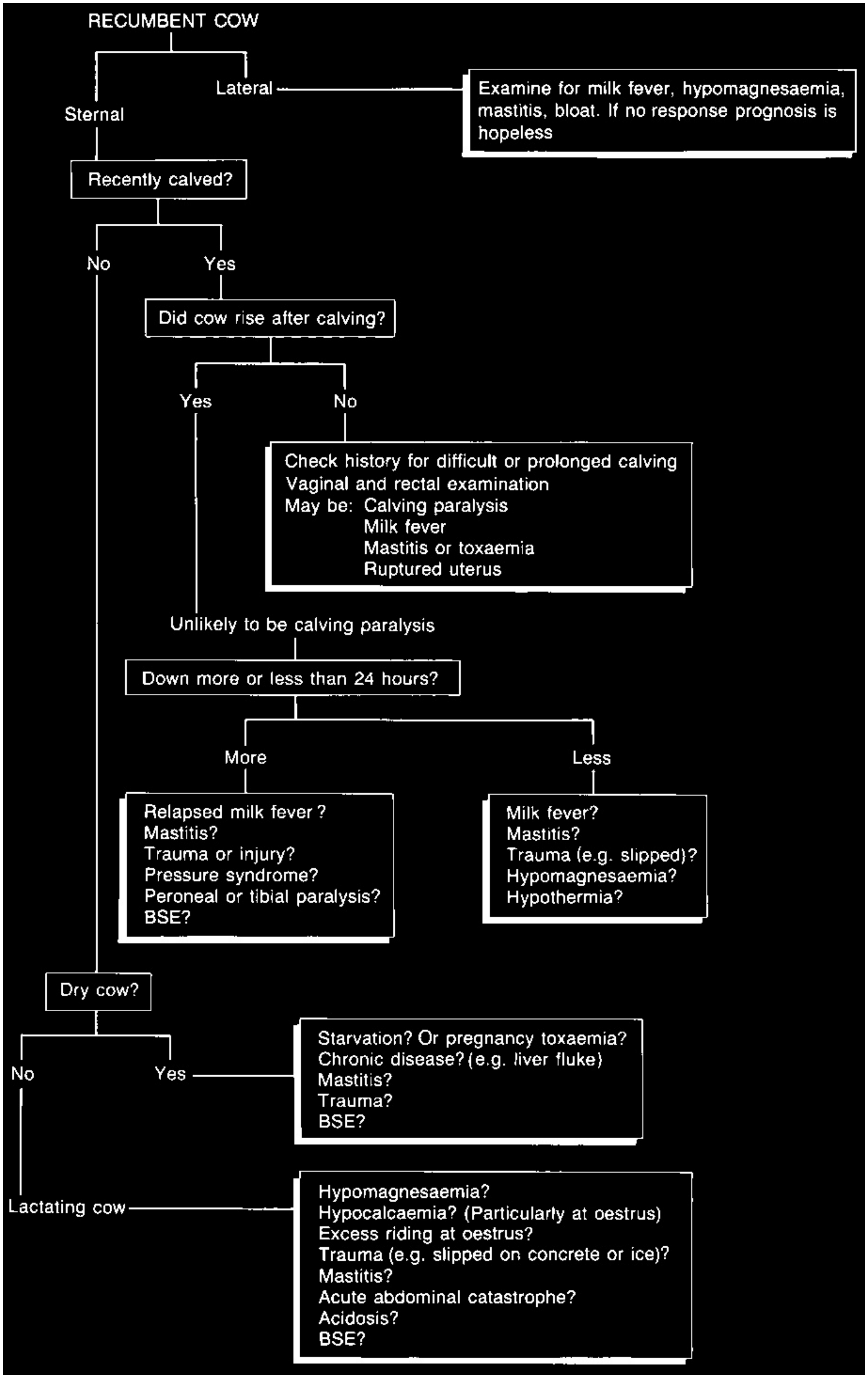

RECUMBENT COW
Sternal
Lateral
Examine for milk fever, hypomagnesaemia, mastitis, bloat. If no response prognosis is hopeless
Recently calved?
No
Yes
Did cow rise after calving?
Yes
No
Check history for difficult or prolonged calving
Vaginal and rectal examination
May be: Calving paralysis
Milk fever
Mastitis or toxaemia
Ruptured uterus
Unlikely to be calving paralysis
Down more or less than 24 hours?
More
Less
Relapsed milk fever?
Mastitis?
Trauma or injury?
Pressure syndrome?
Peroneal or tibial paralysis?
BSE?
Milk fever?
Mastitis?
Trauma (e.g. slipped)?
Hypomagnesaemia?
Hypothermia?
Dry cow?
No
Yes
Starvation? Or pregnancy toxaemia?
Chronic disease? (e.g. liver fluke)
Mastitis?
Trauma?
BSE?
Lactating cow
Hypomagnesaemia?
Hypocalcaemia? (Particularly at oestrus)
Excess riding at oestrus?
Trauma (e.g. slipped on concrete or ice)?
Mastitis?
Acute abdominal catastrophe?
Acidosis?
BSE?

Fig. 46.2

Aid to diagnosis and

prognosis of the downer cow.

damage to the musculature of the leg on which the cow

cows first seen with milk fever at morning milking will

is lying. Cox describes this as ischaemic necrosis as a

have been recumbent for six hours, and some for almost

result of pressure. If the cow is in the same position for

12 hours. Many will be suffering some muscle damage,

12 hours continuously then the damage to the muscle is

particularly if they have been lying on unbedded con-

irreversible and the prognosis is therefore hopeless.

crete. This is why prompt intravenous treatment for

This situation is most common following milk fever,

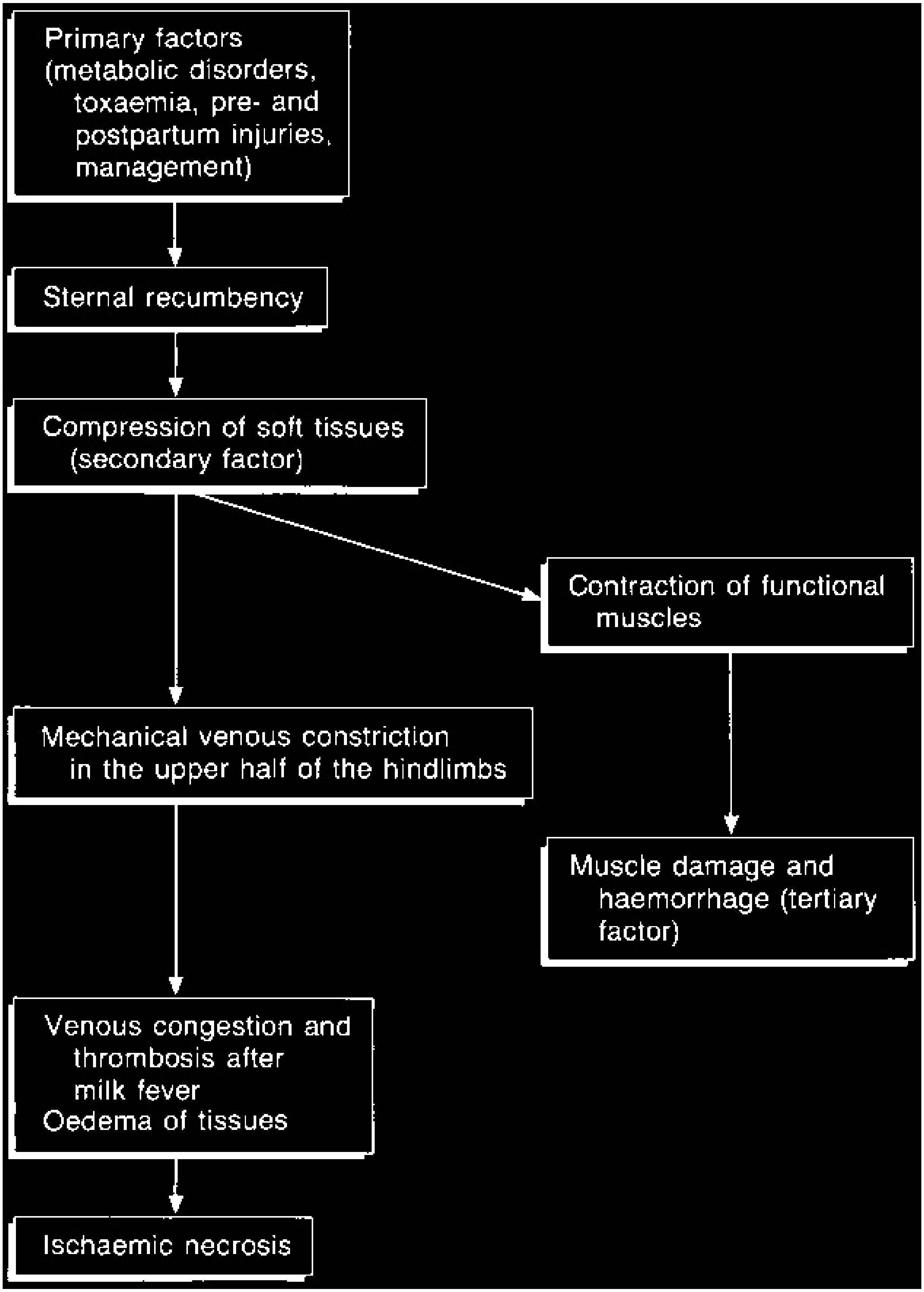
milk fever is essential.

particularly where treatment has been delayed or inef-

Figure 46.3 shows the pathogenesis of ischaemic

fective subcutaneous treatment has been given. Many

necrosis.


Primary factors (metabolic disorders, toxaemia, pre- and postpartum injuries, management)
Sternal recumbency
Compression of soft tissues (secondary factor)
Contraction of functional muscles
Mechanical venous constriction in the upper half of the hindlimbs
Muscle damage and haemorrhage (tertiary factor)
Venous congestion and thrombosis after milk fever
Oedema of tissues
Ischaemic necrosis

Diagnosis and prognosis

Having completed a thorough examination of the recumbent animal that has recently calved and eliminated disease, obvious injury or starvation as a cause of the recumbency, the two most likely problems to be affecting the cow are (i) pressure syndrome (ischaemic necrosis) or (ii) calving paralysis. These cows will be alert, in sternal recumbency, and some will be attempting to rise or crawling along the ground. Appetite for food and water will be good. At this stage it is essential for the clinician to attempt a more exact diagnosis and offer a prognosis. One of the most important inputs that will aid recovery is tender loving care (TLC). The ability and willingness of the stockworker to nurse and attend these cases will be the most important element in successful treatment. So knowledge of the farm and its staff is essential in forming a prognosis, as is the ability to provide soft bedding such as deep litter or a nearby paddock. Diagnosis will be helped if the animal is raised using a Bagshawe hoist and it can be observed *if the cow can take weight on one or both hindlimbs and*

if either or both hindlimbs are abnormal. Abnormali-

ties to observe include the following:

• Flexion of fetlock and extension of the hock, which

will indicate paralysis of the tibial, peroneal or

sciatic nerve (pp. 438, 439).

Fig. 46.3

Pathogenesis of ischaemic necrosis (from Andrews,

• Abduction of one or both hindlimbs will indicate

1986).

obturator nerve paralysis (p. 438).

• Swelling of the upper hindlimb musculature of one

leg would indicate severe pressure syndrome. If the

pressure syndrome is so severe that muscle swelling

is obvious and one upper hindlimb is larger than the

other, prognosis for that limb is hopeless.

Calving paralysis: If the cow has not risen since calving

• Inability to extend or flex the stifle, hock and fetlock

and has not responded to milk fever therapy, and is not

joints.

suffering from any toxic or septicaemic condition such

• *The willingness of the cow to take weight on the*
as mastitis or metritis, then either pressure syndrome
forelegs. If the cow is so weak she cannot take
or calving paralysis should be suspected. The history
weight on the forelegs the prognosis is hopeless.
should indicate whether calving has been difficult but
occasionally a cow will deliver, with difficulty, a large
With calving paralysis one can generalize that if both
calf but second stage labour may last 3–6 hours. In such
hindlimbs are showing signs of nerve paralysis, e.g.
cases, calving paralysis may occur. Calving paralysis as
extension of stifle and hocks and flexion of the fetlock,
a term is preferable to obturator paralysis, sciatic par-
then the prognosis must be hopeless. If only one leg is
alysis or other defined nerve paralyses. The damage
affected and as long as TLC will be available, the prog-
done to the birth canal during prolonged dystokia will
nosis would be guarded but hopeful. It is surprising how
result in a variety of lesions in the pelvic cavity. Gen-
many cows suffering from calving paralysis affecting
erally, the bruising and swelling of the soft tissues of the

one hindlimb only will rise seven to ten days after

pelvic cavity will damage the sciatic nerve and occa-

calving.

sionally the obturator nerve. Obturator paralysis (p.

As an aid to prognosis, several workers have

438), on its own, whether it is affecting one or both

attempted to use blood biochemistry. Serum CK rises

hindlimbs, will not cause recumbency. Such cows can

to astronomically high levels following muscle damage

rise, with difficulty, but will show abduction of one or

but its half-life is short and on its own has not proved

both hindlimbs. Paralysis of the sciatic nerve (p. 439) is

a reliable indicator of success. Raised serum AST levels

more serious and will prevent the cow rising.

will also indicate muscle damage and this parameter is

probably more useful than CK levels. As a prognostic

continuous access to food and water. It is surprising

indicator in cows that have been recumbent four days

how many stockworkers will forget to provide water to

or more AST levels can be quite useful. Interest in *a cow recumbent for 24 hours or more.*

serum myoglobin levels has been reported from

If the hindlimbs are continuously abducted either

Sweden (Holmgren, 1988), where early work would

due to bilateral obturator paralysis or injury from slip-

suggest that in the first three days of recumbency serum

ping on ice or concrete the application of hobbles (Save

myoglobin levels could be a valuable prognostic

A Cow, Arnolds Ltd) or a soft rope to tie the hindlimbs

indicator. Levels below 3 mg/ml would indicate likely

approximately 50 cm apart will prevent further muscle

recovery.

damage. This will sometimes result in the cow rising

It is unlikely that any one parameter will be shown

immediately, the only factor causing the recumbency

to be of value for accurate prognosis. However, a com-

being the persistent hindlimb abduction.

bination of biochemical parameters and clinical signs,

If there is any doubt as to whether the cow may still

particularly attempting to rise, should be useful. Cows

be suffering from milk fever, 8–12 g of calcium should

recumbent for three days or more must be attempting
be administered intravenously. This situation could
to rise, as well as bright, alert and eating well, for there
occur where farmers, treating their own cows, have
to be any likelihood of eventual recovery. The quality
administered subcutaneous CBG on two or more oc-
of nursing available on the farm must also be consid-
casions within 24 hours, the calcium has not been
ered in making a prognosis. Without good nursing, con-
absorbed completely and a state of hypocalcaemia still
tinual attention to bedding, feed and water, prognosis
exists. Some cows with milk fever that recover will
will be poor. Unfortunately, on many large dairy farms
relapse so, if in doubt, intravenous calcium should be
where labour is in short supply, there is often an unwill-
administered. A blood sample analysed for calcium
ingness to break from the normal farm routine to
levels would provide valuable information, if per-
provide extra attention to a recumbent cow. This infor-
formed quickly, either as a cowside test or in the prac-
mation will be available to the regular attending vet-

tice laboratory.

erinarian to the farm and will influence the prognosis.

The most important element of treatment, once the

On such farms, in the interests of the welfare of affected

cow is on a soft bed or in the field, is frequent turning

cows, one will advise immediate slaughter of many

so that she does not spend more than three hours in one

cows, while on other farms where TLC is available, they

position or on one side. Cows that are attempting to rise

would be likely to recover.

will frequently change their position and will move

from side to side. Cows with an injury, whether it is a

nerve paralysis or pressure syndrome, can often be

Treatment

turned to lie on the side opposite to which they are

Where the prognosis is considered hopeless or where it

found, but at the next attempt to rise they fall back on

is known that TLC is absent, all cows should be slaugh-

to the side that is paralysed or injured.

tered humanely as soon as possible. In some countries,

The Bagshaw hoist, which attaches to the pin bones *particularly the UK, such animals can be fit for human*

and is lifted using a fore-end loader or pulley blocks, is

consumption if they are not suffering from septicaemia,

often advocated for treatment. This equipment will

excessive bruising or any other infectious disease.

cause muscle damage and its continuous use on the

However, in the interests of welfare, slaughter must

same cow must be questioned on welfare grounds.

take place on the farm. This is perfectly legal in the UK

However, it can be a useful instrument to aid diagnosis.

as long as the cow is bled on the farm and transported

Occasionally, a cow raised by the hoist will take weight

as soon as possible to the nearest slaughterhouse and

on her hindlimbs, remain standing and slowly walk

the carcass is accompanied by a veterinary certificate

away.

that complies with the Fresh Meat (Hygiene and

In recent years interest has increased in various

Inspection) Regulations 1995. If the slaughterhouse is

inflatable rubber bags (Bovijac, Alfred Cox; Henshaw

EC approved, the carcass must reach it within 30

Airlift, J.M. Henshaw; Downer Cow Cushion, Hamco
minutes of being bled.
Products). The reasoning behind the use of these air
Treatment will of course depend on the diagnosis, but
cushions is to allow improved blood circulation to the
for the cow that has been recumbent for 24 hours or
affected legs. Unfortunately, with most of the inflatable
more a soft bed is essential. A box or barn with an earth
bags available, once inflated and the cow raised, she fre-
floor or deep litter bedding would be ideal, but if the
quently struggles and falls off the side of the bag. Cow
weather is reasonable the best place for recumbent
nets are available and a supportive harness (Downacow
cows is in a field. Cows can be transported to the field
Harness, Alfred Murray) can be quite useful.
on a gate, on a buck rake or with a cattle net on a fore-
In Denmark, water flotation is being used. The
end loader. Wherever the cow is moved it must have
recumbent cow is hauled into a drop-sided water tank
Major Metabolic Disorders • 801
and the tank filled with warm water. The cow will then

in dairy cows at or around calving. Reports of its occur-

stand, aided by the water, and is left in the same posi-

rence came from many countries, including the UK,

tion for up to seven hours a day. The system is called an

USA, France, Hungary and the USSR. The syndrome

Aqua Lift (Rasmussen, 1988).

appears to occur in high-producing dairy cattle where

The use of the Bagshaw hoist (apart from aiding diag-

overfeeding in the dry period results in overfat cows at

nosis) and the various slings and inflatable bags should

calving. Depressed appetite after calving and the con-

be questioned. If a cow cannot stand unaided there is

sequent energy deficit result in a rapid weight loss and

little point in raising her to the standing position.

an accumulation of intracellular fat in the liver. The syn-

Repeated use of the Bagshaw hoist will cause extensive

drome is associated with an increased incidence of

muscle damage and must be discouraged. Until an

metabolic, infectious and reproductive disorders such

inflatable bag has been designed that will prevent a

as milk fever (p. 781), ketosis (p. 793), mastitis (Chapter *raised cow falling off the side, these air bags have only*

23) and retained placenta (Chapter 34). Fat cow syn-

limited use.

drome as described by Morrow (1976) is clinically the

The Danish Aqua-lift would appear to be the most

most extreme manifestation of the syndrome but is

practical aid to the recumbent cow, but the capital cost

probably only the 'tip of the iceberg' and a much larger

of making the lift and providing transport for it may

number of cows were affected by subclinical FLS, as

prevent its widespread adoption.

described by Reid and Roberts (1982).

The only therapeutic agents now licensed for use in

cattle which may be of benefit in treating downer cows

Occurrence

are the corticosteroids and the NSAIDs with intra-

venous glucose as supporting therapy. However, there

The FLS was thought to be widespread in UK dairy

is little or no evidence that would suggest any thera-

cows in the late 1970s and was probably related to gross

peutic agent may have a beneficial effect and TLC *overfeeding of cows during late pregnancy, particularly*

remains the most likely effective treatment.

with the use of high levels of concentrate foods during

the late dry period. However, 'steaming up' with con-

centrates is now out of favour and is rarely practised in

Prevention

the UK, which is probably why the clinical incidence of

Selecting bulls with known shorter gestation lengths

FLS has apparently declined in recent years. However,

and ease of calving scores can, in part, prevent calving

in seasons where grass is in abundance there is still a

paralysis. Feeding of dry cows should also be monitored

danger of cows becoming excessively fat if their diet is

and frequently rationed, particularly in seasons where

not restricted during the dry period and hence FLS can

grass is plentiful. Overfat cows (condition score 3.5 or

and still does occur. At worst 50–90 per cent of freshly

over) more frequently develop dystokia due to relative

calved cows can be affected with FLS, although on some

fetal oversize. If a particular bull has been identified as

farms the incidence was very low or even non-existent.

causing dystokia, then all cows remaining that are preg-

Mortality up to 25 per cent has been reported in herds

nant to him should be considered for induced parturi-

where severe FCS exists (see also p. 796).

tion using long-acting corticosteroids (see p. 687).

The pressure syndrome is a preventable problem.

Pathogenesis

The majority of cases are a sequel to milk fever where

treatment has been delayed or is inadequate. Intra-

As most dairy cows in early lactation are in negative

venous therapy with 8–12 g of calcium as soon as possi-

energy balance they mobilize energy reserves of fat and

ble after the cow becomes recumbent, accompanied by

muscle and consequently lose body weight and condi-

moving the cow into sternal recumbency and turning

tion. The mobilization of body weight reserves involves

her so that she is lying on the side opposite to that in

the release into the blood of free fatty acids from fat

which she was found, will prevent the pressure syn-

depots and glucogenic amino acids from protein stores.

drome occurring. If the cow is down on concrete she

The fatty acids are transported via the blood to various

should be moved onto a soft bed or into a field. Many

organs, e.g. the kidney, liver and muscle, where they are

pressure syndrome cases are the result of subcutaneous

deposited as intracellular droplets of triglyceride. Thus

calcium therapy that fails to be absorbed completely.

at one to four weeks after calving there is an increased

level of fat in the liver. There is a rise in liver fat levels occurring two to three weeks before calving. This fat

Fatty liver syndrome

mobilization before calving is probably brought about

by the changes in hormonal status as the cow

In the 1970s and early 1980s the syndrome of fatty liver

approaches calving. The extent of fat deposition in

(FLS) or fat cow syndrome (FCS) was widely reported

the liver and other organs after calving is probably

determined by a number of factors including high milk

biopsy samples can then be assessed for fat level per-

yield potential, body fatness or condition at calving and

centage. The technique of liver biopsy in cattle is rela-

loss of body condition after calving. Excessively fat

tively easy to perform and should be used by all cattle

cows tend to have depressed appetites so the fat mobi-

practitioners. Levels of fat, as assessed by staining sec-

lization is exacerbated, resulting in even higher liver fat

tions of liver with toluidine blue or oil red 0, in excess of

levels and increased weight loss.

20 per cent would indicate the presence of FLS. Levels

in excess of 50 per cent fat would indicate severe FLS.

Blood biochemistry has been widely explored as a

Signs

measure of fatty liver and various parameters have

The most common indication of the existence of FLS is

been explored, e.g. non-esterified fatty acids (NEFA),

a high incidence of peri- or postparturient disease, e.g.

glucose, AST and glycerol, but these cannot, as yet, be

retained placenta, milk fever, mastitis and ketosis. Cows

interpreted with great confidence. In the USA another

with FLS will subsequently prove to be less fertile.

method of estimating liver fat levels is based on the

However, if FLS is suspected it should be noticed that *buoyancy of needle biopsy samples in water or copper*

a high proportion of the dry cows are excessively fat (in

sulphate solutions.

excess of body condition score 3.5) and many of the

cows four weeks after calving are thin (body condition

Treatment

score less than 2).

There is no proven treatment for either FCS or FLS.

Various empirical treatments have been suggested but

Clinical pathology

there is little evidence that any are of value. The logical

Cows with FLS one week after calving will have signif-

approach would be to use the same treatments that are

icant alterations in their blood constituents. Free fatty

used for acetonaemia. Increasing the glucose supply by

acids, bilirubin and AST will all be increased and

the administration of glucose, glycerol or propionate

glucose, cholesterol, albumin, magnesium, insulin and

and a glucocorticoid followed by the stimulation of

white blood cell count (WBCC) will all be decreased.

protein synthesis by the administration of an anabolic

In cows with severe FCS the WBCC may fall to as low

steroid would appear to be the most logical approach

as 3 ¥ 109/l.

to treatment.

Prevention

Pathology

Fatty liver is a sign of cows too fat at calving and losing

At post mortem, cows with FCS will have large deposits

excessive weight in early lactation. The main element of

of fat around the heart, kidney, pelvis and in the

a prevention programme is to restrict the feeding of dry

omentum. The liver will be enlarged, with rounded

cows so that they calve in a body condition score of

edges and a pale yellow colour. Intracellular droplets of

2.5–3.0. The big reduction in the use of concentrates

triglycerides will be found in liver cells, kidney, adrenal

before calving in recent years has almost certainly

glands, skeletal muscle fibres and cardiac muscle. In the

reduced the number of cows suffering from FLS at

liver the triglyceride globules are deposited within the

calving. Cows in condition score 2.5–3.0 at calving cer-

hepatocytic cytoplasm. The extent of deposition may be

tainly have appetites greater than fat cows and hence

as high as 70 per cent of total hepatocyte volume.

lose less weight in early lactation. However, dry cows

It is important to realize that the findings described

can become fat on grass diets alone in northern Europe

above may be seen in animals that have been deprived

during the spring and early summer, when grass quality

of food 24–48 hours before death. Therefore, post-

is at its best. At such times, therefore, grazing for dry

mortem findings can only assist in the diagnosis of FCS

cows should be restricted or supplemented with low

or FLS when used in conjunction with the herd history

quality fibre such as straw or hay. The rules for preven-

and clinical pathology.

tion of FLS are therefore the same as for acetonaemia

(p. 796).

Diagnosis

The history of increased disease incidence just after

References

calving followed by examination of body condition of *dry cows and cows three to four weeks after calving will*

*Andrews, A.H. (1986) The downer cow. In Practice, **8**, 187–9.*

often give a strong indication of the presence of FLS.

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Confirmatory evidence is best obtained by liver biopsy

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Chapter 47

Metabolic Profiles

D.A. Whitaker

Introduction

804

Introduction

Timing of blood tests

805

In relation to feed changes

805

The use of metabolic profiles in dairy cattle was pio-

In relation to feeding

805

neered by Payne et al. (1970) at the Compton Institute In relation to calving pattern and seasonal feeding

changes

805

of Animal Health. The approach has been adapted and

Selection of cows

805

modified since then (Blowey, 1975; Kelly et al., 1988; Early lactation group

806

Whitaker, 2000) so that it is now widely used in many

Mid lactation group

806

countries in European-type cows (for example in Italy,

Dry cow group

806

Bertoni & Cappa, 1984; in Chile, Wittwer et al., 1987; Background information

806

in Germany, Mansfeld et al., 1996; in Turkey, Sevinc & Interpretation of results at the farm

806

Aslan, 1998; in Belgium, Opsomer et al., 2000). The

Written advice

807

approach has also produced useful information in low

Metabolites measured

807

yielding cows in developing countries (Whitaker et al., Optimum values

807

1999) by drawing attention to potential constraints and

Energy balance

807

b

by confirming that some were not present.

-Hydroxybutyrate (BHB)

807

Non-esterified fatty acid (NEFA or free fatty acid)

807

In Britain the system has been developed as a man-

Glucose

808

agement aid for dairy farmers and their veterinary sur-

Bile acids

808

geons (Ward et al., 1995; Kelly & Whitaker, 2000). It Interpretation of results for energy balance: cows

contributes information for decision making about

in milk

808

nutrition in a more precise and detailed way and more

Expected forage ME

809

quickly than by other, more conventional approaches.

Interpretation of results for energy balance;

Traditionally forages are analysed, stocks of them meas-

dry cows

810

ured, targets for productivity set, financial constraints

Protein

811

considered – and a ration plan is produced from one of

Urea-nitrogen (ureaN)

811

many perfectly satisfactory sets of software. Inevitably

Digestible undegradable protein (DUP)

813

such a ration has limitations, starting with those of the

Albumin

813

Total protein

813

reliability of forage analysis and of assessment of in-

Globulin

813

takes. Furthermore, the ration may not be delivered

Minerals and trace elements

813

in practice according to the theory of the plan. It may

Magnesium

813

well be that the ration plan is for a cow producing 35

Inorganic phosphate

814

litres of milk at 4.0% butterfat and 3.3% protein, but it

Calcium

814

may actually be the only one like that in a group of

Sodium and potassium

814

cows, some of which may have just calved and others

Thyroxine (T4)

814

of which may be 100 days in to their lactations. If the

Copper

814

ration is not adequate, a farmer and his advisers can

Glutathione peroxidase (GSHPx)

814

detect this from individual milk yields, from milk con-

Manganese

815

stituents, from body weight and condition changes, from

Zinc

815

Cobalt

815

weak oestrous signs and from poor conception rates.

Metabolic profiles on milk

815

All of these, with the exception of butterfat percentage,

Metabolic profiles in maiden heifers

815

even if measured regularly and carefully, take weeks or

Metabolic profiles in suckler cows

815

months to alter enough for the presence of a problem

804

Metabolic Profiles • 805

to be clear. And once it is clear, what actually is it? If

with the first cows checked so that the majority can

the metabolic profile approach is used 'properly', then *benefit from the information derived.*

it can, within two weeks of a ration being started, iden-

Of equal importance is the need to test as soon as

tify that there is a problem, what it is and what is the

possible (see previous section) after the introduction of

best and/or the most economic solution.

a new ration, so that the judgement of the cows' bio-

The 'proper' use of metabolic profiles depends on

chemistry can be made available as quickly as possible,

care with the timing of blood tests, the selection of cows

i.e. what the cows, the end users, think of the ration.

to be included and the collection and use of background

Therefore planning of metabolic profile tests needs

information about the farm, feeding and feeding system

to be done in advance and should take into account

and physical state and performance of the cows.

both expected calving pattern and feed changes.

Without planning along these lines, time may be lost

and productivity with it.

Timing of blood tests

In relation to feed changes

Selection of cows

As changes in the diet of ruminants require changes in
The selection of appropriate cows for blood sampling is
the character of rumen activity, blood samples for meta-
very important. This is because some of the metabolites
bolic profiles should not be done until two weeks after
looked at, particularly those relating to energy balance,
a major change and activity has had time to adapt.
can quickly return to the optimum range as cows adapt
Minor changes such as an increase in the quantity of an
themselves, including their productivity, to a nutritional
existing component or in access to the same ration do
constraint. It is possible for cows to experience a sig-
not require a wait of more than 7–10 days. Changes in
nificant energy deficit in the first 2–3 weeks of lactation
forage type, such as turnout to grass, housing or the
because of intake problems, lose excessive body condi-
introduction of silage, require the full two weeks, as
tion, perhaps modify their milk yield and have their
does the introduction of concentrates or of a new type
subsequent fertility efficiency suppressed but yet still

of concentrates.

arrive at four weeks calved with all biochemical meas-

urements within the optimum ranges. This is because

In relation to feeding

the common appetite constraint of the new calved

has worked its way out and there is plenty of food avail-

There can be changes in biochemical values in blood

able for lower performance than anticipated. If blood

associated with feeding. These are most marked in cows

were sampled at four weeks calved or longer, a farmer

receiving all their concentrate ration at milking time. In

could see thin, underproducing cows with poor fertility

such cases two hours should be allowed to elapse after

but with nothing abnormal about their biochemistry.

milking before blood sampling. In circumstances where

Thus the farmer would be entitled to feel the metabolic

the major part of the concentrate input is mixed

profile test was of no value. However, if those cows

with the forages and is available for most of each 24

had been blood sampled at 14 days calved instead of 27,

hours, the timing of tests in relation to feeding is less *the blood results would have been quite different and*

critical. If lower yielding mid lactation cows are

would have identified the nutritional constraint on

included (see later), their results can be used as a check

productivity.

to see whether there is an effect of feeding on the

Individual variations in biochemical values are such

biochemical values in the blood samples. Cows should

that single cows should not be tested. Groups of no less

not be separated at milking time and confined for hours

than five should be sampled. They should not be picked

without access to food when waiting for blood sampling

at random but rather should be typical, average cows

as this can also affect the results.

of their stage of lactation. Cows with extremes of per-

formance – either very high or very low – should not

be selected. Cows with problems should also not be

In relation to calving pattern and

included because the type of analysis carried out is not

seasonal feeding changes

designed to clarify individual problems. It is important

The cow in early lactation is the most important

to make all this clear to farmers in advance because

because what happens to her in the first few weeks after

they cannot be expected to appreciate the limitations

calving has the major influence on her subsequent pro-

of the analyses made. Experience in the Dairy Herd

ductivity, including her future fertility efficiency. There-

Health and Productivity Service (DHHPS) (Kelly &

fore blood sampling for metabolic profiles should be

Whitaker, 2000) suggests that selecting cows for meta-

carried out at the beginning of each new calving season,

bolic profiles may be best done by the veterinary

surgeon himself in advance of the test after looking at

sampled. Cows tested with longer to go than that tend

the calving and production records. If there is a specific

to have normal measurements of energy balance even

concern, such as a poor conception rate, farmers may

though they can still get into difficulty. This is because

expect only cows which have failed to conceive to be

the period of greatest risk is when the volume of the *sampled. This hardly ever delivers helpful information*

pregnant uterus increases to the point that it can seri-

as any nutritional constraints have been compensated

ously inhibit food intake. It follows that, in a seasonal

for by then and blood biochemical values are usually

calving herd, the first dry cows which come in to these

within optimum ranges. The best approach may be to

last 7–10 days ought to be blood sampled, so that the

include such cows as the mid lactation group (see later).

information can be used for the benefit of the others

still to come in to the maximum risk period.

Blood sampling a group of dry cows with a month or

Early lactation group

longer to go to calving at the same time can sometimes

The definition used for this group is most critical for the

provide a useful within-herd comparison with respect

reasons given in the previous paragraph. Since the orig-

to energy balance. It may also identify the presence of

inal Compton metabolic profile (Payne et al., 1970),

dietary protein inadequacy – specifically rumen degrad-

where a high yielding cow was used as the definition, *able – in the early part of the dry period.*

the importance of this group has become increasingly

apparent. The definition also has had to be changed to

take into account changes in farm practice. The way

Background information

cows are fed now – total mixed rations, increased out-

of-parlour concentrate feeding – has reduced the time

So that full value can be obtained by the farmer from

after calving by when they can adapt themselves to an

the metabolic profile approach, information about the

unsatisfactory diet. To be sure of detecting the presence

cows and the farm should accompany the blood

of an energy constraint in particular, blood sampling

samples to the laboratory. This should include cow

should be carried out between 10 and 20 days calved –

identification; last calving date for milkers/expected for

less than 10 days and yield is still too far below peak for

dry cows; bodyweight – by calculation from heart girth

the test to be a realistic one for early lactation per-

measurement with a weighband pulled to a constant

formance; more than 20 days and some cows will be

5 kg tension is the best, because it is not affected by

thin, unproductive and subfertile but have compensated

gutfill, and usually most practical, because no mechani-

for their nutrition and they may have normal blood

cal weighing device/crush is required; body condition

metabolite values.

score by a palpation method; current daily milk yield;

expected current daily milk yield; lactation number;

daily supplementary feed intakes; daily estimated

Mid lactation group

forage intakes; analytical description of feeds and

Some cows which are past the period of peak yield,

current herd milk solids percentages. It is useful to have

and so past the greatest period of potential nutritional

information on herd size, breed, feeding systems and

stress, should always be included. They should be

health and fertility. A note of what concerns the farmer

between 80 and 150 days calved so that they are still

has, if any, should also be made.

relatively high yielding. This group provides a within-

herd comparison with the early lactation cows. Without *this it is very difficult to distinguish between problems*

Interpretation of results at the farm

caused by constraints on intake of food or protein and

energy content, to identify changes in biochemical

Circumstances where the diagnosis of a nutritional con-

values caused by mistiming of tests in relation to

straint from blood samples is clearly correct, but the

feeding or by oddities in the diet such as silage with a

cause is unclear from a distance and there could be

high butyric acid content and to make judgements on

many, are common. Therefore it is very important that

concentrate/forage usage within the herd.

a final interpretation of what is not working and what

are the best and most economic solutions ought to be

made at the farm with the information from the labo-

Dry cow group

ratory to hand. Farm advisory visits should be made as

As the dry period is so important to the success of the

soon as the results are available and discussions held,

following lactation, blood sampling to make sure nutri-

including farm staff and any other advisers involved.

tion is adequate is essential. However, the nature of the

Experience in the DHHPS suggests that such a team

measurements which can be made means that primarily

approach produces a more balanced strategy and is

cows in the last 7–10 days of pregnancy should be

more beneficial than each party working in isolation.

Written advice

important, depending on the metabolite. Group means

should be looked at and compared firstly and then the

Any advice given should be recorded concisely in

individual variations and the number of them within

writing and copies given to all participants on the farm.

each group. Variations which might relate to perform-

This ensures that the agreed path is followed, keeps a

ance, body weight, condition or stage of lactation need

record of it and ensures that the fee is for something

particular attention because they can provide important

tangible.

information on the practical causes of a constraint.

Values within the optimum ranges can also be used, in

Metabolites measured

conjunction with the background information, to give

advice of economic importance on concentrate/forage

The number of metabolites which could be measured

usage (see following sections on interpretation).

is great. For the sake of cost, not overcomplicating

the picture and speed of turn round of results, the

number is usually restricted. Metabolites measured

Energy balance

should also be confined to those from which reliable,

useful and practical information can be derived.

b ***-Hydroxybutyrate (BHB)***

Consequent actions will therefore be beneficial. It

In cows in milk the optimum level for b-hydroxybu-

needs to be borne in mind that aspects of energy and

tyrate (BHB) in blood is below 1.0 mmol/litre. BHB

protein nutrition are the most important and constitute,

reflects fat mobilization as an energy source and so

between them, at least 90 per cent of identified

higher values are associated with greater degrees of

constraints (Kelly & Whitaker, 2000).

negative energy balance. Values below 0.6 mmol/litre
Chosen metabolites need to be stable in the blood
represent a situation where cows are unlikely to be
samples after collection for two to three days while in
losing body condition. Between 0.6 and 1.0 a low and
transit to the laboratory. Methods of analysis need to
acceptable rate of fat mobilization may be taking place,
be quick, accurate and automated. Each laboratory
depending on the stage of lactation. Above 1.0 mmol/
must use an outside agency as a continual check on
litre health and productivity will be affected. Cows with
quality control and so reliability of results.
ketosis will probably have values over 2.0 mmol/litre. In
a small proportion of cows BHB results, if very high in

Optimum values

early lactation, remain outside the optimum range after
What constitutes a 'normal', or rather optimum, value
energy balance has been restored and body condition
or range of values for a metabolite in blood is crucial.
is being regained.
In the DHHPS (Kelly & Whitaker, 2000) we used orig-

Dry cows in the last month of pregnancy should have

inally the values proposed by Payne et al. (1970). These BHB values below 0.6 mmol/litre because they should

were based on population means from 2400 cows plus

be restoring and maintaining energy resources.

or minus two standard deviations. The DHHPS labora-

BHB is stable in blood after collection for several

tory has been operating since 1978, with thousands of

days. Butyric acid from grass silage, directly absorbed

blood samples passing through every year, accompa-

across the rumen wall, has been blamed for increased

nied by information on stage of lactation, feeding, per-

blood values. In our experience since 1978 this is a rare

formance and responses to advice based on optimum

problem. If it is present, all cows with access to that

values used; consequently some of the values have been

silage will have high BHB levels in blood. Including

modified. Account must also be taken of the fact that

lower yielding mid lactation cows receiving the same

variation in some metabolites is skewed. For these we

basic diet, as a within-herd comparison, provides the *have carried out a lognormal transformation (Whitaker*

most reliable means of ruling it out – if those cows have

et al., 1983) before arriving at an optimum range. For lower results than the early lactation animals which are

some metabolites, such as urea, the interest primarily is

eating the same silage.

in low values and so in variation only one way from the

optimum. Some controlled trials, where detailed meas-

Non-esterified fatty acid (NEFA or

urements of weight and condition change have been

free fatty acid)

made with blood sampling (e.g. Whitaker et al., 1989,

1993), have confirmed the otherwise largely anecdotal

The optimum level of non-esterified fatty acid (NEFA)

evidence for what is optimum. These ranges are the

in cows in milk is below 0.7 mmol/litre and for dry cows

ones quoted in the following pages.

within the last four weeks of pregnancy 0.4 or below.

Optimum values should nevertheless not be used too

The reasons for the difference are the same as for BHB.

precisely. Small variations from optimum may not be

NEFA is a more direct measure of fat mobilization than

BHB. It may rise more quickly and it often returns to

Bile acids

within the optimum range quite quickly as well,

Some laboratories include bile acid measurement in

even when negative energy balance is still present.

metabolic profiles as a means of assessing subclinical ill

Cows with ketosis have values in their blood above

health, with reference in particular to heavy fat infil-

1.5 mmol/litre.

tration (lipidosis) into the liver in the peri-parturient

NEFA is less stable in the blood sample after collec-

period as a consequence of severe negative energy

tion than BHB. It is reputed to start to rise after 48

balance. There is not firm agreement on the value of

hours, but we have not seen practical evidence of this

this. West (1991) found bile acids to be significantly

in samples analysed four to five days after collection.

correlated with the degree of a variety of liver diseases

Severe stress prior to blood sampling is also reputed to *including lipidosis, whereas Garry et al. (1994) found no cause the level to rise, but this also has not apparently*

correlation between bile acid level and liver fat content.

happened in the ten years that we have used this

Schrotter et al. (2000) found bile acid levels to be within metabolite. Sampling groups of no fewer than five cows

the normal range in cows with subclinical disorders

and including those in early and mid lactation as within-

and chronic hepatopathy. In the DHHPS (Kelly &

herd comparisons enable these potential problems to

Whitaker, 2000) we have carried out this analysis on

be set aside.

several hundred occasions alongside those for BHB,

plasma glucose and NEFA and have found that it did

Glucose

not appear to add sufficiently to the information

obtained to justify its regular inclusion.

Glucose was the first metabolite used in the Compton

Metabolic Profile (Payne et al., 1970). Because of the fundamental requirement for glucose in the tissues,

Interpretation of results for energy

homeostatic mechanisms are very strong and variations

balance: cows in milk

were not found to be great. Whole blood or serum

Raised BHB and/or NEFA values with or without low

tended to be used, neither of which are as accurate with

plasma glucose results indicate that cows are experi-

respect to energy balance as the plasma content. Added

encing a dietary energy problem and not necessarily a

to the difficulties was the fact that glycolytic enzymes

dietary energy deficiency. The easy response is to rec-

start to break down glucose after sampling. So either

ommend an increase in energy supply through more

analysis needed to be carried out very quickly or blood

concentrates. This can be completely the wrong thing

needed to be collected into a tube containing oxalate

to do, which illustrates that identifying that there is a

fluoride as an anticoagulant. This does not mix as easily

problem is the easy bit and only the start. Identifying

as other anticoagulants and sample tubes have expiry

the cause(s) and the practical solution(s) is the diffi-

dates which are easily overlooked. Glucose is also the

cult bit. Using the type of background information *most likely metabolite to change with delay in transit*

described earlier and seeing what is actually happening

and it goes down. All this has meant that glucose

at the farm are essential parts of the process.

acquired a reputation as not being very useful in assess-

There are a number of possible reasons for dietary

ing energy balance with certainty.

energy problems in milking cows, all of which should be

Our experience suggests that if blood is collected

considered:

into tubes within their dates, mixing is thorough but

gentle and analysis is carried out within four to five days

• The forage component of the diet is being expected

of collection, plasma glucose is a sensitive measure of

to contribute more energy than is reasonable, i.e.

energy balance – even within the optimum range which

not enough concentrates are being fed.

is above 3.0 mmol/litre. Sampling groups within a herd,

• Less concentrate is being fed than supposed

as for BHB and NEFA, allows a check for abnormal-

because of misunderstanding or feeders are in need *ities not associated with nutrition.*

of recalibration.

There are some nutritional circumstances where

• Too much concentrate is being fed, resulting in a

the predominant finding in a metabolic profile is that

concentrate to forage ratio in the rumen which is

plasma glucose levels are low but BHB and NEFA are

in excess of 3 : 1 on a dry matter basis. This causes

within their optimum ranges. These appear to be asso-

underutilization of the energy which is in the diet.

ciated often with a dietary shortage of fermentable

For this calculation grazing, silages, hay and straw

metabolizable energy (FME), judging by the responses

only count as forages. Often the only way to arrive

obtained to dietary adjustments.

at a ratio is to add up the amount of dry matter

Plasma glucose does increase sharply to over 5.0 mmol/

being supplied as non-forages, calculate the theo-

litre in a cow which is severely stressed immediately

retical total dry matter intake of the cow and

prior to sampling.

assume the difference is the amount of forage dry

matter being eaten. Another way of looking for this

• Grass silage can be very low in fibre – uncommon

problem is from an expected forage ME calculation

but can occur if of high quality, having been har-

(see later). Rationing, which is expecting the forage

vested very early in the spring. Mixing 0.5 kg of

component to provide less than the equivalent of

chopped straw with it may be enough.

the energy needs of maintenance (about 65 mega-

• Access to grazing is restricted – strip grazing

joules), is likely to be threatening this ratio. Loose

systems or paddocks not changed often enough;

dung provides supporting evidence.

set stocking systems allowing the development of

• The concentrate amount offered each milking is

fibrous, less nutritious grass.

too high – it is either not eaten or, if it is, causes

• Buffer feeding to grazing may be inappropriate –

transient rumen acidosis; 4 kg per milking is a *poor quality forage used; timing of access; substi-*

reasonable top limit.

tutes instead of supplements grazing; site of access

• Concentrates supplied contain too much readily

inappropriate.

soluble carbohydrate, causing rumen acidosis.

• Too much digestible undegradable protein and not

• Single feeds of concentrates, unmixed with forages,

enough energy in a ration can occur.

supplied at times other than milking, may be too

• Salt deficiency is common in some winters.

great to ensure even intakes between cows – 2 kg

• Water deprivation is easily overlooked – trough

per cow per feed is a reasonable limit.

size, site, filling rate and cleanliness can all be

• Not enough conserved forage is being offered –

constraining.

ideally fresh forages should always be readily avail-

• Inadequate dry cow nutrition and management

able to all cows at all times. Empty troughs militate

can be unnoticed – changes in diet components at *against the cows who are most at risk. Between 5*

calving; failure to allow dry cows to realize their

and 10 per cent more food than the cows are going

potential appetites in late pregnancy; fat mobiliza-

to eat should be supplied if possible/practical, with

tion and body condition loss before calving.

the surplus removed at least once daily.

• Lack of reasonable cow comfort and space can con-

• Silage or silage concentrate mixtures can become

tribute considerably to energy problems for new

stale, because troughs are not cleaned out often

calved cows and especially heifers.

enough.

• Loss of nutrients from silage due to secondary fer-

It is important to see the silage clamp, grazing fields

mentation may occur – from exposure to air or

and water troughs, to be there when food is put out to

water at the clamp face by the way it is handled or

see what happens, both with reference to men and cows,

because rations are mixed too infrequently. Silages

and to check troughs and self-feed faces at other times *of high dry matter content are more at risk. The*

when at the farm. What is said or believed to be hap-

ration warm to the hand or with steam rising from

pening is not always so!

it on a still day shows this as a problem.

There are rare circumstances where BHB levels are

• *Conserved forages may be unpalatable, in UK cir-*

raised and glucose levels are low which do not reflect

cumstances grass silages which are very wet or very

an energy problem. Observation of the cows' body con-

dry are a risk. Modern forage analytical measures

dition and their performance can support this, but

give some indications.

looking at the results in the different groups should

• *Access to conserved forages is restricted, e.g. by*

confirm it. If cows in the mid lactation group, produc-

inadequate trough space and design, troughs not

ing much less milk, have got the same scale of out-of-

filled evenly, self-feed faces tightly compressed,

range results as cows in early lactation producing a lot

severe electrified barriers, not enough ring feeders *more, then some aberration of the timing of sampling*

or the feeding facilities or the route to them are

in relation to feeding or of a direct effect of a diet con-

exposed to bad weather.

stituent, such as butyric acid in silage, is likely to be

• Different forages fed unmixed – grass silage avail-

responsible.

able as an alternative to maize or whole crop, but

not mixed with them, does not deliver the same

Expected forage ME

potential nutritional benefits as a mixture.

• Conserved forage is of low energy content –

More specifically, it is useful to look at the way the

provided it is palatable this can usually be balanced

rationing is set up for the individual cows and what con-

by other components of the diet, if the problem

tribution is being sought from the forage component –

is recognized. Laboratory analysis of forages

the expected forage metabolizable energy (ME) in

can exaggerate the energy content, particularly

megajoules. The energy the cow needs, the required *the fermentable metabolizable energy in maize*

ME (AFRC, 1993), is calculated from the cow's body

silage.

weight, milk yield and milk quality. The energy supplied

as concentrates, the fed concentrate ME, i.e. not

their expected forage ME figures are at least the same

forages, is calculated from the information obtained

as those for cows 1–5 or perhaps even greater. So blood

from the farm on fed amounts and analysis, actual

tests showing the presence of no nutritional constraint

analysis if available or book values if not. The differ-

– often looked at by farmers as a waste of money – can

ence is the energy that the rationing assumes is supplied

be used to guide the important economic management

by the forages. Similar calculations can be made to

of concentrate usage.

assess the energy contribution of forages where systems

Some further points need to be considered, however.

not based on metabolizable energy are used.

The cost of concentrates and forages may not, in every *country, be such that lower use of concentrates is more*

Expected forage ME = required ME -

economic. In addition, a reduction in concentrate input

fed concentrate ME

will mean that cows will look to increase forage intakes.

So there has to be forage offered/available to them to

The amounts of concentrates eaten per cow per day

do this or milk yields will suffer. There may be impor-

are usually the most accurate information available on

tant implications for forage stocks too because they will

feeding – certainly more accurate than the amount of

be used more quickly. Also it is necessary to consider

forage eaten. Where concentrates are mixed in with

the protein content of the ration. A reduction in con-

silage offered ad lib, individual concentrate intakes are centrates in this context is of energy supplied, but it may

less accurate and group means should be considered

mean that effectively protein input is reduced as well

first, not least because it is these which will have been

and that could also reduce milk yield. The protein

used to design the ration.

content of the reduced level of concentrate fed may

Where metabolite values have been disturbed

need to be increased to avoid this. Blood urea levels

because cows have been blood sampled too close to a

may give some guidance. If they are relatively high, no

feed, cows will have similar out-of-range levels, even

increase in protein content may be necessary. This is

though expected forage ME figures vary widely.

likely to be so where this assessment is being made in

This calculation is of further use when assessing the

cows at grass.

economic aspects of concentrate/forage usage. Table

It is worth repeating that optimum levels of BHB,

47.1 shows an example of a blood test in which all the

glucose and NEFA can be found in thin, underproduc-

energy measurements were within the optimum ranges,

ing cows in modern feeding systems after four weeks

indicating that all these cows were having their energy

calved, who have adapted their performance and their

needs met. Cows numbered 1–5 are within the second

metabolic state after experiencing serious energy con-

and third weeks of lactation, the period of greatest

straints earlier in lactation.

potential nutritional stress. Because they are in energy

balance, they must be achieving from forages the figures

Interpretation of results for energy

shown in the expected forage ME column. If they can,

balance: dry cows

then the rest of the herd can too. This means that cows

6–10, who are being asked to get less from forages,

The dry period needs to be one of maintenance and

should have their concentrate input reduced so that

restoration of resources for cows, especially high yield-

Table 47.1

Examples of individual cow results for assessing concentrate usage/forage contribution to energy needs.

Cow

Days calved

BHB mmol/l

Glucose mmol/l

NEFA mmol/l

Expected forage ME (MJ)

1

10

0.4

3.4

0.5

169

2

0.6

3.2

0.2

175

3

to

0.3

3.5

0.3

135

4

0.4

3.2

0.4

181

5

20

0.4

3.2

0.4

150

6

80

0.6

3.4

0.3

152

7

0.7

3.3

0.4

101

8

to

0.3

3.4

0.2

131

9

0.3

3.2

0.3

95

10

110

0.4

3.3

0.3

121

ing ones, to be able to realize their productivity and

matter intakes will be reduced. Expecting cows

longevity potentials. Body condition change during the

to 'fill up' even to 12 kg dry matter by providing

dry period and body condition score at calving – aspects

free access to straw does not work. Failure to *of energy balance primarily – influence productivity*

provide enough fresh, quality forage, in cows

and fertility in the following lactation (e.g. Domecq

receiving concentrates, is the commonest cause

et al., 1997; Markusfeld et al., 1997). So identifying the of negative energy balance in late pregnancy.

presence of undesirable situations during the dry period

(9)

Feed 2–3 kg of good quality concentrates/cow per

is important. Body condition scoring, if done once a

day. This increases the energy density of the total

week, is sensitive enough until the last two weeks of

food intake, compensating for the dropping

pregnancy. Then blood sampling may be the only way

appetite. It allows the rumen environment and

to confirm that there is a problem.

lining to adapt fully to concentrates by the time

The following is a dry cow management 'best prac-

cows are in milk. These processes take at least

tice' list against which current practice on a farm can be

two weeks.

checked where a problem has been found.

(10)

Ensure that these concentrates contain appro-

priate digestible undegradable protein (DUP) if

enhanced milk protein production is desired.

From drying off

(11)

Ensure that the forages contain adequate ERDP

(1)

Look upon the dry period as a unique opportu-

and if not compensate through the concentrates.

nity for rest and recreation for cows.

Specialist dry cow concentrates are usually

(2)

Provide a clean, comfortable environment in the

formulated assuming that cows, if getting grass

first month of the dry period.

silage, will be getting enough ERDP from that.

(3)

Manage cows so that they go dry at body condi-

This is not always the case. A ration with maize *tion score 2.5–3.0 on a scale of 1–5 and maintain*

or whole crop cereal silage included is more at

it until calving (p. 10). This may mean reducing

risk.

concentrate inputs in late pregnancy, which is

(12)

Ensure that appropriate minerals are incorpo-

where much overfatness develops. It may mean

rated in the concentrates or silages fed. Produc-

restricting the quality of forage available in the

tion ration minerals are satisfactory for most

first month of the dry period to stop excessive

farms for most of the time and only need chang-

increase in condition.

ing if cases of hypocalcaemia start. Free access at

(4)

Confine overfat cows at drying off on a diet of

this stage is not satisfactory.

straw balanced with adequate effective rumen

(13)

Include pregnant heifers in this close to calving *degradable protein (ERDP) to maintain rumen*

group, unless to be kept separately in lactation –

function. The restriction should be of quality and

but even then provide the same ration.

not quantity of forage so that rumen fill is main-

(14)

Oversize calves come from overfeeding in the

tained as far as possible. Only 10–14 days on this

seventh or eighth month of pregnancy, extended

regime is advisable and it must be stopped

gestation length (a function of the genetic make-

absolutely by the time of one month to go to

up of the sire) or an underdeveloped heifer with

calving.

a genetic potential to be a lot bigger. The rate of

(5)

Feed overthin cows at drying off generously

growth of the calf in the last month of pregnancy

enough for some condition to be restored.

is at its greatest but it cannot be influenced by

(6)

Provide free access minerals during the first

feeding in that month – either to increase or

month of the dry period if they cannot be mixed

decrease the eventual size of the calf.

in with the forage on offer, which is preferable.

(15)

Provide the same fresh concentrates and forages

in calving boxes/pens. Also ensure fresh water

For the last month of the dry period

supplies.

(7)

Provide the best environment and forages on the

farm.

(8)

Offer 24 hour access to fresh, quality forages in

Protein

the last month of pregnancy. All of the forage

types which are going to be fed in production

Urea-nitrogen (ureaN)

should be included. Cows should be challenged

to eat between 12 and 15 kg of dry matter each

If rumen function is satisfactory blood ureaN level is

day so that they can eat more and get to

above 1.7 mmol/litre. In some laboratories urea rather

maximum intakes more quickly after calving. If

than ureaN is measured. This makes no difference

more than 0.5 kg of straw is included, total dry

except that the values are higher by a multiplication

RUMEN

ABOMASUM

SMALL

INTESTINE

Dietary

Degradation

Multiplication

Microbes

FME

and

of

digested

ERDP

fermentation

microbes

as

protein

amino

source

acids

NH4

Heat

Liver

Fig. 47.1

Diagram of degradation and

digestion of ERDP and FME by ruminants.

Blood urea

factor of 2.14. So the optimum for urea is above

rumen function and so will look for more forage to eat.

3.6 mmol/litre.

Therefore for the approach to work, more silage must

Blood ureaN reflects the rate of arrival in the rumen

be made available to them. However, account must be

of effective rumen degradable protein (ERDP) and the *taken of the fact that forage stocks may be depleted balance there with fermentable metabolizable energy more quickly than previously anticipated. (FME), as illustrated in Fig. 47.1. Low values are the There is a further practical risk arising from the fact most important from a practical, nutritional point of that the theoretical ration plan being followed view but care needs to be exercised in distinguishing often indicates that ERDP is adequate – the reason is between values which are low because of low total food probably a shortcoming in the laboratory analysis of intake or because the diet does not contain adequate forages. Feed advisers may therefore be reluctant to ERDP. This is one of the reasons for including mid lac- agree to more ERDP – partly because it is usually tation cows in a metabolic profile test as a within-herd cheaper than the existing ration – and often suggest comparison. If the new calved cows, which are the most 'higher quality' protein, which is usually digestible likely to have appetite constraints, have low ureaN rumen-undegradable protein (DUP).*

That,

by

results and so do the mids, who should be able to eat

definition, passes through the rumen, plays no part in

readily, then the diet will be short of ERDP. If the mids

rumen function and does not work where ERDP is

have optimum ureaN results though, the diet should be

short.

adequate in ERDP but the new calved are not eating

Low ureaN results in dry cows are quite common for

as much as they should. If diet intake is the predomi-

the reasons indicated in the dry cow/energy section. As

nant problem, some of the energy metabolites may be

a dietary shortage of ERDP inhibits rumen function,

out of their ranges too. Obviously the approach to this

reduces potential appetite and enforces a change in

is different – and importantly so – from a diagnosis of

rumen function at calving, it is important to identify it.

a dietary shortage of ERDP.

The same high level of ureaN can reflect (i) an excess

On farms where maize and grass silages are not

of ERDP and adequate FME, (ii) an excess of ERDP
mixed but are offered so that cows can make a choice,
and inadequate FME or (iii) adequate ERDP but low
or where one silage is fed for 12 hours and the other for
FME. Only (ii) and (iii) need action and some other
the next 12 hours, low blood ureaN may not always
evidence of nutritional imbalance is desirable to make
relate to an overall diet shortage of ERDP. The best
the diagnosis more certain – some energy metabolites
solution then may be to promote mixing of the forages
outside their reference ranges for example. Where
rather than a change in concentrates.
ureaN results are above 3.3 mol/litre and there is evi-
Where an ERDP shortage is diagnosed and more is
dence of an energy constraint, it is worth increasing the
to be supplied, cows will respond with increased milk
level of FME in the diet. This may mean substituting
yield within 24–48 hours. They will have improved
energy sources not available in the rumen, such as pro-

tected fats, with wheat or barley for example, which are *liver health or a poor supply of amino acids from the*

high in FME.

diet. Any effect from diet is long term. Low levels will

It is not advisable to try to correct an excess of ERDP

only appear after prolonged and severe underfeeding

in relation to FME (examples ii and iii) by reducing the

of protein. If the cause is disease, the effect can be more

amount of ERDP in the diet. This is because it may be

immediate and may involve a raised globulin level as

impossible not to reduce the DUP supplied as well and

well.

so precipitate an unwelcome fall in milk yield. The sup-

Serum samples as opposed to plasma produce

position that high blood urea levels directly affect fer-

albumin results between 2 and 5 g/litre lower.

tility remains controversial and unproven. Certainly

many cows retain good fertility, or even have improve-

ments, when turned onto grass in spring with high blood

Total protein

urea levels. It is possible that observed subfertility in

Measurement of total protein is required to deduce *cows with such high levels occurs primarily because of*

globulin level. This is not directly measured and is the

negative energy balance. Therefore care should be

difference between albumin and total protein. As total

taken, if looking at metabolic profile results in herds

protein consists of something based on diet and some-

with fertility problems, before drawing definitive

thing based on disease and inflammation, it should not

conclusions.

be shown on result sheets. If it is, people who are not

aware of its content frequently draw exclusively dietary

conclusions, which are incorrect.

Digestible undegradable protein (DUP)

Higher yielding cows cannot meet their total protein

requirements from ERDP and the production in the

Globulin

rumen of microbial protein alone; DUP is required as

Globulins are produced in response to inflammation of

well. This passes through the rumen unaffected and is

the chronic type. The optimum level is below 50 g/litre.

digested in the abomasum and small intestine as an

If it is higher, the individual cow concerned has a recent, additional source to microbial protein. There is no way acute or chronic inflammation problem. The globulin of directly assessing the dietary adequacy of DUP measurement is crude and not specific, consequently a through metabolic profiles. However, if milk yield is raised value does not indicate with any accuracy the below expectation and cows are maintaining good body severity of the problem or how recently it took place. In condition in early lactation – and if ERDP supplies are some cases a cow may have some disease process clini- adequate – increased dietary DUP should be tried. As cally obvious, but the globulin has not risen at the time with ERDP, the milk yield response should be within of blood sampling. The whole value of the measurement 24–48 hours and also as with ERDP cows will be is to draw attention to the possibility of individual or looking for greater forage intakes. More must be made herd disease problems and so stimulate discussion and available and account taken of a greater rate of deple- investigation. The commonest individual complaints are *tion of conserved forage stocks.*

mastitis, metritis or lameness. The most likely herd

Before embarking on this approach a metabolic

problem in the UK is infection with Fasciola hepatica, profile test to confirm satisfactory energy balance and

when albumin levels will be low as well (p. 276).

adequate dietary ERDP is strongly advisable. As part

of a dietary shortage of DUP is often a complaint that

milk protein production is low and as energy con-

straints are the commonest cause of this, the check

Minerals and trace elements

metabolic profile test is the first step in such a com-

plaint. Farmers need to be advised as well that feeding

Magnesium

more DUP, where there has been a dietary shortage,

Blood magnesium levels should be between 0.8 and

should result in an increase in milk and milk protein

1.3 mmol/litre. This reflects current dietary intake rather

yield but not necessarily an increase in milk protein

than body tissue resources from which magnesium is

percentage.

not readily available. Low blood levels can therefore be

a matter requiring urgent action to avoid clinical

hypomagnesaemia. A number of slightly low magne-

Albumin

sium results may indicate subclinical hypomagne-

Albumin is a protein that is synthesized in the liver. The

saemia, which can affect appetite, performance and

optimum level is over 30 g/litre. Low levels reflect poor

behaviour.

Because of the complex nature of the dietary factors

to identify an iodine deficiency or the presence of

which interfere with the absorption of magnesium from

goitrogens, although the iodine content of the gland

the diet, a check test 10–14 days after increased supple-

may be. Histopathology of the thyroid gland should

mentation is advisable to make sure that it has worked.

provide confirmation. Iodine deficiency has been asso-

Low dietary magnesium in the dry period may be

ciated with poor production as well.

involved in the incidence of hypocalcaemia, but low

Measurement of inorganic iodine in plasma is also

blood levels may not be detected until a few days before

widely practised. Caution is required over interpreta-

calving. Clinical hypomagnesaemia is rare in dry cows

tion as the level is very sensitive to variation in daily

but it can occur and, if it does, is usually fatal. Under-

iodine intake. A cow which has not eaten will have a

feeding and exposure to severe adverse weather condi-

low result primarily because of appetite.

tions are the predisposing factors.

Copper *(see also p. 298)*

Inorganic phosphate

Blood copper levels are not an accurate guide to body

Plasma values also reflect current dietary intake

and liver status where most of it is found. So, while the

primarily. Optimum levels are between 1.4 and

optimum level is over 9.3 mmol/litre, clinical copper defi-

2.4 mmol/litre.

Unlike magnesium and calcium,

ciency can be found with results above or below that.

however, low levels in diet and blood can be tolerated

A number of individual results below that in a meta-

without harm to health and fertility for months

bolic profile merit further, clinical enquiry because defi-

(Brodison et al., 1989). A check blood test, a few weeks ciency, if present, will affect health and productivity.

after some low results occur, is advisable before

Recent reports of copper toxicity in cattle, perhaps

embarking on potentially expensive and probably

associated with higher absorption rates from the use

useless supplementation. Measurement of this mineral

of chelates or proteinates in minerals or overzealous

is usually carried out because of the widespread mis-

supplementation, suggest that blood levels over

conception that dietary deficiency is a common cause of

20 mmol/litre should be followed up (p. 948).

poor fertility because of the aggressive marketing of

Much more difficult is assessing the possible primary

supplements to meet this perceived need.

role of excessive molybdenum on fertility and second-

Hypophosphataemia can be a contributory cause of

arily on copper status (Phillippo et al., 1987). Suttle the downer cow syndrome (pp. 439, 797). However, mis-

(1993) suggested that this problem would not be

diagnosis can take place because a blood sample taken

present unless the forage offered contained more than

after a cow has been recumbent and not eating for 24

5 mg/kg molybdenum on a dry matter basis. Telfer et al.

hours may be low because of that only. Firm diagnosis

(1996) believe that forage values can be lower than this

can only be on response to treatment with phosphate.

and the problem may still be present because of molyb-

denum in concentrates. They have developed a complex

Calcium

system of testing blood involving a ratio between

plasma copper and serum caeruloplasmin, trichloracetic

Homeostatic control of the level of calcium in the blood

acid precipitated copper and superoxide dismutase.

is so strong that variations are small and do not reflect

This may be too arduous for many laboratories. If this

dietary intake at all. Measurement of calcium should not

problem is suspected – and forage analysis frequently

therefore be carried out as part of a metabolic profile

encourages farmers to think it is – the most practical *and should only be done as part of clinical diagnosis.*

solution may be to administer for six months an

intrareticular copper bolus to alternate cows as they go

Sodium and potassium

dry or calve and see what happens.

Homeostatic control of sodium and potassium is also

too strong to allow measurement in blood to be a reli-

Glutathione peroxidase (GSHPx) *(see p. 302)*

able indicator of dietary intake.

The optimum level is over 50 units/g of haemoglobin or

over 15 units/ml of red blood cells. As this is an enzyme

Thyroxine (T4)

containing selenium and as it has a half-life of some

Thyroxine provides an indication of the iodine status

weeks, GSHPx values reflect historical selenium intake.

of the cow. The optimum level is above 22 nmol/litre

Low values in early lactation cows, satisfactory ones in

(Whitaker, 1999). Low values have been associated with

mid lactation and lower but still satisfactory ones in dry

abortion and stillbirth. Weighing the thyroid gland of

cows describe a dietary deficiency in the dry period, *stillborn calves does not appear to be sensitive enough*

with production rations taking care of it. GSHPx values

can be dropping while selenium intake is rising and vice

measured and is virtually the same as the level in blood.

versa. Isolated groups of cattle sampled can therefore Methods of assessing energy balance through measure-produce a deceptive picture. Clinical assessment of pos-

ments in milk are available – b-hydroxybutyrate, aceto-

sibly related problems is necessary – such as muscular

acetate, ketones. There are technical difficulties, for

dystrophy, poor fertility in maiden heifers, retained pla-

example because of volatility. The practical value is less

centa, stillbirth or mastitis in early lactation. Because of

clear at the time of writing and measurements may not

the relationship with vitamin E, measurement of this in

be as sensitive as for metabolites in blood. Minerals and

blood may be advisable as well if a problem is sus-

trace elements can also be measured in milk, but there

pected. Blood selenium itself can be measured, but the

is no reliable information on reference values. Further-

analysis is too expensive for routine use.

more, as milk is manufactured for the specific purpose

of feeding a young animal, it contains concentrated

amounts of many elements, bearing little or no relation

Manganese *(see p. 305)*

to levels in blood, body or dietary intake.

Estimation of blood levels is practised but the relevance

Bulk milk measurements are generally unhelpful.

of results is questionable. Since Wilson (1966) found no

Analysis for urea is widely practised and frequently

differences in conception rates between supposedly

misunderstood by farmers causing unnecessary con-

manganese deficient supplemented and unsupple-

cern. A number of milk purchasers have now given this

mented herds no published evidence has appeared that

up. The problem is largely because the result is an

this trace element is limiting on fertility. More recently,

average for the herd and because of variations in urea

Gelfert and Staufenbiel (2000) found no evidence of

in cattle which relate to intake rather than to diet

effects on fertility in 70 dairy herds in Germany where,

content. Only if bulk milk urea is very low should there *according to published values for the manganese*

be any response and that should be a proper metabolic

content of hair and serum, deficiency should have

profile to determine the nature of the constraint.

existed.

Metabolic profiles in maiden heifers

Zinc *(see p. 305)*

In response to complaints of poor conception rates in

Optimum values for zinc concentrations in blood are

heifers, blood samplings in housed animals often show

equivocal. In UK circumstances the likelihood of

diets to be inadequate in ERDP. Sometimes minerals

primary zinc deficiency is low. Furthermore, specially

and trace elements do not all fall into optimum ranges

prepared sample tubes need to be used to avoid con-

either. Anecdotally responses are achieved by correct-

tamination from the glass or the cork.

ing the ERDP query. So investigation of this type of

complaint should not be confined to minerals and trace

Cobalt *(see p. 295)*

elements, which is where feed advisers and farmers *often expect the problem to lie.*

Levels of vitamin B12 in blood below the reference

value of 90 ng/litre are commonly found in productive,

healthy and fertile cattle. It is probable therefore that

Metabolic profiles in suckler cows

what is usually measured is not biologically active or

cattle can exist with lower levels than this without

In the DHHPS metabolic profile samplings are often

coming to harm. It may therefore be preferable to avoid

carried out in suckler herds on cows in late pregnancy

altogether the expense of a laboratory analysis of

and when new calved. While these sometimes suggest

doubtful practical value.

the presence of some mineral or trace element short-

comings, it is common to find evidence of considerable

negative energy balance at these stages, using the same

Metabolic profiles on milk

optimum blood values as in dairy cows, which may

inhibit subsequent fertility. As with dairy cows, waiting

If the same rigorous 'rules' are applied to the selection

to blood sample until inseminations are about to start

of cows, timing of tests and the use of background infor-
is likely to miss identifying the presence of the most
mation as for blood samples, using the more easily col-
probable nutritional constraint. Equally, if sampling is
lected milk can provide useful information on energy
not done until a problem of low pregnancy rates
balance and protein intakes. Failure to follow the 'rules'
is apparent, the true cause may not be revealed by it.
and failure always to check energy and protein together
Then it may be better to wait until pregnant cows are
lead to erroneous conclusions. Milk urea can be readily
available before the start of the next calving season.

Dietary shortages of ERDP are also common in
Kelly, J.M. & Whitaker, D.A. (2000) Multidisciplinary
housed suckler cows fed on low quality conserved
approach to dairy herd health and productivity manage-
forages, resulting in the waning of body reserves when
ment. British Society of Animal Science Occasional Publi-
they should be maintained.
cation, **26: Vol. 1**, 209–22.

A dangerous degree of hypomagnesaemia present in

Kelly, J.M., Whitaker, D.A. & Smith, E.J. (1988) A dairy herd health and productivity service. British Veterinary Journal, autumn and winter suckling cows is quite commonly

***144**, 470–81.*

revealed. Follow-up tests can assess the success of

Mansfeld, R., Gruneberg, W., Thiemann, E. & Grunert, E.

supplementation.

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Opsomer, G., Grohn, Y.T., Hertl, J., Coryn, M. & de Kruif, A.

be used as a way of 'asking the cows what they think of

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their nutrition'. If the timing of this question is planned

cyclicity post partum in high yielding dairy cows. Repro-

for as soon as possible in each new feeding regime, any

duction in Domestic Animals, Suppl. 6, 54–7.

shortcomings can be quickly identified and corrected

Payne, J.M., Dew, Sally M. & Manston, R. (1970) The use of before major losses in productivity, including fertility,

*a metabolic test in dairy herds. Veterinary Record, **87**, are inevitable. While the approach may well help in*

150–8.

Phillippo, M., Humphries, W.R., Atkinson, T., Henderson, G.D.

problem solving, continued use as a preplanned

& Garthwaite, P.H. (1987) The effect of dietary molybde-

exercise in the DHHPS since 1978 in Britain (Kelly &

num and iron on copper status, puberty, fertility and

Whitaker, 2000) shows that its most valuable asset is as

*oestrous cycles in cattle. Journal of Agricultural Science, a means of providing more information to cow man-Cambridge, **109**, 321–36.*

agers, more quickly and more precisely, than is possible

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by any other means.

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in tropical and subtropical countries on smallholder dairy

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73.

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Adult Cattle

System and Miscellaneous Conditions

Chapter 48

Alimentary Conditions

R.G. Eddy

The mouth and associated structures

821

Winter dysentery

852

Salivation

822

Bovine virus diarrhoea/mucosal disease

853

Simple stomatitis

822

Johne's disease (paratuberculosis)

857

Necrotic stomatitis (calf diphtheria)

822

Tenesmus

858

Papular stomatitis

822

Diseases of the rectum and anus

859

Mucosal disease

822

Rectal prolapse

859

Mycotic stomatitis

823

Rectal tears

859

Phlegmonous stomatitis

823

Recto-vaginal fistula

859

Wooden tongue (actinobacillosis)

823

The jaw

824

Fractures

824

The mouth and associated structures

Abscesses of the jaw

824

Retropharyngeal abscess

824

Examination of the mouth, muzzle, mucous mem-

Lumpy jaw (actinomycosis)

824

branes, tongue and teeth should form a part of the

Teeth

825

normal clinical examination. Mouth lesions can be signs

The oesophagus

825

of systemic diseases such as foot-and-mouth disease,

Emesis or vomiting

825

mucosal disease, bluetongue and various poisonings.

Disease of the oesophagus

826

Lesions of the muzzle and lips and occasional conges-

Oesophageal trauma

826

tion of the oral mucosa can be a feature of photosensi-

Oesophageal stenosis

826

Choke

826

tization. Injuries occasionally occur and there are a

Upper alimentary squamous cell carcinoma

828

number of infections and allergic diseases that produce

Diseases of the rumen

828

lesions of the lips, tongue and jaws. Diseases of the

Indigestion

829

gums and teeth are rare in cattle, although chronic flu-

Rumen acidosis

829

orosis (see p. 949) where it occurs will cause mottling,

Rumen parakeratosis

832

discoloration or hypoplasia of the teeth, particularly in

Bloat (rumen tympany)

832

growing animals. Even problems associated with excess

Vagal indigestion

835

tooth wear are uncommon, presumably because the

Cold cow syndrome

836

majority of cattle are slaughtered well before they

The oesophageal groove

837

reach ‘old age’.

Traumatic reticulitis

837

The main signs associated with mouth lesions are sali-

Abomasum

839

Displacement of the abomasum to the left

839

vation, excess chewing movements, frequent protrusion

Right-sided abomasal dilatation and torsion

842

of the tongue and licking of the lips and muzzle.

Abomasal ulceration

844

Swellings of either jaw will indicate lesions of the jaw,

Abomasal impaction

844

the most common of which are abscesses, infections of

Abomasal impaction in calves

845

the buccal mucosa, e.g. calf diphtheria, or lumpy jaw

Colic and acute intestinal obstruction

845

(actinomycosis). Submandibular swelling may indicate

Tympanic intestinal colic

846

mouth lesions, e.g. wooden tongue (actinobacillosis), or

Torsion of intestines (red gut in calves)

846

be a sign of cardiac or liver dysfunction, e.g. liver fluke

Prolapse of intestines through mesentery

846

(p. 276) or severe hepatitis (p. 147).

Caecal dilatation and torsion

847

Swelling of the submandibular and retropharyngeal

Intussusception

847

lymph nodes may be the result of infections such

Diaphragmatic hernia

848

Fat necrosis

849

as tuberculosis, actinobacillosis or lymphosarcomata.

Peritonitis

849

Swollen salivary glands do also occasionally occur due

Diarrhoea

850

to tuberculosis infection or infections resulting from

Salmonellosis

850

penetrating wounds.

Salivation

wedged between the mucosa and the teeth; this pro-

duces a swelling on the side of the face. Removal of the

Ruminants normally produce large quantities of saliva,

offending material and treatment with a course of par-

which acts as a buffer in the rumen to maintain the

enteral antibiotics (penicillin and streptomycin) results

normal ruminal pH. Adult cattle normally produce

in recovery, although further accumulation of cud

5–10 ml/100 kg body weight/minute. A 600 kg cow can

material may occur and this has to be removed daily

therefore produce 60 ml/minute of saliva.

until the lesion heals.

Excess salivation occurs as a result of many diseases:

The treatment of these conditions is generally

• Foot-and-mouth disease (p. 700) and infectious

symptomatic. The foreign bodies are removed, anti-

bovine rhinotracheitis (p. 289).

biotics may be administered and corticosteroids or non-

• The various causes of stomatitis, e.g. wooden tongue

steroidal anti-inflammatory agents may help to reduce

(p. 823), calf diphtheria (p. 250), and teeth-related

the painful effects of the inflammation. Most conditions

problems (p. 825).

recover quickly when removal of the offending

• Pharyngeal paralysis, although rare in cattle, is a

material has occurred.

sign of rabies (p. 908), Aujeszky's disease (p. 907),

botulism (p. 721) and occasionally tetanus (p. 733).

Necrotic stomatitis (calf diphtheria)

• Obstruction of the oesophagus, the most common

of which is choke (p. 826).

Fusobacterium necrophorus will be associated with

• Eating plants or chemicals that are themselves

necrotic lesions of the mouth, tongue and larynx. In

irritant and cause inflammation in the mouth

calves the condition is extremely common, but it does

(Chapter 54).

occasionally occur in growing or adult cattle. A fre-

• Certain chemicals such as copper, lead, mercury and

quent site is the buccal mucosa and this may be a cause

arsenic also stimulate excess saliva production

of decaying cud accumulating between the teeth and

(Chapter 54).

buccal mucosa as described above. The lesions are

necrotic and often contain caseous material. Necrotic

Salivation can be controlled using atropine at a dose

glossitis has been reported in feedlot cattle with the

of 30 mg for adult cattle and can be used 20 minutes

necrotic lesions present on the tongue. The aetiology is

prior to anaesthesia. However, the use of atropine to

unknown but is probably infectious and may be viral.

control excess salivation is not to be recommended or

The signs are of excessive salivation, swollen cheeks

considered necessary. The primary cause of the problem

when the buccal mucosa is affected and a foul smel-

should be diagnosed and corrected.

ling breath. Treatment with parenteral antibiotics or

sulphonamides is generally very effective if given over

a period of three to five days (see p. 250).

Simple stomatitis

Inflammation of the oral mucosa is characterized by

Papular stomatitis

redness and excess salivation. There are a variety of

causes, which include the following:

Papular stomatitis is a virus condition producing vesi-

cles that rupture and produce ulcerative lesions. It is a

• Traumatic injuries from the use of balling and

common condition in calves (see p. 252) but is of little

drenching guns, mouth gags and stomach tubes may

economic significance. It is, however, a differential diag-

occasionally be encountered.

nosis of foot-and-mouth disease and lesions caused by

• Foreign bodies, such as sticks and vegetable roots,

mucosal disease, but there are not usually any signs of

may damage the roof of the mouth or be wedged

systemic disease and there is no excess salivation.

between the teeth and the buccal mucosa.

• Injuries to the tongue may also occur, for example

it may be accidentally amputated by sharp metal.

Mucosal disease

Stomatitis caused by chemicals is more common.

Erosions or shallow ulcerative lesions of the dental pad,

Creosote, discarded engine oil, formalin, acids or caustic

the mucosa below the tongue, the roof of the mouth and

soda used for forage preservation, chemical dips or

occasionally the tongue occur as a sign of mucosal

sprays are all found on most livestock farms and, if left

disease, which sporadically affects growing cattle

unprotected from animals, the inquisitive cow may well

around nine to 18 months of age. The lesions are similar

consume small quantities, resulting in inflammation to

to papular stomatitis, except that vesicles do not

the oral mucosa.

precede them. Diarrhoea and wasting are also present.

Inflammation or infection of the buccal mucosa is

Mucosal disease and bovine viral diarrhoea (BVD) are

occasionally seen. Also, decaying cud may be found

described in detail on p. 853.

Mycotic stomatitis

The organism does not normally invade healthy skin

or mucosa but trauma to the mucosal surface from

Mycotic stomatitis caused by Monilia spp. is thought to sharp objects such as sticks, dried thistles, straw or

be a specific disease entity and is characterized by

barley awns will allow entry of the organism. Although

yellow necrotic lesions on the buccal mucosa, which

wooden tongue is the most common clinical manifesta-

erode, coalesce and become covered in a fibrinous

tion of A. lignieresi, the organism will produce lesions necrotic membrane. It is likely that the fungal infection

elsewhere, e.g. the oesophageal groove, the rumen wall,

is secondary and it has been suggested that bluetongue

and other soft tissues of the head and neck. It is fre-

virus (see p. 691) may cause the primary disease.

quently isolated from cervical and pharyngeal lymph

Muzzle lesions similar to mycotic stomatitis also occur

nodes. The organism, once it has gained entry into

occasionally.

tissues, produces small multiple swellings that develop

into small abscesses 2–5 mm in diameter. The sur-

Phlegmonous stomatitis

rounding tissues swell as a result of the inflammation

and the tongue may increase in size by 50 per cent.

Phlegmonous stomatitis and deep-sited cellulitis occur

sporadically in adult cattle. It takes the form of an

acute, deep-seated, diffuse, rapidly spreading inflamma-

Signs

tion of the oral mucosa, pharynx and surrounding struc-

Wooden tongue has a sudden onset, with excess saliva-

tures. It may often follow injury to the mucosa by a

tion, difficult mastication and therefore reduced feed

foreign body. Fusobacterium necrophorus, streptococci

intake. There is considerable submandibular swelling

and Escherichia coli have all been isolated from lesions.

and frequently swollen submandibular and retropha-

The onset of signs is sudden, commencing with exces-

ryngeal lymph nodes. The tongue will frequently pro-

sive watery salivation and lacrimation. The rectal tem-

trude from the mouth. The tongue (particularly the

perature is raised to 40.5–41.5°C (105–107°F) and the

dorsum) will be swollen, hard to the touch and on the

heart rate and respiratory rate are increased. There is

surface will be seen round, discrete, yellow lesions 2–

marked swelling of the face, mouth, muzzle and the sub-

5 mm in diameter. These are abscesses situated just

mandibular area. There is a foul or fetid smell to the

below the tongue epithelium. If left untreated the

breath and the oral epithelium frequently peels off. In

disease progresses so that eating becomes impossible

severe cases death may ensue within 24 hours.

and weight loss follows. Eventually death will occur due

Treatment is successful if commenced early and

to starvation.

the condition usually responds to sulphonamides or a

course of injections with penicillin and streptomycin.

Treatment

Wooden tongue (actinobacillosis)

If initiated early in the course of the disease, treatment

is generally successful. However, if treatment is delayed

Wooden tongue is a well-defined disease producing

beyond two weeks it is less likely to be so. Traditionally,

stomatitis and glossitis, mainly in adult cattle. The causal

treatment consisted of intravenous sodium iodide 7

agent is Actinobacillus lignieresi. The disease is found g/100 kg body weight administered as a 10 per cent solu-worldwide but the incidence varies considerably *tion and repeated in 10–14 days. Oral treatment with*

between countries. In the UK the incidence of the

sodium or potassium iodide is also effective.

disease has declined considerably in recent years;

Iodine treatment should continue until signs of

whereas 25 years ago the annual incidence was of the

iodism occur, such as dry scaly skin rather similar to

order of 20–30 per 10 000 cattle it has declined to less

dandruff. Sodium iodide should not be administered

than 5 per 10 000.

to heavily pregnant animals because of the risk of

abortion (see pp. 261, 302).

Antibiotics are effective. Streptomycin at a dose rate

Aetiology and pathogenesis

of 10–15 mg/kg daily given intramuscularly for 10 days

The aerobic, Gram-negative coccobacillus A. lignieresi

is effective in most cases. However, penicillin is less

is the causative organism and it produces small

satisfactory. Some workers advocate the streptomycin

abscesses commonly referred to as 'sulphur granules' in

should be injected into the lesion. Besides being soft tissues. The bacteria do not survive outside the

extremely painful to the animal this does not appear to

animal host for longer than five days but have fre-

be necessary.

quently been isolated from the faeces of normal healthy

Animals that have been affected and untreated for

animals. It is considered to be a normal inhabitant of

two weeks or more and animals that do not recover

the upper respiratory and alimentary tracts.

within two weeks of treatment should be slaughtered.

Prevention

Abscesses of the jaw

In most situations the disease of wooden tongue is spo-

Jaw abscesses present as round discrete swellings of the

radic. However, herd outbreaks have been known to

cheek and are quite common in calves and growing

occur, which may be the result of feeding hay or straw

cattle. Their size varies but frequently they are about

containing thistles, gorse or brambles. In any case

the size of a tennis ball (7.5 cm or 3 inch diameter).

affected cattle should be isolated to prevent spread of

Diagnosis is usually confirmed by paracentesis. Treat-

the infection and feeds such as those described above

ment by incising into the abscess, removing the pus

should not be offered. The reduction in UK incidence

and flushing with clean water should only be attempted

in recent years may well be related to a sharp decrease

if a soft area is apparent on the abscess surface. If pal-

in the use of hay and a corresponding increase in silage

pation of the abscess reveals the external surface to be

as a method of grass conservation.

hard all over, treatment should be delayed until a soft-

ening and pitting of one area is noticeable. This is called

pointing of the abscess. Abscesses that are opened and

The jaw

drained prematurely have a tendency to recur.

A number of conditions affect the jaw of adult cattle,

Retropharyngeal abscess

usually the lower jaw or mandible. Fractures of the

Abscesses of the retropharyngeal lymph nodes occur

symphysis (annual incidence 1 per 10 000) are a result of *occasionally. These are presented as discrete round*

falling on ice or slippery concrete and hitting the

swellings the size of a tennis ball (7.5 cm or 3 inch dia-

jaw on a hard surface. Fractures of the mandible

meter) behind the vertical ramus of the mandible. The

usually result from accidental collision with a farm

cause may be actinobacillosis or the result of infection

vehicle or occasionally a pathological fracture due to

entering a pharyngeal wound. Tuberculosis needs to be

lumpy jaw (actinomycosis) or neoplasia. Jaw abscesses

considered in countries where it is present. The treat-

are seen in calves and growing cattle. In calves these are

ment is the same as for jaw abscesses. There are a few

the sequel to untreated calf diphtheria but in growing

differential diagnoses to consider. However, the author

cattle they may be caused by infections being introduced

once encountered such a round hard swelling the size of

at the time of tooth eruption. Actinomycosis is a well-

a tennis ball in a Friesian cow. As the swelling was hard

defined infection of the mandible, but only occurs rarely.

with no defined softening the farmer was advised to wait *three weeks, by which time lancing the abscess should be*

Fractures

possible. Three weeks later, as no softening had occurred

and the cow was experiencing some difficulty with swal-

Fractures of the symphysis are presented as an acute

lowing, the animal was anaesthetized and the pharynx

onset problem. Some swelling, occasionally blood-

explored, where a tennis ball was discovered!

stained, of the lower lip will be noticed and some excess

salivation. The animal continues to eat, but with

Lumpy jaw (actinomycosis)

obvious difficulty.

Examination of the jaw will reveal bruising of the

Lumpy jaw is a chronic infectious disease characterized

lower lip and excess mobility of either side of the

by suppurative granulation of the bones of the head,

mandible. The front teeth may or may not be displaced,

particularly the mandible and maxilla. There is gross

loose or even lost.

swelling, abscesses are present, fistulous tracts and

These animals will recover in about three weeks,

extensive fibrosis all contribute to the granulomatous
provided they are isolated from the herd and food is cut
lesion. Its occurrence is quite rare in the UK (1–2 per
and brought to the animal. Grazing or feeding from
100 000 annual incidence) but is said to be more
self-feed silage faces will prove difficult for affected
common in the western and mid-western states of the
animals. Abnormal positioning of the front teeth may
USA. However, it is found at varying incidence levels
be present after healing has completed.
worldwide where grazing cattle exist.
Trauma-induced fractures of the mandible may be
Aetiology and pathogenesis
more difficult to manage. If there is no obvious dis-
placement of bone at the fracture site and no dislocation,
The causative organism is Actinomyces bovis, a Gram-
healing will take place in three weeks providing food is
positive filamentous anaerobe, which is a normal inhab-
cut and brought to the animal. If there is severe dis-
itant of the mucous membranes of the oral cavity, upper
placement at the fracture site or dislocation is present,

respiratory tract and digestive tract of most animals.

casualty slaughter is usually the wisest course of action.

The organism gains access to the soft tissues as a result

Pathological fractures due to infection will not heal

of mucosal damage caused by sharp objects or erupting

and immediate slaughter should be advised.

teeth. It generally affects cattle two to five years old.

The organism causes a low-grade inflammatory reac-

Jaw abscesses may result from infection gaining

tion. There follows a proliferation of connective tissue,

access during tooth eruption.

invasion with leucocytes and the resulting formation of

Occasionally, heifers will experience problems with

a walled tumour-like mass. The granuloma then invades

feed when teeth are erupting. This will be particularly

the bones of the mandible or occasionally the maxilla.

noticeable if the forage is in the form of self-feed silage

The hard, immovable, circumscribed lesion that results

and the clamp well compacted.

may reach a considerable size (15–25 cm in diameter)

Foreign bodies do occasionally become lodged

and will eventually interfere with mastication. The

between the teeth or between the teeth and the buccal

development of the lesion takes several weeks. Inter-

mucosa.

connecting abscesses and fistulae breaking to the

exterior and discharging small quantities of pus are a

Anatomy

frequent sequel. The pus may contain yellow granules

that, on compression and staining, will reveal the Gram-

Cattle have both temporary and permanent dentition.

positive filaments of A. bovis. The granulomatous lesion The upper front teeth are absent and the premaxilla is

will continue to invade the soft tissues of the head and

attached by a layer of fibrous tissue covered by a thick

neck and the teeth are frequently displaced or become

horny epithelium. There are 20 deciduous teeth with a

dislodged and the lower jaw may be displaced laterally.

dental formula of:

Pathological fracture of the mandible may occur (see p.

0

0

3

0

824).

I–

C–

P–

M–

¥ 2 = 20

3

1

3

0

Pathology

In the permanent dentition the three pairs of pre-

Rarefying osteitis, osteoporosis interspersed with gran-

molars in each jaw are supplemented by three pairs of

ulomatous tissue and pockets of thin pus-containing,

upper and lower molars:

yellow, sand-like granules are the main pathological

0

0

3

3

changes found in this condition. The soft tissues of the

I–

C–

P–

M–

¥ 2 = 32

head, the oesophagus and oesophageal groove may also

3

1

3

3

be involved. The lymph nodes are not involved.

The front teeth, three incisors and one canine are all

spatulate and arranged in a broad arch. The fixation

Diagnosis

of the teeth allows some dorsoventral movement

Diagnosis is straightforward and based on the clinical

within the alveoli. There is a large gap or diastema *signs. Confirmation of diagnosis is made by staining the*

separating the front teeth from those of the cheek. The

crushed yellow granules found in the pus and demon-

cheek teeth increase in size caudally and the lower pre-

strating the Gram-positive filamentous rods.

molars and molars are narrower than the upper ones.

The age of tooth eruption varies between Bos taurus

and Bos indicus and also depends on breed, sex and state Treatment

of nutrition. Examination of the permanent incisors is

Treatment with iodides as recommended for actino-

frequently used to give an indication of age.

bacillosis is sometimes advocated (see p. 823). Injecting

The deciduous teeth have little use in age determi-

the swelling with penicillin is also occasionally recom-

nation. Calves are frequently born with fully erupted

mended; however, because of the nature of lesions such

incisors and all will be in place by one month of age.

treatment is unsatisfactory. Intramuscular injection of

The average age for tooth eruption in European-type

penicillin may assist, but once better casualty slaughter

cattle is shown in Table 48.1. However, the standard *should be advised as lesions are likely to recur.*

deviation is approximately 10 per cent of the average

age. Thus for a given age of development, e.g. 2.5 years,

95 per cent of the population will be 2.5 years ± 0.5

Teeth

years, i.e. 2–3 years.

Dental problems are rare in cattle. Fractures of the

mandibular teeth occur occasionally and traumatic in-

The oesophagus

juries can result in incisor teeth being displaced or lost.

Excessive wear of the incisors indicates advancing age.

***Emesis or vomiting** (see p. 139)*

Discoloration of the teeth may result from prolonged

treatments with oxytetracyclines during the teeth devel-

Emesis (vomiting) is not a common sign in ruminants.

opment phase (see p. 1043). Discoloration and pitted

Reverse peristalsis of the oesophagus is a normal

enamel will occur as a sign of fluorosis (see p. 949).

physiological process in rumination.

Table 48.1

Average age for tooth eruption in European-type

Oesophageal trauma

cattle (Bos taurus).

The usual cause of lacerations to the oesophagus is the

Tooth

Deciduous

Permanent

result of careless use of a probang, stomach tube, or

bolusing, which can sometimes cause rupture. As the

1st incisor

Before birth

22 months

probang is rarely used in cattle practice nowadays

2nd incisor

Before birth

27 months

this problem is uncommon. If rupture of the oesopha-

3rd incisor

Before birth to 2 weeks

37 Months

gus is suspected, then immediate slaughter should be

Canine

Before birth to 2 weeks

44 months

recommended.

1st premolar

Birth to 3 weeks

27 months

2nd premolar

Birth to 3 weeks

24 months

3rd premolar

Birth to 3 weeks

33 months

Oesophageal stenosis

1st molar

–

6 months

Stenosis due to pressure outside the oesophagus can be

2nd molar

–

12 months

caused by gross swelling of the mediastinal lymph

3rd molar

–

24 months

nodes. This used to be a problem associated with tuber-

culosis, but more recently it has been reported to be

associated with lymphomatosis. Oesophageal stenosis

caused by swollen mediastinal lymph nodes resulting in

However, vomiting (when rumen contents are

chronic bloat in calves three to six months old is some-

ejected from the mouth) does occasionally occur in acti-

times reported in calves recovering from pneumonia.

nobacillosis of the oesophageal groove or with painful

conditions of the mouth caused by teeth erupting. The

Choke

ejection of rumen contents is also frequently seen in

the terminal stages of milk fever, the result of

Oesophageal obstruction or choke is a relatively

rumen pressure caused by tympany accompanying

common problem in cattle. As cattle consume food

oesophageal relaxation that occurs with hypocalcaemia,

*rapidly, incomplete mastication is normal. Regurgitation
not by reverse peristalsis. Grain overload (rumen aci-
and remastication of food boluses is relied upon to
dosis), traumatic reticulitis, diaphragmatic hernia, vagal
ensure food is ground into small particles. Apples, potato
indigestion and abomasal impaction have all been
tubers or portions of root vegetables, such as turnips,
reported to produce emesis, but in the author's experi-
fodder beet or mangolds, will all be swallowed in rela-
ence vomiting is not normally associated with these
tively large pieces, often without any mastication. The
conditions. Emesis as a herd problem has been reported
occurrence of choke therefore mirrors the fashions in
to occur following the consumption of spoiled maize
feeding cattle. When potatoes are in excess and inex-
silage. In the UK poisoning with azalea or rhododen-
pensive they are used as cattle feed and when mangolds
dron species (see p. 943) is probably the most common
and turnips were widely used choke was common. The
cause of vomiting in cattle, although poisoning by lily
presentation of the root crops also affects the occurrence*

of the valley (Convallania majalis) and sneezeweed

of choke. If large roots such as fodder beet or mangolds

(Helenium loopesii) has been reported to cause

are fed whole then choke is uncommon, but if chopped

vomiting in cattle in the USA.

they will attempt to swallow without mastication pieces

of root that are too big to pass down the oesophagus.

Strip-grazing root crops, such as stubble turnips, also

Diseases of the oesophagus

rarely results in choke. Presumably cattle bite relatively

Disorders of the oesophagus are relatively rare.

small pieces at a time. This is probably why the most

Mucosal disease/BVD does produce shallow ulcerative

common causes of choke are apples and potatoes, which

lesions of the oesophagus (see p. 853). Malignant

are the right size to obstruct the oesophagus, are difficult

catarrh (see p. 935) also produces characteristic lesions

to masticate being round and slippery and are rarely

of the oesophagus and occasionally oesophageal lesions

chopped before being fed. If potatoes are being fed,

may be found in calves suffering from calf diphtheria *ample bunker space is essential for all cows to eat simul-*

(see pp. 250, 822). Primary conditions of the oesopha-

taneously. If not, cows trying to barge through to reach

gus are:

the feed bunker may cause the cow eating inadvertently

to swallow a whole potato it might otherwise chew.

• Traumatic lacerations

• Stenosis caused by pressure from outside the

Signs

oesophagus

• Obstruction or choke

Profuse salivation, followed by bloat, are the principal

• Dilatation (see p. 139)

signs of choke because the obstructed oesophagus pre-

vents swallowing of saliva and eructation of rumen gas.

is in distress because of bloat, this is relieved by insert-

Affected cows will look distressed, the head is extended

ing a cannula into the rumen in the left sublumbar fossa,

forwards and frequent attempts to swallow are often

using a standard bovine trochar and cannula.

evident. Excess chewing movements are frequently

If the obstruction is in the cervical oesophagus a

observed and coughing, due to saliva accumulation in

spasmolytic such as hyoscine N-butylbromide and dipy-

the pharynx, may occur.

rone or butylscopolamine bromide and metamizole is

The extent of the rumen tympany is related to the

administered by intravenous injection and five minutes

length of time choke has been present and the nature

allowed to elapse before attempting to move the

of the object. A round object such as an apple or potato

obstruction. The spasmolytic will relax the smooth

will completely obstruct the oesophagus and death

muscle of the oesophagus, which is in spasm and con-

from bloat may be a sequel. If the offending object is

tracted firmly around the obstruction. Five minutes

irregularly shaped, such as a root or a portion of a

after the spasmolytic has been administered the opera-

potato, some gas may escape past the obstruction and

tor, using his fingers in the jugular groove with an

death from bloat will be avoided.

assistant holding the head forward, gradually pushes

the obstruction up the oesophagus until it reaches the

Diagnosis

laryngeal area. Frequently, when at this position and the

spasmolytic has taken effect, upward pressure with

Diagnosis is usually made on the basis of the signs of

the fingers will cause the object to be ejected into the

excess salivation, rumen tympany, forward extensions

mouth. If this does not happen then a mouth gag has to

of the head and the history of the availability of offend-

be applied to keep the mouth open and a second assis-

ing feeds. The obstruction is usually at one of three sites:

tant places his forearm into the mouth and pharynx

- *Alongside the larynx in the upper oesophagus*

and, simultaneously with the operator pushing the

- *At the entrance to the chest*

object upwards, will grasp it and be able to remove it.

- *In the thoracic portion of the oesophagus.*

If the object is large and appears reluctant to move, this

latter procedure can be carried out under anaesthesia.

The cervical sites are more commonly involved than the

It is the author's experience that anaesthesia has not

thoracic oesophagus and occasionally the obstruction

been required since spasmolytics have been available.

will be between the laryngeal area and the entrance to

If the obstruction is in the thoracic oesophagus this

the chest.

will have been detected by the use of a stomach tube.

Usually the obstruction can be seen and palpated as a

The application of gentle pressure with the stomach tube

discrete swelling, although if it is present alongside the

will dislodge the obstruction and push it into the rumen.

larynx confusion with the thyroid cartilage may occur. If

Again spasmolytic administration will enable the

in doubt or an obstruction in the thoracic oesophagus is

obstruction to be more readily moved. On occasions the

suspected the passage of a stomach tube will aid the diag-

obstruction will move on into the rumen without pres-

nosis. If the stomach tube reaches the rumen and the

sure following the spasmolytic injection. If the efforts

tympany is relieved, an obstruction, if it existed, will

described do not remove a thoracic oesophageal

probably have been dislodged. The differential diagno-
obstruction, a probang may be used. However, care must
sis should not present problems, although indigestion
be exercised when using the probang, as the pressure
and tympany may be mistaken for bloat. Bronchitis,
applied must not be too severe for fear of lacerating the
because of the cough and protruding tongue, may be, but
oesophagus. If the probang fails to dislodge the obstruc-
should not be, confused with choke. Once the obstruc-
tion a rumenotomy may be considered and the object
tion has been located, either by palpation or by stomach
removed from the oesophagus manually via the rumen.
tube, diagnosis presents no problems except with rabies
In preference to a rumenotomy and if it is certain that
(p. 908). Excess salivation is the only sign both rabies and
the obstruction is caused by vegetable matter, a rumen
choke have in common so the possibility of rabies must
trochar may be sutured in place in the left sublumbar
be eliminated by assessing other signs before proceed-
fossa to prevent bloat and the obstruction allowed to
ing along the diagnostic pathway to choke.

macerate. This may take two to four days but is usually

effective.

Treatment

Before treatment commences, the animal will need to

Prevention

be restrained in a cattle crush or at least tied in a byre

stanchion. A bulldog-type nose handler is used by an

Choke can be prevented by the shredding or chopping

assistant further to restrain the animal and keep the

of root vegetables into small pieces that will not cause

head from moving. The first element of treatment is to

obstruction. If potatoes are fed, ample feeding space is

assess the severity of the rumen tympany. If the animal

required and if they are offered at pasture they should

be placed in the field before the cows enter. Cows will

Ruminal tympany syndrome: Carcinoma of the reticu-

follow a vehicle that is unloading food and will attempt

loruminal cardia or thoracic oesophagus will produce

to eat while on the move. If they attempt to eat pota-

intermittent ruminal tympany following a period of one *toes or apples while on the move they are more likely*

to six months of gradual weight loss. The passage of a

to choke. It is rare for apples to be intentionally fed to

stomach tube will prove difficult. Papillomata of the

cattle. However, when cattle graze orchards, windfall

mouth and pharynx will usually be present and profuse

apples should be collected before allowing cattle access.

diarrhoea is a common feature.

This will not only prevent choke but also rumen acido-

sis (see p. 829) from overeating apples.

Wasting and diarrhoea syndrome: If the carcinoma is

present in the dorsal pigmented area of the rumen symp-

toms of rumen indigestion will be present. The tumours

Upper alimentary squamous

in the rumen can reach 30–50 cm (12–20 inches) in

***cell carcinoma** (see also p. 946)*

diameter. A slow loss of weight over up to nine months

Occurrence

is followed by diarrhoea, which contains much

fibrous undigested material. Ruminal tympany is

Squamous cell carcinoma of the upper alimentary tract *usually present and the abdomen is often pendulous.*

occurs sporadically in cattle grazing bracken areas.

Papillomata are usually found in the mouth or pharynx.

The problem usually affects beef cows and has been

reported in Scotland and North Wales. It occurs on

Diagnosis

farms with a high bracken cover but is less common

than another bracken-induced disease, enzootic haema-

The diagnosis may at first be difficult, as the signs may

turia (see p. 947). Both conditions have been reported

resemble choke (p. 826) or rumen indigestion (see p.

in the same animal. The disease generally occurs in

829). However, the history of the slow weight loss, the

animals over six years old. Almost invariably alimen-

presence of bracken and the occurrence in older beef

tary papillomata, in which papilloma virus can be

cows will considerably aid the diagnosis. As papillomata

demonstrated, occur in animals affected with bracken-

are almost invariably found in the mouth or pharynx of

induced squamous cell carcinoma. It is thought there-

affected animals a thorough examination of the mouth *fore that the disease is caused by a toxic factor present*

should be made if the other signs are present. Johne's

in bracken that activates papillomata in the alimentary

disease (p. 857) may also be confused with this condition

tract to develop into squamous cell carcinomas.

but the distinguishing feature is the consistency of the

faeces. In Johne's disease the faeces are homogeneous,

Signs

there being no signs of undigested fibrous material.

The clinical signs can be divided into four main syn-

dromes that are related to the site of the carcinoma,

Treatment and prevention

which can occur in the pharynx, oesophagus or rumen.

There is no treatment and as the condition is invariably

fatal affected animals should be slaughtered as soon as

Oropharyngeal syndrome: The presence of the carci-

possible.

noma in the oropharyngeal region will produce a chronic

To prevent the condition, cattle should not have access

wasting condition of one to six months' duration. A

to bracken. Where bracken exists on a farm cows will *cough may be present in the last two to four weeks of the*

rarely eat the bracken if adequate food is available.

disease and excess salivation and drooling will often be

evident. Snoring may also be a feature and halitosis is

frequent. Examination will reveal a tumour in the mouth

Diseases of the rumen

or pharynx. Papillomas will also be present. The sub-

mandibular lymph nodes may be enlarged.

There are a number of diseases that affect the rumen,

all of which cause inappetence, reduced milk yield and

Oesophageal syndrome: If present in the oesophagus

failure to thrive. An essential element in a thorough

the carcinoma will produce signs similar to choke

clinical examination of the bovine is to observe whether

with partial or complete occlusion of the oesophagus.

the rumen is tympanic by observing distention of the

Halitosis, coughing and drooling may be present and

left sublumbar fossa, the animal is chewing its cud,

gurgling sounds may be heard coming from the

eructating normally and normal rumen contractions are

oesophagus. The passage of a stomach tube may prove taking place. Rumen contractions can be detected by

difficult. The history will include a gradual weight loss

palpating with slight pressure in the left sublumbar

over a period of one to three months. Papillomata may

fossa and detecting the rumen movements, which occur

be present in the mouth or pharynx. A palpable mass

approximately every 30 seconds. Eructation will accom-

in the oesophageal region will be present.

pany every second rumen contraction.

Indigestion

Diagnosis

Simple indigestion is to be suspected if the rumen con-

Diagnosis of simple indigestion will be based on the clin-

tractions are weaker than normal, are less frequent and

ical examination and the elimination of any other

the clinical examination has revealed no other evidence

disease. There is very little in the way of laboratory tests

of disease.

that can be useful. An increase or decrease in rumen pH

Simple indigestion is frequently seen in dairy cows

*may be a useful guide but tends not to be used in prac-
when new feeds are suddenly introduced to the diet.
tice because of its impracticability. The history may be
Intakes of large quantities of very wet grass, frosted
the most useful clinical indicator and may suggest a ‘feed
feeds, sour or spoiled feed, e.g. butyric or soil-
problem’. If only one cow in the herd is affected the
contaminated silage, or the sudden introduction of large
history may not be helpful and the diagnosis more diffi-
quantities of concentrate feeds may all predispose to the
cult. However, if the whole herd or a substantial part of
onset of indigestion. The accidental intake of small
the herd were suddenly affected with inappetence it
quantities of antibiotics, which disturb the rumen flora,
would be quite logical to suspect a ‘feed problem’.
will also precipitate indigestion, as is seen in feedlot beef
Other diseases that may be readily confused with
cattle when rations containing monensin sodium are first
simple indigestion are displaced abomasum, traumatic
introduced. Dairy cow concentrate rations containing as
reticulitis, lesions of the oesphageal groove, early milk*

little as 0.005 mg/kg dry matter (DM) of lincomycin have

fever and acetonaemia. A thorough clinical examina-

been incriminated in causing severe indigestion of whole

tion will eliminate these other diseases.

dairy herds with a consequent 50 per cent reduction in

the herd milk production. The lincomycin contamina-

Treatment

tion occurred at the compound mill where the milling

Many animals suffering from indigestion will recover

equipment was used to produce dairy concentrate

spontaneously in two to three days if they are removed

immediately following the production of a pig feed con-

from the offending diet and allowed access to good

taining lincomycin.

quality hay.

Relatively minor changes in rumen pH are likely to

A large number of treatments for indigestion have

cause atony of the rumen. The intake of any indigestible,

been employed and were administered as drenches.

stale or sour feeds will interrupt the process of rumen

Historically mixtures containing nux vomica, gentian, *fermentation, which changes the pH resulting in rumen*

sodium bicarbonate, magnesium carbonate, etc. were

atony. The sudden introduction of new feeds to which

frequently used and acted by altering the rumen pH and

the rumen is unaccustomed will have a similar effect.

stimulating appetite and even providing vitamins and

The rumen is a versatile fermentation chamber and

trace elements essential for rumen microbial synthesis.

will accommodate a wide, variety of feeds, e.g. 100 per

However regulations on the use of licensed medicines

cent cereal diets in feedlot beef production, extremely

in food animals have resulted in all such preparations

wet grass in some seasons and highly fibrous foods such

being withdrawn by the manufacturers.

as hay or straw. However, if changes to the diet are made

If the rumen is atonic for more than 24 hours the

the rumen flora have to adapt to the new feed and to

administration of rumen inoculum obtained either from

prevent indigestion occurring, the changes should be

an abattoir or a healthy cow will aid recovery. Probi-

gradual. Thus new food should be introduced in small *otics may also be helpful.*

quantities at first, with the intake being gradually

increased daily.

Prevention

The prevention of indigestion is not always straightfor-

Signs

ward. The avoidance of abrupt changes in feeds and of

indigestible, sour or putrefied feeds is relatively easy.

The first clinical sign of simple indigestion will be

However, cows will break out into pastures where they

reduced appetite and in dairy cattle a simultaneous

should not be and will, if given the opportunity,

milk yield reduction will be apparent. The reduction in

consume foods of dubious quality in large enough

feed intake may be as much as 50 per cent with no other

quantities to be harmful. The frequency of occurrence

obvious signs. The cow may be slightly depressed.

of simple indigestion on a farm is likely to be inversely

Rectal temperature will be normal and heart rate raised

related to the quality of management that exists.

slightly to around 80/minute. There may be mild diar-

rhoea and a mild rumen tympany may be present. In

Rumen acidosis (grain overload,

chronic cases of indigestion undigested fibre may be

overeating syndrome, barley poisoning)

present in the faeces. Rumen contractions will be

reduced in strength and frequency, often to as few as

Wherever intensive livestock production is practised

one contraction every 3 or 4 minutes.

acute indigestion as a result of excessive intakes of

grain, beans or compound feed is common, either as a

Chemical damage to the rumen mucosal epithelium

result of cattle gaining accidental access to grain stores

results in bacterial and fungal organisms penetrating

or by the sudden introduction of unlimited supplies of

the rumen wall and in chronic acidosis will lead to the

grain to the diet. There are two distinct syndromes asso-

occurrence of liver abscesses, which are frequently seen

ciated with overeating.

in beef cattle raised on 100 per cent cereal diets.

The most common is acute acidosis as the result of

Urine output will be decreased as a result of the

consuming excess carbohydrate, which rapidly ferments

dehydration and will also be acidic, containing high

leading to lactic acidosis followed by acute dehydration

levels of lactate. The damage to the rumen epithelium

and depression. Accidental access to compound feed

leads to a chronic rumenitis, which in turn causes an

stores by cattle, who will readily consume 15–20 kg of

increased incidence of bloat. This is often seen in feed-

concentrate, is the most common scenario but the

lots as a cause of sudden death. Although the main signs

problem is also seen in feedlot beef cattle fed ad libitum of acidosis are the result of lactate absorption an addi-cereal-based diets, particularly when the diet is first

tional component may be the absorption of endotoxins

introduced. Excess intake of apples by cattle grazing

released from the destruction of large numbers of

orchards is also a common cause of rumen acidosis.

Gram-negative bacteria in the rumen.

Alkalosis: A less common syndrome occurs as a result

Signs

of excessive intake of highly fermentable proteinaceous *feeds, e.g. soya bean, which results in excess ammonia*

The speed of onset and the severity of clinical signs will

production in the rumen leading to alkalosis with

depend on the quantity and nature of the food consumed

excitement and hyperaesthesia.

and whether the rumen is adapted to that particular

feed. Newly introduced feeds may well prove fatal to

animals that are not accustomed to the particular feed

Pathogenesis

in quantities that other animals consume regularly. Also,

The rumen can be visualized as a continuous culture fer-

feedlot animals that are apparently accustomed to cereal

mentation vat. The rumen microflora constitute the

diets will sometimes overeat for no apparent reason.

culture, which grows on the substrate or medium being

Feedlot cattle being fed cereal diets are probably in a

provided by the feed the animal consumes. The rumen

continuous state of mild acidosis and a relatively small

microflora form a balanced colony of bacteria and

increase in intake will produce enough lactic acid to

various protozoa. If the feed content changes the *destroy the remaining Gram-negative bacteria and*

balance of the microflora will need to change, e.g.

produce clinical signs of acidosis. Problems also arise

increase in intakes of highly fermentable carbohydrate

should cattle on ad libitum feed run out of cereal and will lead to streptococci and lactobacilli organisms pre-then are immediately introduced to the old level. Water

dominating. With a normal balanced microflora the fer-

deprivation can also produce a problem.

mentation end products are the volatile fatty acids

Clinical signs usually become apparent 12–36 hours

(acetic, propionic and butyric acids), which are absorbed

after the engorgement. Incoordination and ataxia are

from the rumen. Bacterial cell proteins for digestion and

the first signs to be noticed with the stockworker report-

absorption in the lower intestine and water-soluble

ing the cattle as 'drunk'. The animals will be anorexic,

vitamins are also products of the fermentation process.

they may appear to be blind and will rapidly become

The streptococci and lactobacilli organisms that

weak and depressed. The rumen will be distended

predominate when excess carbohydrate is ingested *producing abdominal pain, which causes the animal*

produce lactic acid as a fermentation end product.

to grunt or grind its teeth and ruminal movements cease.

Lactic acid production increases the rumen osmotic

Dehydration becomes apparent within 24–48 hours

pressure and fluid is drawn into the rumen from body

and severe diarrhoea will be evident in animals that do

tissues. The rumen pH also drops and the majority of

not die immediately. The faeces will be a pale 'pasty'

Gram-negative bacteria and protozoa are destroyed.

colour. Respiratory rate will be raised because of the

The pH may drop to 4.5. The lactic acid is converted to

acidosis, the rectal temperature depressed by 1–2°C

sodium lactate, which is absorbed directly from the

(2–4°F), the heart rate is in excess of 180/minute and

rumen into the blood or is passed down the intestinal

the pulse weak. Severe cases will become recumbent

tract and absorbed from the abomasum or small intes-

with the head resting on the shoulder, as in milk fever.

tine. The presence of sodium lactate in the small

Death will occur within 24–48 hours in acute cases.

intestine produces an osmotic gradient and draws water

In feedlot cattle that recover some animals fail to

into the small intestine, thus contributing to the diar-

thrive even after apparent recovery and this can be

rhoea. The sodium lactate in the blood reduces blood

due to chronic rumenitis, liver abscesses, or chronic

pH.

laminitis (p. 420).

Alkalosis: The signs are not completely typical but

Table 48.2

McSherry's solution.

they do involve muscle tremors, convulsions and slow

shallow respiration. In the later stages there may be

Sodium chloride

4.95 g

dyspnoea and hyperpnoea.

Sodium acetate

7.50 g

Potassium chloride

0.75 g

Calcium chloride

0.30 g

Clinical pathology

Magnesium chloride

0.30 g

Affected animals are dehydrated and show haemocon-

Water

1 litre

centration. Blood pH may also be depressed. The pH of

rumen contents will be 4 or lower and urine pH around 5.

However, in practice, laboratory tests are rarely per-

dration and acidosis corrected using a balanced elec-

formed because of the necessity to institute treatment

trolyte, e.g. McSherry's solution (see Table 48.2), and 5

quickly and the diagnosis is rarely a problem. In

per cent sodium bicarbonate solution intravenously. Up

order to assess blood pH, bicarbonate and total carbon

to 60 l of electrolyte solution will be required for an adult

dioxide levels need also to be measured.

cow over a 24-hour period. Up to 300 ml of 5 per cent

At post mortem of acute cases the rumen will be dis-

sodium bicarbonate solution may also be administered,

tended, containing excess fluid with evidence of grain

the quantity required depending on the degree of aci-

particles present. Rumen pH evaluation at post mortem

dosis present and can be assessed by observing a slowing

is of no value unless done immediately after death

down of the respiratory rate during its administration, if

because post-mortem changes will increase the pH.

given slowly. Supportive therapy should include intra-

Chronic acidosis as a result of long-term cereal intake

venous calcium borogluconate (400 ml of 30 per cent

may be characterized by rumenitis, although to observe

solution) and 400 ml of 40 per cent dextrose solution.

this the examination must be performed soon after

For less acute cases that are still standing, the oral

death. Multiple liver abscesses may also be present in

administration of magnesium hydroxide, magnesium

chronic acidosis.

carbonate or aluminium hydroxide at a dose rate of

1 g/kg body weight mixed in 10 l of warm water and

Alkalosis: If the less common syndrome of alkalosis is administered by stomach *tube will help restore rumen*

present due to the ingestion of excess soya beans or

pH. The dehydration and acidosis is corrected using

similar high-protein feeds, the rumen pH may be alka-

an electrolyte solution and sodium bicarbonate intra-

line and the urine and blood pH will also be raised. On

venously as for peracute cases. Intravenous administra-

occasions there is a paradoxical acidic urine.

tion of a vitamin B/vitamin C mixture is widely used in

the UK with apparent success. Doses of 30–50 ml intra-

Diagnosis

venously are frequently used and are thought to aid

detoxification of lactate in the liver.

Diagnosis is not usually difficult and is frequently made

Antihistamines are also considered to be of value by

on the history together with signs of incoordination and

some clinicians. Calcium borogluconate and 40 per cent

ataxia. In feedlot beef animals it is usual for several of

dextrose are also useful as supportive therapy when

the group to be affected, but with dairy cattle any

administered intravenously.

number may be affected, depending on how many cows

had accidental access to the grain store, which is the

Alkalosis: Treatment of alkalosis resulting from soya

most common scenario. Cows grazing orchards will

bean or high-protein engorgement should consist of an

consume large quantities of apples, particularly after a

electrolyte mixture containing excess chloride such as

storm, and again the history should be of considerable

Ringer's solution. Volumes of 30–50 l will be required

help in reaching a diagnosis.

over a 24-hour period, but no bicarbonate should be

Laboratory tests are not normally necessary and

used. All concentrate feeds should be withdrawn from

unless a result can be available within an hour or so are

the diet and only hay or silage offered.

of no value in the practice situation because to be effec-

tive, treatment must be administered as quickly as pos-

Prevention

sible. The prognosis for peracute recumbent cases is very

poor, but for the less acute standing cases the prognosis

Bulk storage of concentrates in large bins has reduced *is relatively good provided treatment is not delayed.*

the incidence of acidosis in many dairy herds where

accidental access of feed stores with concentrate stored

in bags was once quite common.

Treatment

In feedlots where concentrated food is fed ad libitum, In peracute recumbent cases the rumen should be

often to the exclusion of long fibre, introduction to the

emptied by rumenotomy (pp. 834, 1106) and the dehy-

concentrate must be gradual and the feed bunkers

should be of adequate size to allow all animals to feed

ticularly towards the end of the feeding period. Com-

together. The feeders should not be allowed to empty

plications such as peritonitis, septicaemia or even endo-

to avoid excessive intake by hungry animals once the

carditis may occasionally be evident.

feeders are refilled. Continuous access to the food will

allow 'little and often' intakes of food. Ideally, some

Diagnosis

roughage should always be available even if it only rep-

The diagnosis in the live animal is extremely difficult

resents 10 per cent of the DM intake. Roughage avail-

because the reduced growth rate and inappetance are

ability has been shown to reduce the incidence of liver

signs of many diseases. As it is a group problem the

abscesses in cereal-produced beef in the UK. It is also

detection of the rumen wall lesions and liver abscesses

advisable that the grains should not be finely ground,

at post mortem will be the best diagnostic indicator.

which in itself encourages rapid fermentation. The grain

should be cracked or rolled and more recently whole

Treatment and prevention

grain has been fed without seriously affecting the diges-

tion of the cereal.

The treatment of individual cases by the time they show

inappetance and poor growth rates is unrewarding

Rumen parakeratosis

because of the severity of the damage to the rumen wall

and liver. However, if the problem is suspected (by the

Parakeratosis of the rumen epithelium is a common

post-mortem examination of some animals from the

sequel to the feeding of 100 per cent concentrate diets
same farm at the abattoir) feeding 10–20 per cent of the
to cattle. The disease is characterized by enlargement
diet in the form of long roughage will prevent deterio-
and hardening of the rumen mucosa papillae and may
ration and allow the animals to reach slaughter weight.
affect 100 per cent of animals reared on 100 per cent
Prevention depends on the inclusion of 10 per cent long
cereal diets. The disease syndrome also includes the
fibre in the diet, although recent experience has shown
associated lesions of liver abscesses and possibly lamini-
that feeding whole grains will reduce if not eliminate
tis. Parakeratosis may occur as a secondary stage of
the problem of rumen parakeratosis and liver abscesses.
acute rumen acidosis.

Bloat (rumen tympany) *(see also p. 234)*

Pathogenesis

Bloat or rumen tympany is a disease easily recognized
The association between liver abscesses, lesions of the
and feared by cattle farmers. Bloat refers to an exces-
rumen mucosa and the feeding of 100 per cent concen-

sive accumulation of gas in the rumen and, because

trate diets to ruminants has long been recognized. The

of a failure to eructate, rumen distension occurs, fre-

lower rumen pH associated with concentrate diets and

quently resulting in death. It is a major cause of death

the consequent increase in lactic acid production pro-

in cattle in all intensive livestock areas of the world.

duces an inflammatory reaction of the rumen mucosa.

There are two types of bloat, gaseous bloat or sec-

This damage to the mucosa allows debris to adhere to

ondary rumen tympany and frothy bloat or primary

the mucosa causing ulceration and infection and result-

rumen tympany.

ing in abscess formation in the rumen wall. The rumen

papillae become enlarged and thickened and may clump

Gaseous bloat (secondary rumen tympany): Any con-

together to form bundles in response to the inflamma-

dition that causes an oesophageal obstruction or that

tory reaction. The papillae may contain excessive layers

interferes with eructation will produce gaseous bloat.

of keratinized epithelial cells, particles of food and bac-

The condition is generally sporadic in occurrence and

teria. A sequel to the damage to the rumen mucosa is the

is less common than frothy bloat. The following condi-

presence of liver abscesses. Some workers also report

tions will lead to gaseous bloat:

that laminitis is a later sequel but, as laminitis has been

found in the absence of rumen and liver lesions, the role

• Lesions of the oesophageal groove, e.g. vagus indi-

gestion, abscessation or infection with A. lignieresii

of acidosis in the aetiology of laminitis is far from clear.

obstruct the groove and prevent eructation (pp.

826, 837).

Signs

• Physical obstruction of the groove with afterbirth

Rumen parakeratosis does not necessarily produce

has been reported (p. 836).

signs of disease, although it has been reported that the

• Physical obstruction of the oesophagus with pota-

addition of 10 per cent hay or silage to the diet of 100

toes or other root vegetables causing choke will

per cent cereal-fed cattle will improve appetite and *prevent eructation (p. 826).*

weight gain. Some individual animals that are seriously

• Pressure on the oesophagus by enlarged mediastinal

affected with abscesses in the rumen wall and liver may

or bronchial lymph nodes prevents gas escaping

show reduced appetite and reduced growth rate, par-

through the oesophagus. This is a common problem in

growing cattle three to six months old, particularly

bloom stage, undoubtedly predispose to the occurrence

those that have been affected with pneumonia (p. 239).

of frothy bloat. Frothy bloat does also occur in feedlot

• Inability to eructate is also a feature of tetanus (p.

cattle, particularly if fed on finely ground grain. This

733) and milk fever (p. 781) and gaseous bloat is a

may be due to the gases being trapped by the fine par-

frequent feature of these diseases.

ticles of feed, but the rapid fermentation that follows

• Prolonged lateral recumbency as a result of disease

the feeding of finely ground grain is undoubtedly a con-

or animals that are cast for prolonged surgery will *tributory factor. Adaptation to a particular feed is also*

frequently lead to gaseous bloat because of the

important. As the rumen microflora adapts itself to the

inability of the rumen gas to escape. Cattle that

particular pasture or ration there is a tendency towards

inadvertently fall in dorsal recumbency into ditches

reduced susceptibility.

will generally die of bloat if not retrieved in time.

• Severe damage to the rumen epithelium following

Signs

acute acidosis may lead to rumen atony and accu-

Rumen tympany, as evidenced by distension of the left

mulation of gas (p. 829).

sublumbar fossa, is well recognized by most stockwork-

• Excess cereal ingestion usually results in gaseous

ers and should present no problems. With severe

bloat (p. 829).

tympany the animal will be exhibiting signs of pain, e.g.

Frothy bloat (primary rumen tympany): Frothy bloat is

kicking its ventral abdomen and bellowing. The bellow-

much more common than gaseous bloat and usually *ing can frequently be heard up to 500 m (1/3 mile) away.*

affects several animals in the group at the same time.

In acute frothy bloat the disease progresses rapidly and

Although frothy bloat does occur in feedlot cattle it is

the animal soon becomes recumbent and can die in

more generally associated with pasture feeding. Pas-

30–60 minutes from the onset of tympany.

tures that are most commonly incriminated in the cause

Pathology

of frothy bloat usually contain high levels of legumi-

nous plants, particularly clover or alfalfa.

Post-mortem bloat in ruminants that die from other

Frothy bloat is extremely common in some countries,

causes can be confusing to the diagnosis of the condition.

e.g. New Zealand (p. 127), due to the high content of

If the animal is seen soon after death, death from bloat

clover in the sward. In these situations the problem is

will be obvious because of the gross abdominal disten-

well recognized and anticipated so that prevention reg-

sion and at post-mortem examination oedema in the

imens are universally applied. In the UK, frothy bloat

inguinal and ventral perineal region together with con-
can appear suddenly without warning on lush spring or
gestion and haemorrhage in the anterior parts of the
autumn pastures and up to 25 per cent of the herd may
carcass will be evident. The liver will be extremely pale
be suddenly affected. Some of these pastures may not
due to compression and the rumen will be grossly dis-
contain a high clover content. The onset may be ex-
tended and contain froth. The quantity of froth present
tremely sudden, often 4–6 hours after milking and return
declines after death. Rupture of the diaphragm and the
to the grazing areas. The only warning that the farmer
abdominal musculature, particularly in the inguinal
experiences is the bellowing of several cows in extreme
region, may also be apparent. Death from gaseous bloat
pain, and on reaching the field there may be several cows
is less common, but the absence of froth and the finding
recumbent or even dead, with many others exhibiting
of a primary lesion should differentiate it from frothy
rumen tympany to varying degrees of severity.
bloat.

Pathogenesis

Diagnosis

Bloat is the result of the inability to eliminate gas from

The preliminary diagnosis presents no problems and is

the rumen by eructation. With gaseous bloat this is sec-

based on distension of the left sublumbar fossa. If only

ondary to some other condition or disease.

one animal is affected in the herd the bloat is probably

With frothy bloat eructation is prevented by the

a gaseous bloat but if several animals are affected to

accumulation of froth, which prevents gas escaping into

varying degrees and they are at pasture the diagnosis

the oesophagus. The production of froth or foam is a

will certainly be frothy bloat. However, if there is any

result of the raised viscosity of the rumen fluid and the

doubt the passage of a stomach tube will provide the

small bubbles of gas, the natural product of rumen fer-

answer. If the problem is one of gaseous bloat and the

mentation, cannot coalesce. Under certain conditions

stomach tube reaches the rumen and possibly removes

some naturally occurring plant substances, e.g. saponins, *an obstruction on the way, the gas will escape through*

pectins, hemicellulose and certain proteins, will raise the

the stomach tube and the rumen will rapidly revert to

viscosity of rumen fluid. There also appears to be an

its normal size. If gaseous bloat is confirmed and the

individual animal susceptibility. Succulent, high-protein

bloat relieved, a full clinical examination should be per-

plants, particularly the leguminous plants in the pre-

formed to ascertain the cause of the failure to eructate.

If the bloat is due to froth little or no gas will escape

standard surgical closure. Antibiotics are administered

via the stomach tube, which will itself become blocked

postoperatively and recovery is usually uneventful.

with froth.

Chronic gaseous bloat in calves and feedlot animals

is often treated by establishing a 10–15-cm length

rumen fistula. Under local anaesthesia the skin and

Treatment

musculature of the sublumbar fossa are incised and the

The traditional treatment for bloat was the passing of a

rumen exposed. The rumen is then incised and the
5 mm diameter trochar and cannula into the rumen via
rumen wall sutured to the skin. Alternatively, a pros-
the left sublumbar fossa. Many farmers possess such a
thetic device may be sutured into the abdominal wall
trochar and cannula. However, this instrument is of
and the rumen, allowing gas to escape (see p. 827). This
little use because gaseous bloat can nearly always be
device may be removed two to three months later and
relieved by stomach tube and only when this is not pos-
the wound allowed to granulate, by which time the
sible should a rumen trochar and cannula be used. For
primary cause of the bloat will have corrected itself.
frothy bloat the cannula itself becomes blocked with
froth and does little to relieve the tympany.

Prevention

Treatment for all but the peracute cases necessitates
the passing of a stomach tube and, if this reveals the
To prevent further cases of frothy bloat occurring when
bloat to be frothy, antifoaming agents that reduce the
a sudden acute outbreak is encountered at pasture the

viscosity of the rumen contents and disperse the froth

cattle should he removed immediately, provided with

can be passed down the stomach tube. Vegetable oils

dry food such as hay or straw and all cows showing any

such as linseed, peanut, corn or soya bean oil are all

degree of rumen tympany drenched with an antifoam-

useful antifoaming agents. Traditionally, 500 ml of

ing agent. The pasture should not be used for grazing

linseed oil to which is added 50 ml of turpentine was

for at least 10 days.

effectively used as a bloat drench, but this does tend to

Where risk pastures exist, e.g. those containing high

taint the milk. Oil mixed with detergent will disperse

proportions of legumes, gradual access to the pasture

faster in the rumen ingesta.

should be practised, starting with 10 minutes a day and

Proprietary bloat drenches containing silicone or

increasing by 10 minutes each day. Long fibre should be

poloxalene are available (Table 48.3) and are equally

fed before access is allowed to the pasture. Strip-grazing

effective. Within five minutes of administration of the

*to restrict intake can be practised, but is not favoured
antifoaming agent the animal will start to eructate and
by stock farmers who currently prefer paddock grazing
in most cases the tympany will be relieved within one
or set stocking. However, during high-risk periods in
hour. If tympany still exists after one hour, a further
problem areas these methods alone will not be satis-
administration of an antifoaming agent by drench may
factory. In New Zealand and Australia, where the risk
be given. If tympany still exists one hour after the second
from bloat can be exceedingly high, during the spring,
drench the diagnosis should be reassessed and a stomach
when the pasture is fast growing, the only satisfactory
tube passed to ensure there is no oesophageal obstruc-
method of control has been the daily administration
tion. Once the diagnosis of frothy bloat has been estab-
of antifoaming agents by drench after milking. Oils
lished in a group of affected animals the less acute cases
may be given at doses of up to 240 ml/day in high-
can be treated by drenching alone.
risk periods, although 60–120 ml/day would be more*

In peracute cases where death is imminent and the

common. Poloxalene, a non-ionic surfactant, is fre-

animal is recumbent, it will be necessary to conduct an

quently used at 10–20 g/head per day and up to 40 g/day

emergency rumenotomy (p. 1106). A 10–20 cm vertical

in high-risk periods.

incision is made in the mid point of the sublumbar fossa,

If strip grazing is practised, the antifoaming oils can be

using a sharp knife. On incising the rumen there will be

emulsified with water and sprayed on the grass daily.

an explosive release of rumen contents and marked relief

Addition to the water supply is sometimes used, but

for the cow. Following the release of the frothy rumen

effectiveness does depend on adequate individual intake.

contents the wound is cleansed and sutured using the

Poloxalene can be added to grain mixtures or com-

pound feed or even mineral blocks. However, in grass-

rich areas, grain is rarely fed to cattle, particularly in the ***Table 48.3***

Treatments available for frothy bloat in the UK.

bloat-risk season of fast grass growth, and mineral

blocks suffer from variable individual intake. Daily

Name

Active ingredient

Manufacturer

drenching has therefore become the preferred method

of bloat prevention. The rumen implantation of a slow-

Birp

Dimethicone

Arnolds

release device containing an antifoaming agent has

Bloat Guard

Poloxalene

Agrimin Ltd

been developed in New Zealand and Australia.

Alimentary Conditions • 835

The ultimate objective in bloat control is to develop

(1)

Pyloric obstruction and abomasal impaction;

pastures that have a low bloat-producing potential yet

(2)

Ruminal distension with atony;

still possess the characteristics for high levels of

(3)

Ruminal distension with hypermotility. In some

production. The direction of development will be to

cases combinations will occur.

develop strains of leguminous plants that have a low

bloat-producing potential. To date some progress has

Pyloric obstruction and abomasal impaction: If the abo-been made in identifying the strains of red clover with

masum is involved there is a pyloric stenosis, which pre-

the ability to produce less bloat, although it is recog-

vents ingesta leaving the abomasum. The ingesta

nized that sainfoin produces fewer tympany problems

accumulates, the abomasum becomes distended and can

than clover. At the moment, pastures should not

be palpated in the abdominal flank. Later the rumen

contain more than 50 per cent clover until such strains

becomes atonic and distends with fluid and ingesta.

of clover are developed (p. 128).

Ruminal distension with atony: This is due either to a primary effect of the paralysed vagus nerve on rumen

Vagal indigestion

function or it can occur following (1) from a backflow

Vagal indigestion is a chronic condition of adult cattle

from the distended abomasum. The effect of this is to

with a slow insidious onset, but is still a differential

produce a characteristic shape to the abdomen. The

diagnosis of rumen atony, simple indigestion or mild

left flank is distended and well rounded as in mild bloat

bloat. The incidence of vagal indigestion is now quite

and the right flank is distended in the lower regions of

rare, the annual incidence being less than 1 in 10 000,

the abdomen, giving the right flank a pear-shape appear-

having decreased in recent years, probably mirroring

ance. This shape is characteristic of vagal indigestion. In

the decline in the incidence of traumatic reticulitis.

some cases of vagal indigestion where only the rumen is

affected the organ will be grossly distended, containing

Aetiology

large quantities of fluid. Rumen contractions are infre-

quent and no rumen sound will be audible. Faecal output

Vagal indigestion is caused by interference with the

is decreased and the faeces are frequently of a pale pasty

function of the vagus nerve. The condition has been

consistency. Rectal temperature is normal, the heart rate
produced experimentally by severing the vagus (Xth
may be normal but in some cases is markedly decreased
cranial) nerve. The clinical syndromes vary slightly
to around 40/minute. There is also dehydration,
depending on the site of the nerve severence. In prac-
decreased milk yield and a gradual but progressive loss
tice, the most common cause of nerve damage is the
of body condition. Rectal examination will reveal a
adhesions formed around the reticulum in advanced
grossly distended rumen, reaching into the pelvic canal,
cases of traumatic reticulitis. The vagus nerve passes
and also the ventral rumen distended well over to the
through the diaphragm in the region of the reticulum
right side of the abdomen. The abomasum is not usually
and is susceptible to damage in that area from the
palpated per rectum. The fluid content of the rumen and
inflammation and infection that follow traumatic retic-
the abomasum can be assessed by ballottement of the
ulitis. Other lesions that may damage the nerve would
abdominal wall on both flanks.

include actinobacillosis of the reticulum, infections of

the mediastinal lymph nodes, e.g. tuberculosis, ruptured

Ruminal distension with hypermotility: There is slight diaphragm or pleurisy. Sometimes cattle that survive

ruminal tympany, and frequent and forceful rumen con-

surgery for abomasal torsion (p. 842) later develop signs

tractions. Recent body weight loss will be evident.

of vagal indigestion. This could be the result of damage

Faeces are scant and pasty. Rectal palpation will reveal

to the nerve caused by the torsion.

a gross distension of the dorsal sac of the rumen and the

Because of the loss of function of the vagus nerve,

ventral sac will possess a U-shaped distension.

ingesta are not transported from the rumen to the abo-

masum or from the abomasum through the pylorus,

Clinical pathology

with the consequent result that the rumen and often the

abomasum distend with fluid and ingesta producing

The experienced clinician will make his diagnosis on the

abdominal distension.

clinical signs described and there are no laboratory tests *that can be considered specific for vagal indigestion.*

The dehydration will increase the packed cell volume.

Signs

If pyloric stenosis is present a metabolic alkalosis will

The clinical signs are variable in that the abomasum is

be present with the effect of reducing scrum chloride to

not always directly involved. Depending on the level at

40–50 mmol/l. An elevation of rumen chloride concen-

which the vagus nerve is damaged various syndromes

tration (above 30 mmol/l) indicates abomasal reflux

can develop that are clinically classed as follows:

into the rumen.

Diagnosis

Cold cow syndrome

Veterinary advice is usually sought by the stockworker

Another rumen indigestion syndrome that has been

because it is noticed that the cow has slowly developed

reported from different areas of the UK has been

an abdominal distension and it is considered that the

named the cold cow syndrome. This syndrome usually *animal may be affected with bloat. A thorough clinical*

occurs in early spring in lactating cows when grazing

examination must be performed to establish the differ-

ryegrass pastures. The onset is sudden but not related

ential diagnosis.

to change in pasture use. Both poor and lush pastures

If the animal is passing small quantities of pale pasty

have been involved and the occurrence is not related to

faeces, the left flank is rounded and distended, the right

levels of fertilizer use. The morbidity is high and varies

flank distended in the lower half only and the distension

from 8 to 100 per cent of the herd, but mortality is nil.

is due to fluid accumulation in the rumen and aboma-

Milk yield may be depressed by up to 50 per cent but

sum, and if the rectal temperature is normal and heart

recovers within two days. The condition was first rec-

rate normal or slightly depressed, then a diagnosis of

ognized in Northern Ireland in the late 1970s and in the

vagal indigestion can be made. However, many cases are

southwest of England in 1982 and has been reported in

brought to the veterinarian's attention before all the *several years since.*

signs have fully developed and perhaps the right flank

distension is not obvious. The insidious onset will distin-

Aetiology

guish the condition from bloat as will the fluid-filled

rumen. Abomasal impaction must be distinguished by

The aetiology is unknown but several suggestions have

ballottement, which will indicate firm abomasal contents

been made. These include unusually high levels of

in impaction and fluid contents in pyloric stenosis.

soluble carbohydrate found in grass being grazed by

Accumulation of fluid within the peritoneal cavity

affected herds (Jack, 1985). Other suggestions have

from ascites, peritonitis (p. 849) or ruptured urinary

been the oestrogenic zearalenone or other metabolites

bladder can be differentiated by paracentesis. Hydrops

of field microfungi or the presence of high levels of

allantois or amnii (p. 1119) will also produce severe

soluble proteins or a protein metabolite. Climatic con-

abdominal distension, but will be differentiated on

ditions have been investigated and cases have occurred *rectal examination.*

during periods of frost, cold wet weather and during

warm dry springs. Large night/day fluctuations in

atmospheric temperature of the order of 17–18°C

Treatment

(30–32°F) accompanied one series of outbreaks.

The prognosis in vagal indigestion is generally poor to

Clinical pathology

hopeless and in most cases immediate slaughter is

advised. If treatment is embarked upon because of the

Blood samples from affected cows have been examined

value of the animal the dehydration and any chloride

for a wide range of biochemical parameters but no

deficit should be corrected. As much as 40–50 l of

abnormalities have been detected.

Ringer's solution may be required over 24 hours and

given intravenously. It must be remembered that oral

Signs

fluid therapy must not be contemplated because of the

A sudden onset of ataxia and incoordination, with a few

fluid retention in the rumen.

animals being weak and becoming recumbent, followed
Following rehydration an exploratory laparotomy
by a copious non-smelling acute diarrhoea are the prin-
and rumenotomy may be performed. Adhesions around
cipal clinical signs. The cows behave as though they are
the reticulum can be palpated. A rumenotomy partially
drunk. The cows are characteristically cold to the touch
to empty the rumen is then performed and the reticu-
as though in a state of shock but rectal temperatures
lum and oesophageal groove examined for tumours or
are normal. Appetite is much reduced if not absent and
other lesions. The author, on one occasion, found a com-
the milk yield falls by up to 50 per cent in the herd and
plete afterbirth wedged in the oesophageal groove in a
in some individuals by up to 100 per cent. The duration
cow that had not eaten since calving 10 days previously
of the disease is short as appetite and milk yield return
and was showing signs of rumen atony and disten-
to normal in two to three days. If cows regraze the same
sion. Removal of the afterbirth led to an uneventful
pastures later in the season no disease is seen.

recovery.

Even if tumours, adhesions or oesophageal lesions

Treatment and prevention

are discovered the prognosis is still likely to be hope-

less so surgery should only be contemplated in valuable

Because of the rapid recovery treatment appears

animals and a poor prognosis given before surgery

unnecessary, except that the herd should be housed on

commences.

dry food for 24 hours and then moved to new pasture.

Symptomatic treatment of recumbent cows may be

cerning eating habits of the cow, it is quite common for

required.

cattle to ingest metallic objects with their food. Some

Until the aetiology of this condition is understood,

abattoir surveys have demonstrated over 50 per cent of

preventative measures will not be possible.

cattle reticula to contain foreign objects of metal, wood

or stone. If pieces of metal wire or nails 5–10 cm long

The oesophageal groove

are ingested these will accumulate in the reticulum and when rumen contractions occur may penetrate the Lesions of the oesophageal groove will interfere with the reticulum wall. The incidence of this disease varies con- normal rumen digestion process. Tumours or granuloma- siderably around the world. The incidence in the UK tous lesions will occlude the oesophagus and prevent has declined in the last 30 years and the present annual eructation and lead to a gaseous bloat or secondary incidence is around 5 cases per 10 000 cows. However, rumen tympany. The same lesions may interfere with in some areas the disease is still extremely common and normal rumen contractions and cause signs of simple indi- may reach an annual incidence of 100–200 per 10 000 gestion. Although not common (annual incidence 1 per cows.

10 000 cattle) actinobacillosis of the oesophageal groove This disease is probably related to standards of man- does occasionally occur. Some lesions of the oesophageal agement that exist on the farm, e.g. rusty, poorly main- groove may be due to upper alimentary squamous cell *tained, barbed wire fences are a frequent source of the*

carcinoma in bracken areas (see pp. 828, 946).

offending wire. It is thought that the incidence has

Signs

declined since string has replaced wire to secure bales

of hay and straw and much barbed wire fencing has

The presenting signs of actinobacillosis of the

been replaced by electric fences. However, cases of this

oesophageal groove will be inappetence, reduced milk

disease will still be encountered on untidy farms where

yield and possibly mild tympany evidenced by distension

nails, wire and other metallic objects are left lying

of the left sublumbar fossa. The rumen contraction will

around in fields and where they can be accidentally

be weak, occurring once every 1 or 2 minutes. Rectal

picked up by hay or silage making machinery.

temperature and heart rate will be normal. Examination

of the faeces will reveal strands of undigested fibre.

Although this latter finding is in itself only an indication

Pathogenesis

of indigestion, and several lesions of the rumen or rumen

Metal objects that are ingested invariably lodge in the

wall or dental problems may lead to undigested fibre

floor of the reticulum due to their relative mass and the

appearing in the faeces, the most common cause is likely

position of the reticulum. It is only short sharp objects

to be actinobacillosis of the oesophageal groove.

that penetrate the reticulum wall and these are usually

5–10 cm long. The penetration occurs as a result of the

Diagnosis

ruminal and reticular contractions. On entering the wall

Only a tentative diagnosis can be made based on the

of reticulum the wire will continue to penetrate until it

clinical observations described above. Although diag-

reaches the peritoneum. Infection from the rumen then

nosis would be confirmed by performing an exploratory

follows the wire and a localized peritonitis is produced,

laparotomy and a biopsy of any oesophageal groove

causing local abscess formation and adhesions. If the

lesion discovered, this is unlikely to be performed in

direction of the wire is forward the diaphragm and peri-

practice because of economic considerations.

cardium may be punctured, which produces a localized

pleurisy and pericarditis (p. 731). If the direction of the

Treatment

wire is left or right of the forward direction the

diaphragm may not be involved but extensive peritoni-

Although the prognosis in these cases must be guarded

tis (p. 849) could well develop, with adhesions contain-

because of the uncertainty of the diagnosis, cows pre-

ing a variety of abscesses being produced. If the

senting the above described lesions are worthy of treat-

peritonitis is extensive, adhesions between the reticulum

ment. Treatment using antibiotics over a prolonged

and liver or spleen may be evident. Sequelae to trau-

period of at least 10 days can be successful. The antibi-

matic reticulitis include localized or diffuse peritonitis,

otic of choice is streptomycin and a dose of 5–6 g daily

liver abscessation, splenitis, pleurisy and pericarditis.

for 10 days is effective in a proportion of cows exhibit-

These sequelae may take several weeks to develop.

ing the above described signs.

Traumatic reticulitis (traumatic

Signs

reticuloperitonitis, hardware disease, wire)

The condition is generally progressive and the clinical

Traumatic reticulitis is a well-described disease affect-

signs change as the disease progresses from the initial

ing mainly adult cattle. Because of the rather undis-

acute phase through a subacute to a chronic phase.

In the initial acute phase the cow is anorexic and milk

tion. Cows with traumatic reticulitis can often be made

production is reduced. The cow may exhibit an arched

to grunt by pressing down firmly on the withers, thus

back and the abdomen is tucked up.A grunt may be heard

making the animal lower its back. However, this test is

when the animal walks, although on occasions there will

only an indication of peritonitis and not specific for

be reluctance to move and also a reluctance to lie down.

traumatic reticulitis. Grunting can also be induced by

Rectal temperature will be elevated to 39.1–40°C

applying sharp pressure just to the left of the xiphoid

(102.5–104°F) and although the frequency of rumen

process using a clenched fist. This will specifically indi-

contractions may be reduced they are often increased

cate pain in the region of the reticulum.

to three or four per minute. Respiratory movements

The most successful diagnostic test is known as the

will be shallow, increased in rate and mostly thoracic.

'reticular grunt' or Williams test (Williams, 1975). This

Frequently, farmers mistakenly diagnose the condition

test uses knowledge of the cycle of reticulo-rumen con-

as pneumonia. The heart rate will be raised to around

tractions:

75–90/minute.

(1)

Contractions of the reticulum, followed by contra-

The acute phase may last three to five days and then

ction of the rumen. There is no eructation at this

the rectal temperature will fall to around 39°C (102°F)

stage.

or sometimes to normal. The subacute phase will last

(2)

Following relaxation of the reticulum and rumen, *several weeks, showing signs of mild indigestion.*

an independent contraction of the rumen occurs.

Rumen contractions will be weak and infrequent, there

This contraction is accompanied by eructation.

may be a mild tympany and undigested fibrous mate-

(3)

Relaxation of the reticulum and rumen completes

rial may be evident in the faeces. Sometimes apparent

the cycle. The 'reticular grunt' is based on the cor-

recovery from the acute phase will occur and the animal

relation of pain with contractions of the reticulum.

will return to near normal production, but a relapse will

Since the reticular contractions occur in conjunc-

occur several weeks later. This relapse is usually asso-

tion with rumen contractions, the clinician should

ciated with the onset of pericarditis. The animal will be

observe for signs of pain during or just before the

reluctant to move, may occasionally grunt but signs of

non-eructating rumen contractions. These signs of

cardiac insufficiency will predominate. A firm pro-

pain will be a mild grunt, and shuffling of the

nounced jugular pulse will be noticeable, together with
forelegs. To help detect the grunt, observation of
oedema of the brisket and auscultation of the lungs may
the left costal arch may reveal the animal holding
reveal signs of congestion or even pleurisy. Auscultation
its breath just before it grunts.
of the heart will sometimes be difficult, as the heart
sounds will be muffled and difficult to hear. However,
This test is specific for traumatic reticulitis, but is only
splashing and tinkling sounds over the heart region will
effective in the acute phase of the disease.
confirm the presence of pericarditis (see p. 731).
Diagnosis of the subacute phase may prove extremely
difficult, as the signs are often vague and only indicative
Pathology:
of a non-specific indigestion. If such cases are encoun-
tered and a diagnosis of indigestion made, but a return to
During the acute phase there will be a measurable
normal is not rapidly achieved, subacute traumatic reti-
increase in circulating neutrophils with white cell counts
culitis/peritonitis must be considered as a differential

rising to 30 ¥ 109/l (30 000/ml). Ketone bodies may be

diagnosis.

present in urine or milk indicating a secondary aceton-

The use of metal detectors has been advocated by

aemia. During the subacute phase, when peritonitis is

some workers. However, because metal objects are fre-

developing, the white cell count may be subnormal.

quently found in the reticulum a positive metal detec-

At post mortem, the degree of peritonitis can be dra-

tor test will often be misleading.

matic with adhesions between the reticulum, rumen,

Diagnosis of pericarditis is more straightforward. The

diaphragm, liver and spleen. Incising through the adhe-

jugular pulse and brisket oedema will lead the clinician

sions may reveal multiple abscesses. Abscesses may also

to auscultate the heart in detail. Muffled heart sounds

be present in the liver. The pericarditis, when present, will

and splashing, fluid or tinkling sounds around the heart

also be dramatic with gross thickening of the pericardium

will confirm pericarditis.

and large quantities of pus present in the pericardial sac, *so-called bread and butter heart. Pleurisy, and localized*

Treatment

pneumonia and abscessation may also be present.

Various treatment regimens have been advocated for

traumatic reticulitis and they can be classified into sur-

Diagnosis

gical and conservative.

The diagnosis of the acute phase is based on the signs

If a diagnosis is made during the acute or subacute

described and discovered during the clinical examina-

phase and there are no signs of pericarditis, the surgical

approach has much to commend it. In many cases the

There are three important conditions that probably

diagnosis is only tentative and the rumenotomy is

have a similar aetiology and epidemiology, yet produce

exploratory to confirm diagnosis or establish another

widely differing clinical syndromes. These are left dis-

diagnosis. Under paravertebral anaesthesia, an 18-cm

placement of the abomasum (LDA), dilatation and

vertical incision is made in the sublumbar fossa, the *torsion in the right flank (RDA) and ulceration.*

rumen wall exteriorized and a 10–15-cm incision made

Impaction of the abomasum has also been reported.

into which a McLintock ring is fitted, thus temporarily

The three important conditions (LDA, RDA and ulcer-

fixing the rumen wall to the exterior and preventing peri-

ation) appear to be the result of intensive management

toneal contamination with rumen contents. A scrubbed

of cattle and have not been recorded in wild ruminants.

arm is inserted into the rumen and the reticulum located.

In fact their occurrence, particularly LDA, is almost

Each crypt of the reticulum should be explored as the

entirely restricted to dairy cattle and rarely found in

offending wire may have penetrated to the extent that

suckler beef cows. Diet undoubtedly has an important

very little is left protruding into the reticulum. Adhe-

role in the aetiology of these diseases, with the use of

sions between the reticulum and diaphragm or abdomi-

concentrated cereal-based feeds and low-fibre diets

nal floor can be detected by attempting to lift the

generally being incriminated. In some countries the reticular wall. Once located, the offending wire should

feeding of root crops that are heavily contaminated

be slowly withdrawn back through the reticular wall and

with soil, sand and gravel has also been incriminated.

removed from the rumen. The rumen incision is closed

In the UK and USA, LDA is much more common than

using Lembert sutures and the abdominal wall incision

RDA or ulceration. However, reports from Scandinavia

closed in the usual way (see p. 1106).

would indicate that RDA is much more frequently seen

Five days of antibiotic treatment should follow the

there than in the UK or USA and may be the result of

surgery to prevent the spread of the peritonitis initiated

much greater use of root feeds such as fodder beet.

by the foreign body. This operation can be very satis-

factory to conduct in practice and the majority of cases

Displacement of the abomasum to the left

make an uneventful recovery.

The conservative treatment involves restricting the

Left displacement of the abomasum is by far the most

animal's movement by tying it in a byre stall with the *common of the abomasal diseases encountered in cattle front feet raised 35–40 cm higher than the hind feet for in the UK or USA. Its occurrence is almost entirely three weeks. Parenteral antibiotics will also be given for confined to dairy cattle, although it has very occasion- five to seven days, and in some countries a magnet will ally been seen in bulls, where it is probably secondary be inserted into the reticulum using a balling gun.*

to some other condition. The author has, on one occa- If pericarditis is evident immediate slaughter must be sion only, diagnosed the condition in a Friesian bull and recommended, as there is little likelihood of recovery.

in that case the animal was suffering from severe endo- On no account should a rumenotomy be considered carditis. It was likely that this particular LDA was a sec- because even if the wire is located, removing it may well ondary condition brought about by the inappetence cause the heart to stop and death during surgery will be caused by the endocarditis. The overall incidence varies the result.

considerably between years and between seasons. In *some years the annual incidence can be as high as 25–30*

Prevention

per 10 000 and in others as low as 4–6 per 10 000.

There appears, in the UK, to be a definite seasonal

The main thrust of prevention must be to avoid leaving

pattern to the incidence with the majority of cases

wire or nails lying around to be picked up by cattle

occurring in late winter–early spring, i.e. January to

during feeding. The use of metal detectors on forage

April, the period of winter housing in the UK.

harvesting equipment to prevent damage to the equip-

However, it is now being seen throughout the year,

ment has undoubtedly reduced the incidence of metal

although at lower numbers during grazing. In the USA,

objects being found in cattle feeds. Some workers have

LDA is reported to be more common in the winter

advocated the routine use of magnets. These are

housing period. However, the problem is encountered

inserted into all cattle on the farm. There is no real evi-

in countries where spring calving predominates and the

dence that these have been successful.

cows are at pasture during the susceptible period, e.g.

Ireland, Australia and New Zealand, although the inci-

Abomasum

dence varies considerably between farms. The author

has experienced the condition in eight cows in a 110-

Diseases of the bovine abomasum comprise an inter-

cow herd in one year, all occurring from January to

esting group of conditions only really appreciated in

April; yet there are many farms that have never, know-

comparatively recent years (Pinsent, 1978).

ingly, experienced the condition. Breed susceptibility

has been investigated and there has been no authorita-

80–100/minute. Rumen movements will usually be

tive confirmation that there is a genetic predisposition.

absent or at least infrequent and in some cases palpation

However, it is thought that the condition generally

of the rumen in the left sublumbar fossa will be impossi-

affects the higher yielding cows, mainly in early lacta-

ble because of the presence of the gas-filled abomasum

tion, although occasionally during late pregnancy.

between the left abdominal wall and the rumen. A

Rothera's test on urine or milk will usually be positive

Aetiology and pathogenesis

and thus in many instances the cow will be presented as

a suspected case of acetonaemia. In the more acute cases,

The precise aetiology of LDA is not readily understood

which are more common in late pregnancy, distension of

but the occurrence of the problem soon after, or occa-

the left flank will be evident.

sionally just before, parturition would suggest that the

presence of the gravid uterus or the process of parturi-

tion predisposes to the condition. Certainly it has been

Diagnosis

observed that in normal cows in late pregnancy the

The diagnosis of LDA is relatively easy, providing the cli-

presence of the gravid uterus displaces the abomasum

nician always keeps the condition in mind when making

forwards and to the left, and after calving the organ

a clinical examination of dairy cows. Confirmation is

returns to its normal position. To remain displaced after

based on auscultation, percussion and auscultation, or *calving, the abomasum must have developed atony and*

ballottement and auscultation of the left flank. The

the subsequent accumulation of gas. Atony of the abo-

stethoscope is placed on the last intercostal space in line

masum is likely to be caused by one of four factors:

with the lower limit of the left sublumbar fossa and the

penultimate rib is percussed by 'flicking' it with the finger.

(1)

Feeding of rapidly fermentable concentrate feeds,

If a 'ping' or high-pitched resonant sound is heard, this is

which have a tendency towards the production of

indicative of a gas-filled organ inside the abdominal wall.

acidosis.

Should the first attempt fail to elicit the characteristic

(2)

The accumulation of sand or gravel in the aboma-

'ping' the stethoscope is moved so that an area repre-

sum, which damages the abomasal mucosa.

senting a 20 cm square forward and below the first stetho-

(3)

Stress conditions or metabolic diseases that *scope site is auscultated and the second to last and third*

frequently occur around the time of parturition.

last ribs percussed in the same way as described above.

Hypocalcaemia will itself cause atony of the

If a high-pitched resonant sound is heard over this area,

abomasum.

confirmation of the diagnosis should depend on auscul-

(4)

The occurrence of systemic diseases that produce

tation only and a short series of tinkling sounds reminis-

toxaemia, such as acute metritis.

cent of raindrops falling on a metal roof will be heard.

(5)

A lack of a suitable quantity of long fibre roughage.

The frequency of these tinkling sounds is quite vari-

It is likely therefore that atony of the abomasum and

able and the clinician may have to auscultate for up to 10

the accumulation of gas within the organ is the prime

minutes in some cases. Ballottement of the lower left

factor in the pathogenesis of the condition. The mechan-

flank at the same time as auscultation of the target area *ical effect of displacement by the gravid uterus may well*

described above may frequently elicit the same tinkling

have some involvement in originally displacing the abo-

sounds. The diagnosis, by auscultation of the tinkling

masum. Once displaced to the left and the organ is

sounds without recourse to ballottement, is to be

located between the left abdominal wall and the rumen

favoured because ballottement may elicit splashing

the atonic nature of the abomasum and the presence of

sounds from the rumen that can be difficult to distinguish

gas will prevent the organ returning to its normal position.

from the high-pitched tinkling sounds diagnostic of

LDA. However, a negative diagnosis can fairly quickly

be achieved by using the percussion and auscultation

Signs

technique over a 20 cm square area forward of and

The clinical signs of LDA can vary considerably,although

ventral to the lower limit of the left sublumbar fossa.

in general the signs are similar to chronic acetonaemia.

Only when this technique produces a pinging noise

Mild cases are encountered that show little more than a

should it be necessary to spend time in auscultation alone.
slightly depressed appetite, rumination and milk yield.
All cows that are presented with inappetence and have
At the other extreme, acute cases can be encountered
a normal rectal temperature, particularly in early lacta-
with complete inappetence, absence of rumination, loss
tion or late pregnancy, should be subjected to the per-
of condition, scanty diarrhoea and grunting with some
cussion and auscultation technique to eliminate LDA as
signs of mild colic. The most common clinical picture is
part of a normal clinical examination. If this is performed
one of refusal to eat concentrates,some reduction in milk
the clinician is unlikely to fail to diagnose LDA.
yield and scanty soft or pasty faeces. Rectal temperature
However, it must be said that a small number of cases
will be normal but the heart rate may be raised to
are not diagnosed at the first examination and a diag-

nosis of acetonaemia or, occasionally, indigestion is
It is essential if the LDA has been corrected by
made and the corresponding treatment administered.

rolling that the animal is re-examined 48 hours later to
Such cases will show a temporary recovery but the signs
ensure that a relapse has not occurred. In the experi-
will relapse two to five days later. It is essential when
ence of the author, and many others, relapse is to be
treating acetonaemia or indigestion that the farmer is
expected in over 75 per cent of cases of LDA that have
instructed to seek further veterinary advice if the con-
been corrected by the rolling technique. Quite fre-
dition regresses. Many cases of LDA are diagnosed in
quently if relapse does occur, the signs may not be so
cows that have been treated for acetonaemia two to five
severe as those present before the correction and the
days previously, either by the farmer or a veterinarian.
animal may well complete its lactation, albeit with a
Following a complete clinical examination the differ-
reduced total milk yield. In such cases, chronic LDA
ential diagnosis of LDA is related to whether the high-
exists and ulceration of the abomasum with adhesions
pitched resonant sounds can be confused with anything
to the abdominal wall may well develop, thus shorten-

else. Once heard, these sounds are never forgotten.

ing the productive lifetime of the animal.

However, similar sounds do occur in conditions of the

The surgical approach to treatment consists of

rumen that produce rumen atony, a rumen mildly dis-

laparotomy, returning the abomasum to the right side

tended with gas accumulation, as is seen in vagal indi-

of the abdomen and suture fixation of the organ to the

gestion, actinobacillosis of the oesophageal groove,

abdominal wall. Many different surgical techniques

localized peritonitis or mild rumen tympany. However,

have been described for this procedure but the one

if the tinkling sounds are heard spontaneously and not

favoured by the author is the right flank approach with

induced by ballottement, the likelihood of misdiagnos-

the animal standing. The animal is starved of water and

ing these other conditions as LDA is slim. The author

food for 24 hours prior to surgery to reduce the size of

has on one occasion, having made a diagnosis of abo-

the rumen. Using paravertebral anaesthesia, a 20-cm

masal dilatation in the right side of the abdomen by rec-

incision is made in the abdominal wall, starting at the

ognizing the tinkling sounds, performed a laparotomy

lower limit of the right sublumbar fossa and extending

to discover the sounds were produced by a large sub-

vertically downwards. The left arm then enters the

peritoneal abscess in the upper right abdomen.

abdominal cavity and moves carefully down the right

side of the abdomen, along the floor and up the left side

with the hand always in contact with the peritoneum.

Treatment (see also p. 1109)

The hand can then locate the distended abomasum sit-

The treatment for LDA falls into two categories, con-

uated high in the left flank between the rumen and the

servative or surgical.

abdominal wall. The hand is then placed over the top

Conservative measures include drug therapy and

of the abomasum and downward pressure exerted.

rolling. Drug therapy using calcium borogluconate

Several attempts at downward pressure may be

solution, neostigmine and saline cathartics has been

required to disperse the gas present in the organ. The

attempted with very little success. The usual conserva-
organ is then pushed down and below the rumen. It is
tive treatment is to roll the cow. The cow is cast, using
important that contact by the hand is maintained with
the Reuff's method, on to its right side. The cow is then
the abomasum during this stage of the operation
rolled into dorsal recumbency and kept in this position
because if it is lost it may be difficult to find the abo-
for 5 minutes. During this time the animal may be
masum without causing trauma to the small intestines.
rocked to the left and right and the abdomen massaged
When the organ has been brought across to the right
vigorously to encourage the abomasum to rise into the
side, the pylorus is located and brought to the abdomi-
ventral abdomen. The animal is then rolled over to a
nal wall incision. Using non-absorbable suture material,
left side lateral recumbency and maintained in this posi-
e.g. monofilament nylon, and a round-bodied needle a
tion for a further 5 minutes, allowing time for the abo-
suture is placed in the greater curvature of the aboma-
masum to return to its normal position. During this

sum close to the pylorus and this is then sutured to

process, splashing and gurgling sounds can be heard

the peritoneum and abdomen wall at the base of the

coming from the abdomen as the abomasum moves.

incision. The abdominal wall incision is closed in the

The animal is then allowed to rise. The left flank is then

normal way and postoperative antibiotics administered.

auscultated to ensure the abomasum is still not present

Appetite is stimulated by the administration of rumen-

in the LDA position.

stimulant drenches and the animal allowed immediate

One variation of this procedure reported to be suc-

access to good quality fodder and water. The author has

cessful by one UK practitioner (B. Jeffrey, pers. comm.)

used this technique for over 20 years and on one occa-

is to cast the cow into left-sided lateral recumbency and

sion only has correction not been possible. In this case

restrain the animal in this position for 30 minutes. The

adhesions were present between the abomasum and the

gas present in the abomasum allows the organ to 'float'

left abdominal wall. A second incision was then made *back to its normal position.*

in the left sublumbar fossa, and the adhesions were

broken down revealing a perforated ulcer. The ulcer

Prevention

was excised, sutured using a purse string suture and the

Advice on prevention is difficult because the precise

abomasum returned to the right flank where an assis-

nature of the aetiology is unknown. Furthermore, most

tant located and sutured it as described above. This

cases occur only sporadically and it is rare for farms to

right-sided approach has been used widely in the UK

experience more than one or two cases in a season. If the

and is suitable for operating on the farm.

incidence is higher on a particular farm, attention to the

The right paramedian approach is also widely used.

feeding regimens may prove worthwhile. Dry cows

The animal is cast into dorsal recumbency and local

should be fed a diet of long fibre and very little concen-

anaesthesia administered for an incision posterior to

trates. Dry-cow diets should always contain less than 30 *the sternum and midway between the midline and the per cent concentrate on a DM basis. Maize silage, which right subcutaneous abdominal vein. The abomasum is itself contains up to 50 per cent grain on a DM basis, located, returned to its normal position and fixed using should be restricted to no more than 15 kg/day during the catgut or monofilament nylon sutures 2–3 cm from the dry period. The change in diets that occur at calving margin of the incision. This technique does return the should be made as gradually as possible. Ideally, 2 kg abomasum to its normal position, whereas in the former daily of concentrates for the last two weeks of the dry the fixation of the pylorus to the abdominal flank period will help the rumen microflora adjust to the wound results in the abomasum being slightly out of increased concentrate intake that occurs in early lacta- position. In the author's opinion the abomasopexy tion. The approach to prevention of LDA is much the should be performed with non-absorbable suture mate- same as the approach to the prevention of acetonaemia. rial as the few cases that have relapsed following* *abomasopexy were mostly sutured with catgut.*

A modification of the right paramedian approach, the

Right-sided abomasal dilatation

Sterner–Grymer closed suture technique, has been

and torsion

gaining popularity in recent years and with consider-

Occurrence

able success (Gordon, 2001). The cow is cast onto her

right side and rolled into dorsal recumbency, as above,

Right-sided abomasal dilatation and torsion occurs

and the hind legs restrained. The abomasum is auscul-

much less frequently than LDA in the UK and USA,

tated by percussion using a stethoscope and should be

although it appears to be more common in Denmark.

on the right of the midline. A DA Trochar and Cannula

The annual incidence in the UK is of the order of 2–3

(Kruuse UK Ltd) is inserted firmly through the skin,

per 10 000. It normally occurs in early lactation and

muscle and peritoneum 10 cm caudal to the xiphoid

rarely in the dry cow, but although predominantly

process, 10 cm to the right of midline and into the *affecting dairy cows it has been reported in bulls, young*

abomasum, avoiding the right subcutaneous abdominal

animals, beef cows and feedlot cattle.

vein. The trochar is removed and a toggle attached to a

suture (Kruuse UK Ltd) quickly inserted through the

Pathogenesis

cannula. Minimal gas should be released when placing

As with LDA, the aetiology of RDA is not fully under-

the first suture. The procedure is repeated with a second

stood but the pathogenesis is probably similar to that

toggle inserted 5 cm cranial to the first, allowing as

of LDA. Atony of the abomasum followed by the

much gas as possible to escape from the abomasum to

accumulation of feed, fluid and gas produces a grossly

reduce tension on the sutures. The two toggle sutures

distended organ. The presence of gravel and sand in the

are tied together and the cow rolled onto her left side

abomasum has commonly been observed in affected

and allowed to stand.

animals, which may account for the higher incidence in

Another technique involves a left flank approach, *Denmark, where large quantities of fodder beet are fed*

pushing the abomasum back to the right side and then

that often is contaminated with soil. Torsion is fre-

entering the rumen as in a rumenotomy to transfix the

quently a sequel to the dilatation and this is purely a

rumen to the floor of the abdomen by using a large

mechanical effect of the increased weight and size of

needle and a long suture. The suture needle is passed

the dilated organ. The torsion can be in several direc-

vertically down through the rumen wall and abdominal

tions, e.g. the organ may be rotated dorsally 90–180°, or

wall to the exterior. The needle is removed from the

counterclockwise up to 180° as viewed from the rear or

suture and the procedure repeated with the other end

the torsion may incorporate the omasum.

of the suture material and the suture tied as a mattress

suture on the exterior of the ventral abdomen. This pro-

Signs

duces an adhesion between the ventral rumen and the

ventral abdomen that will prevent a recurrence of the

The onset of dilatation is insidious with inappetence, *LDA.*

milk yield reduction and varying degrees of ketosis.

Rumination ceases and rumen contractions are weak

However, in valuable animals and less severely

and infrequent. Faecal quantity is reduced but its con-

affected cows, surgery can be successful (p. 1112). Intra-

sistency is usually diarrhoeic, foul smelling and often

venous drip therapy should be set up immediately using

contains occult blood. Rectal temperature is normal

Ringer's solution or isotonic sodium chloride. Cows

and heart rate raised to 80–100 beats/minute. Mild colic

with RDA plus torsion will be suffering from metabolic

signs may also be evident and there is often a notice-

alkalosis and will be short of chloride ions. Sodium

able distension of the right flank. Once torsion occurs,

bicarbonate or sodium lactate should not be used. To

the signs become peracute. Then there is a subnormal

restore normal hydration, 40–50 l of electrolyte are

temperature, with a heart rate up to 160/minute, cold

likely to be required over a 24-hour period.

extremities and extreme dullness. These signs indicate

Having set up the intravenous drip, surgery should

severe shock and frequently colic may be observed. At

commence immediately. Under paravertebral anaesthe-

this stage the animal is anorexic and the rectum will be

sia an incision is made in the right abdominal wall with

empty except for some tar-like mucus.

the animal standing. If the animal cannot stand it is likely

her condition is so severe that surgery would not succeed

Diagnosis

and casualty slaughter should be advised. On entering

the abdomen and the abomasum located the first proce-

Diagnosis should not present any problems if the tech-

dure is to deflate the organ using a wide bore (12G)

niques of percussion and auscultation, ballottement and

needle and rubber tube. Having deflated the organ the

auscultation and auscultation alone are applied to the

direction of the torsion should be identified and an

right flank in the same way as described for the diag-

attempt made to correct the torsion without removing

nosis of LDA on the left flank. The same ‘ping’ and tin-

the fluid. If correction of the torsion is not possible then kling sounds if heard on the right flank will indicate an half of the fluid should be siphoned out of the aboma- RDA. Determination of whether torsion exists will rely sum. This will ease the recognition of the torsion direc- on the severity of the signs exhibited, e.g. the presence tion and more readily allow repositioning of the of a very fast heart rate, subnormal temperature, the abomasum. Abomasopexy is carried out as for LDA cor- signs of shock and the consistency of the rectal contents. rection. The abdomen is closed in the normal way. If Rectal palpation may also reveal the presence of a RDA exists without torsion the abomasum should be grossly dilated viscus in the right sublumbar region. Dif- emptied of fluid by siphoning and then the organ opened ferential diagnosis of RDA plus torsion will include all and all debris, which may include straw or hairballs, causes of acute abdominal obstruction, particularly stones or gravel,should be removed.The abomasum inci- caecal dilatation and torsion, torsion of small inte- sion is then closed, the abomasum is returned to its *stines, intussusception and perforated abomasal ulcer.*

normal position and the abdomen closed in the normal

However, being able to palpate the organ on rectal

way. Abomasopexy is not normally required in this situ-

palpation and hearing the characteristic high-pitched

ation. Fluid therapy is continued until the animal has

sounds should not cause problems in diagnosis.

rehydrated and postoperative antibiotics are adminis-

tered for five days. Following recovery diarrhoea will be

Treatment

present for two or three days.

If torsion is not present there is often a temptation to try

Recovery rates of 75–80 per cent are reported by some

conservative treatments using antacids by mouth and

workers in hospital situations and around 50 per cent

spasmolytics, vitamins or antibiotics by injection. This is

when the omasum is involved in the torsion. Recovery

not to be recommended. Although some cases of dilata-

rates for on-farm surgery are likely to be lower and this

tion do recover spontaneously, many do not. Many cases

must be appreciated before embarking on surgery in *will remain dilated and a chronic state of abomasal*

preference to casualty slaughter.The likelihood of recov-

dilatation develops where the animal loses weight and

ery will depend on the length of time that elapses from

milk production, and eventually is culled as a 'poor doer'.

torsion occurring to operation and the level of shock that

Often the dilatation progresses to torsion and surgery to

exists at the time operation commences.

correct abomasal torsion is much less successful than cor-

recting dilatation without torsion. This is because of the

Prevention

severe shock that is induced in the animal by the torsion.

The decision on whether to attempt surgery in cases of

Measures to prevent RDA are the same as for LDA

RDA plus torsion will depend on the degree of shock that

(p. 842) but as the condition is relatively rare, specific

exists. In severe cases casualty slaughter should be

measures to prevent RDA are academic. If root

advised. Recently, successful treatment of dilatation

vegetables are used in large quantities for fodder they

without torsion has been reported using metoclopramide *should be washed before feeding to remove the soil*

hydrochloride, although not licensed for this purpose.

contamination.

Abomasal ulceration

The diagnosis of abomasal ulcers with perforation is

difficult. The signs are of mild colic and pain in the right

Ulceration in the form of small multiple ulcers occurs in

ventral abdomen. Confirmation will only come from an

the abomasal mucosal surface in a number of systemic dis-

exploratory laparotomy. Abomasal ulcers may well be

eases but these are rarely diagnosed, their presence being

present in many apparently normal cows and undoubt-

masked by the other signs present of the systemic disease.

edly many do heal, but the sudden onset of signs asso-

However, a syndrome of peptic ulceration in adult

ciated with acute haemorrhage or perforation would

cattle does occur sporadically and may result in perfo-

indicate that until such dramatic consequences occur

ration and peritonitis or haemorrhage, which can be

the ulcers may not be harmful.

mild and recurrent or acute and be a cause of death. The

actual incidence of abomasal ulceration is probably

Treatment

much more common than generally realized as many

cases are difficult to diagnose and may produce little

Treatment is purely academic. Ulcers without perfora-

harmful effect until perforation or haemorrhage occurs.

tion or haemorrhage are unlikely to be diagnosed. The

The aetiology is uncertain, but feeding regimens involv-

prognosis in haemorrhaging ulcers is so uncertain that

ing a sudden introduction of concentrate feeds are likely

casualty slaughter should be advised. Perforated ulcers,

to be implicated much the same as in the presumed aeti-

if not sealed with omentum, are usually only discovered

ology of LDA and RDA. The author has experienced

at post-mortem examination. Ulcers that have perfo-

three sudden deaths in a herd of 120 dairy cattle that

rated and become sealed with omentum are unlikely to

were caused by perforated abomasal ulcers. The abo-

be diagnosed,except on exploratory laparotomy in a cow

masum contained large quantities of sand and gravel, *showing signs of right-sided anterior abdominal pain and*

which were the result of a depraved appetite. The cows

when discovered they are probably best left undisturbed.

were constantly eating soil, which was later confirmed

to be due to hypocuprosis. The aetiology of peptic abo-

Prevention:

masal ulceration is therefore similar to LDA and RDA

and is considered by some workers to be another man-

With the current state of knowledge on aetiology, the

ifestation of the same syndrome. Certainly, ulcers are

best advice on prevention is to follow that for LDA and

found in the abomasum of both LDA and RDA.

RDA (p. 842).

The ulcers occur singly or occasionally in twos and

threes and vary in size from 2 to 6 cm in diameter. Fungal

Abomasal impaction

hyphae are frequently found in the depths of the ulcers,

Impaction of the abomasum may occur occasionally but

which tend to extend into the submucosal layers until, in

is certainly of no great significance in adult cattle. Its

some cases, perforation occurs. If the perforation occurs *annual incidence would be less than 1 per 100 000 and*

at a point covered by omentum the ulcer may be sealed

appears to be more common in beef cows than dairy

by omental adhesion. However, if the ulcer perforates at

cows as a result of feeding poor quality fibrous mate-

a point lateral to the omental covering,the abomasal con-

rial. Cases can be the result of lymphosarcoma (p. 693).

tents spill into the peritoneal cavity and death soon

The impaction occurs with the accumulation of large

follows. Another complication occurs when the ulcer

quantities of fibrous food, sand or gravel close to the

erodes into a blood vessel producing haemorrhage. This

pyloric outlet. The onset is insidious, with a gradual loss

may be only temporary and the blood vessel heals, but

in milk production and inappetence. Progressively,

more often the haemorrhage does not stop and the

rumen impaction occurs, rumination ceases and consti-

animal dies from blood loss.This can be a cause of sudden

pation sets in. Rectal temperature is normal but heart

death. The annual incidence for abomasal ulcers with

rate will exceed 100/minute. At first there is little or no *haemorrhage would be in the order of 5–10 per 10 000.*

abdominal pain but progressively pain becomes evident

in the anterior right ventral abdomen (as distinct from

Diagnosis

the left anterior abdomen in traumatic reticulitis).

The only occasion where the syndrome can be diag-

Pinching of the withers at this stage may elicit a painful

nosed with certainty is when haemorrhage occurs. A

grunt. It is unlikely that a positive diagnosis will be

cow presented with inappetence, reduced milk yield

made without recourse to an exploratory laparotomy

and passing black tarry faeces, which contain large

when an enlarged doughy abomasum will be palpated.

quantities of occult blood, will almost certainly be suf-

Pinsent (1977) was of the opinion that many cases of

fering from a haemorrhaging abomasal ulcer. Severe

abomasal impaction reported in the past may well have

cases will be anaemic, the heart rate fast and loud and

been vagus indigestion as workers reported enlarge-

death can occur within 24 hours. The prognosis in such

ment of the fundus of the abomasum, which contained

cases is extremely guarded for, although animals do
dry rumen contents, and an accumulation of fluid within
appear to make a recovery, relapses are common.
the rumen.

However, if such a case is encountered at exploratory
of management, whether extensive or intensive. A thor-
laparotomy, abomasotomy and removal of the offend-
ough clinical examination will be required to differenti-
ing contents can be attempted.
ate the many problems that produce colic. By far the most
common cause of colic is tympanic intestinal colic, which

Abomasal impaction in calves

is very similar to the syndrome so frequently seen in the
horse. Intussusception, caecal dilatation and prolapse of
Abomasal impaction does appear to be more common
the small intestine through the mesentery are much less
in calves than adult cattle. Calves from three weeks to
common and in the UK each would have an annual inci-
three months can be affected, although six to ten weeks
dence of less than 1 per 10 000.

is the most common period. Depraved appetite, causing

the calves to eat bedding and lick hair, is thought to be

Signs

the cause. Finely ground grains made into pellets have

also been incriminated in the aetiology, presumably the

The clinical signs of colic in cattle are firstly reduced

result of rapid fermentation. Coarse ration where the

appetite or even anorexia, reduced milk yield and a

grain ingredients are rolled or cracked is preferred to

noticeable change in behaviour – kicking at the ventral

pellets by many calf rearers because fewer 'digestive

abdomen,shifting weight from one hind foot to the other,

upsets' appear to occur.

licking at the flank or chest wall, frequently lying down

and then standing and generally restless. The intensity of

Diagnosis

the signs exhibited will vary with the degree of pain. On

some occasions the signs are quite mild, with only occa-

Affected calves usually have a brown, mild diarrhoea

sional kicking at the ventral abdomen,and may be missed

and normal rectal temperature. The most striking *by all but the most astute stockworker. The above signs*

feature is the result of ballottement of the lower right

are all indicative of pain, but not necessarily abdominal

abdomen, which will reveal loud splashing noises over

pain. Conditions that will produce similar signs include

a large area, usually indicating an enlarged abomasum

photosensitization (p. 884), particularly if the teats are

containing excess fluid.

affected, strangulated scrotal hernia, uterine torsion,

urolithiasis (p. 263) and ureter obstruction.

Treatment

Treatment using antacids such as magnesium hydroxide

Diagnosis

or magnesium carbonate or mild laxatives such as liquid

The diagnosis of the cause of the signs of colic will include

paraffin or linseed oil may be helpful. In early cases sur-

a thorough clinical examination. The rectal temperature

gical interference to empty the abomasum can be effec-

may be raised, the pulse will certainly be increased and

tive. It is interesting to note that the abomasum of veal

the more acute the problem, the faster and weaker will *calves slaughtered at 14–16 weeks old and reared solely*

be the pulse. Abdominal sounds may be present or

on liquid milk substitute diets frequently contains one

absent. In intestinal obstruction the sounds will be

or several hairballs many up to 20 cm in diameter

absent. The mucous membranes will be injected in acute

without abomasal ulceration or any abnormal effects

problems and the eyes sunken. Ballottement of the

being noticed before slaughter.

ventral abdomen should always be performed and may

reveal splashing fluid sounds. A rectal examination

Colic and acute intestinal obstruction

should also be performed. In intestinal obstruction the

rectum will be empty and sticky. Enlarged viscera or

abnormal positioning of the viscera may be palpated on

Colic signs are frequently reported in adult cattle. They

rectal palpation. A detailed description of the use of

may indicate a tympanic intestinal colic or they may

rectal palpation in the diagnosis of abdominal disorders

signal some more serious problem. This section will

has been recorded by Stober and Dirkson (1977).

discuss the differential diagnosis of colic signs and will

In many cases of intestinal obstruction diagnosis

describe in detail: tympanic intestinal colic, intussus-

may only be confirmed on exploratory laparotomy.

ception, caecal dilatation and torsion, prolapse of small

Exploratory laparotomy as a diagnostic procedure as

intestine through a ruptured mesentery and torsion of

opposed to its use solely as a surgical treatment is to be

small intestine around the root of the mesentery.

recommended (Pinsent, 1978) where the attitude of the

farmer and conditions conducive to surgery exist. Many

Occurrence

farmers, with their increased education and training, will

Colic is a sporadic condition affecting only individual

understand the value of an exploratory laparotomy if the

animals,it being extremely rare for more than one animal

problem is fully explained. Furthermore, exploratory

to be affected at any one time. Signs of colic are reported

laparotomy may well reveal the cause of acute intestinal

quite frequently in all ages of cattle and under all types

obstruction and allow surgical correction and recovery to take place, whereas if surgical intervention is unnecessarily delayed the likelihood of recovery is always reduced. The author has, on two occasions, performed an exploratory laporotomy where an unknown intestinal obstruction was thought to exist to find that on both occasions a thin fibrous strand or adhesion was present in the abdomen and a loop of small intestine had become entwined around the strand, thus causing the obstruction. Severing the strand released the bowel and in both cases the animal made an uneventful recovery.

ing rolling of cows to correct uterine torsion or left displacement of the abomasum. The entire small intestine twists up to 360° around the root of the mesentery. In calves, the condition is more common and is known as red gut and is associated with the feeding of milk substitutes. It appears to have increased in incidence in recent years and is more commonly seen in loose-housed, machine-fed, calf rearing systems, where the intake of milk is uncontrolled and can be quite excessive. Although the aetiology is uncertain, the pathogenesis is *thought to be the rapid fermentation of lactose in the*

Tympanic intestinal colic

ileum, which leads to gas production and gross dilatation

of the intestine, which then twists at the mesentery root.

Tympanic intestinal colic is by far the most common

Affected calves are normally three to six weeks old and

condition to produce colic signs. It can occur at any age

are presented showing severe colic signs with death fol-

and calves are presented with colic signs as frequently

lowing within 12 hours. It can also be a cause of sudden

as adult animals. The signs are of sudden onset, but in

death. Diagnosis is rare in the live animal,mainly because

lactating cows they are frequently observed at milking

of the rapid progression of the disease and it is not pos-

time and in calves during or just after feeding.

sible to differentiate it from tympanic intestinal colic.

At post mortem the findings are quite dramatic. The

Diagnosis

small intestines are grossly dilated with gas, are a bright-

As all the usual colic signs are present the clinical exam-

red colour and the whole of the intestinal mucosa is *ination will reveal normal rectal temperature, raised bright red. To detect the torsion, the post mortem must heart rate (80–90/minute) and normal mucous mem- be performed with care because if the abdomen is fully branes. Abdominal sounds will be present, sometimes opened and the intestine allowed to spill out, the at an increased intensity. Rectal examination will reveal torsion will untwist and therefore not be detectable. faeces in the rectum and it is unlikely that any abnor- In adult cows the presenting signs of intestinal mality to the viscera will be palpated. It is important to torsion are those of severe colic. Rectal temperature ensure that the differential diagnoses mentioned above may be raised, the pulse weak and fast, mucous mem- are not present. Uterine torsion will only be present in branes are injected and the eyes sunken. Rectal exam- late pregnancy but photosensitization is fairly common ination will usually reveal multiple gas-distended loops (5–10 per 10 000) and must be eliminated from the diag- of small intestine in the right side of the abdomen and nosis by careful examination and palpation of any white* *these may distend into the pelvic cavity. The site of the*

areas of skin.

mesentery twist will normally be beyond reach, but

In the calf, abdominal palpation should be per-

tense strands of mesentery may be palpable.

formed, as intussusception (p. 847) is relatively common

and can sometimes be palpated. The diagnosis will be

Treatment

confirmed by response to treatment or spontaneous

Immediate surgery is indicated. Laparotomy is per-

recovery within 24 hours.

formed under paravertebral anaesthesia in the right sub-

Treatment

lumbar fossa. Loops of distended bowel may protrude

through the abdominal incision. The root of the mesen-

The most effective treatment is the intravenous admin-

tery will be located in the region of the left kidney and

istration of a spasmolytic such as hyoscine- N-butylbrothe direction of the twist should be determined. The

mide and dipyrone or butylscopolamine bromide and

torsion is corrected by manipulation of the intestines,

metamizole. Oral treatment with mild purgatives,such as
some of which will need to be exteriorized to allow room
linseed oil or liquid paraffin, has been used in the past but
in the abdomen to correct the twist. This surgery is cer-
these are unnecessary and not as effective as spasmolyt-
tainly of a heroic nature, but nevertheless can succeed if
ics and may well be contraindicated.
the animal is not too severely shocked when the opera-
tion commences. Follow-up treatment with intravenous

Torsion of intestines (red gut in calves)

fluids and antibiotics should always be administered.
Torsion of the intestines around the root of the mesen-

Prolapse of intestines through mesentery

tery is extremely rare in adult cattle (1 per 10 000), but
has been reported to occur spontaneously and the cause
This condition is usually only seen in adult cattle and is
is unknown. It has also been reported to occur follow-
more common than torsion at the mesentery root. Its

annual incidence is still only approximately 1 per 10 000.
Usually, the dilated caecum will be palpable at the

The acute nature of the signs is identical to torsion at

entrance to the pelvic cavity and many even protrude

the mesentery root and rectal palpation will reveal gas-

into the pelvic cavity. If the caecum has ‘kinked’ rectal

distended loops of small intestine, which make it clini-

exploration of the abdominal cavity will be required to

cally indistinguishable. If untreated, death will occur

detect the dilated organ.

within 12 hours.

Treatment

Treatment (see p. 1113)

Successful treatment using butylscopolamine bromide

Immediate exploratory laparotomy will reveal the

and metamizole (Buscopan) has been reported in cases

grossly gas-distended intestine, but it may be difficult to

of dilatation where torsion is absent. It would be wise to

distinguish from torsion of the intestines. Palpation of

monitor the effect of treatment by rectal examination at

the root of the mesentery must be performed first to dis-

6-hourly intervals so that surgical intervention can be

tinguish the condition from torsion. One clue to the *instigated if there is no response or torsion occurs. If*

problem being one of prolapse of intestine through

medical treatment fails or torsion occurs, surgical inter-

mesentery will be the presence of normal intestine. Pal-

vention should always be considered in an animal that is

pation of the gas-distended intestine will reveal that it

not too shocked and where the condition has not been

is protruding through a hole in the mesentery. The hole

present for too long.

must first be enlarged and the intestines slowly fed back

A right-flank laparotomy is performed and, on explo-

through the aperture, after which the mesenteric

ration, the grossly enlarged caecum can be detected.

rupture is sutured. It must be emphasized that surgery

Palpation of the root of the mesentery should be carried

should only be contemplated if the animal is not too

out to try and determine whether torsion exists.

severely shocked. As death can occur quickly with this

The first stage of the operation is to siphon off the

condition, casualty slaughter is commonly advised.

fluid present in the caecum, thus reducing its volume to *a manageable size. It is possible in some cases to siphon*

off 30–40 l of dark, foul-smelling fluid. When as much

Caecal dilatation and torsion

fluid and gas as possible have been removed a purse-

Caecal dilatation is a distinct clinical entity in adult

string suture is used to repair the incision through which

cattle. Its occurrence is sporadic (approximately 1–2 per

the siphon tube was inserted and an attempt is made to

10 000) and usually occurs in early lactation, although

relocate the caecum back to its normal position. If the

the condition has been reported in bulls. The aetiology

caecum is kinked or twisted, removal of the fluid may

is thought to be related to high levels of volatile fatty

well allow the torsion to correct itself. The laparotomy

acids in the caecum, which originate from the rumen or

is closed in the normal way. Postoperative treatment is

from fermentation of undigested starch in the caecum.

usual with fluid therapy if dehydration is evident and

The fatty acids cause atony of the caecum and the gas

antibiotics to prevent peritonitis developing. This can

accumulates. Mild dilatation probably causes no signs, *be a rewarding operation and most animals make an*

but severe dilatation will produce typical colic signs.

uneventful recovery.

However, many cases of caecal dilatation progress to

caecal torsion. Strictly speaking this is not a torsion but

Intussusception *(see p. 1114)*

due to the gross size of the dilated caecum and the large

Intussusception or telescoping of the bowel occurs in

quantity of fluid it contains, the distal end falls forward

adult cattle and calves. The annual incidence in adult

producing a kink in the organ. Occasionally, the weight

cattle is around 1 or 2 per 10 000, but may be more

of the distended caecum produces a torsion at the

common in calves. The condition is caused by strong

mesentery root and the colon, caecum and small intes-

peristaltic movements of the intestine and either the

tine are involved in a torsion rather similar to the

small intestine telescopes into small intestine or occa-

torsion of the small intestines at the mesentery root.

sionally through the ileo-caecal valve into the caecum.

In calves the condition is usually a sequel to profuse

Diagnosis

diarrhoea, but this appears not necessarily to be the

Diagnosis is based on the presence of the signs of colic,

case in adult cattle. Some workers have suggested that

although sometimes the colic signs are quite mild. Bal-

a tumour or inflammatory growth in the lumen of the

lottement of the right flank will elicit copious splashing

affected part may be a causative factor in adult cattle.

and fluid sounds and the right flank may be noticeably

Signs

distended. Rectal examination will reveal an empty

rectum and if a reliable history is available the animal

When the intussusception first occurs there will be mild

will not have passed any faeces for 24 hours or more.

signs of colic. These signs frequently go unnoticed by

the stockworker or if they are seen they are discounted

prompt, on no account should an attempt be made to

because they do not last for long and the animal makes

unravel the intussusception. Although this may well be

an apparent recovery. Two to three days later the *possible, the offending length of gut must be considered*

animal's milk production declines, inappetence sets in

to be diseased because it will certainly re-form as an

and the astute stockworker may notice the animal to be

intussusception within 24 hours of correction. Some

constipated. This is the most frequent time veterinary

workers have suggested that if intussusceptions are not

attention is sought.

removed surgically, but conservative treatment princi-

Examination will reveal a normal rectal temperature,

ples applied, the necrotic tissues of the intussusception

the heart rate raised to 80–120/minute and auscultation

will slough out in 10–14 days and the animal will

will reveal bowel stasis. A rectal examination will reveal

recover. This approach to treatment is not to be re-

an empty rectum or the presence of scanty bloodstained

commended because, in the author's experience,

faeces or thickened mucus. On questioning, the stock-

animals that are not treated surgically will die.

worker may admit that colic signs were evident two to

The intestinal anastomosis does require some surgi-

three days earlier.

cal skill but should not be beyond the majority of large

animal surgeons. The technique has been performed

quite satisfactorily on the farm.

Diagnosis

In many cases rectal palpation will reveal a hard,

Intussusception in calves

sausage-shaped mass in the right abdomen. The

absence of any dilated organ and complete bowel stasis

In calves intussusception is a sequel to acute diarrhoea.

will indicate a strong likelihood that an intussusception

Signs of colic will be present in the initial stages of the

is present, even if it cannot be palpated, although simple

disease, but frequently the animal is presented because

rumen indigestion may be difficult to differentiate. Pal-

it is not defecating or is collapsed. Occasionally, the

pation of the offending intussusception may be made

intussusception can be palpated through the abdominal

easier if the floor of the abdomen is raised using a pole

wall and if the calf is not in an advanced state of shock

under the ventral abdomen and lifted by two persons.

an exploratory laparotomy may be considered and the

The course of this disease is not as acute as other causes

offending lesion removed surgically and intestinal anas-

of intestinal obstructions; thus if the clinician is not

tomosis performed. Unfortunately, in calves the condi-

certain of the diagnosis, mild purgatives such as liquid

tion is most commonly encountered at post mortem.

paraffin or linseed oil may be administered orally and

the case re-assessed 24 hours later. These will do no

Diaphragmatic hernia

harm if an intussusception exists and, if the problem is

one of indigestion, faeces will be passed within 24 hours.

Diaphragmatic hernia has occasionally been reported in

It is important to instruct the stockworker to isolate the

cattle but the condition is rarely diagnosed and the inci-

animal in a clean pen for this period so that any faeces

dence is probably less than 1 per 100 000 per year.

voided will be observed. One of many problems with

Diaphragmatic hernia can be a congenital or acquired

loose-housing systems is that accurate history of

defect of the diaphragm with partial or complete entry *whether an animal is eating forage, defecating or uri-*

of abdominal organs (usually the reticulum) into the tho-

nating is frequently unavailable.

racic cavity. Congenital defects usually manifest before

If no faeces have been voided in the 24 hours of

the animal is 12 months old and acquired defects are

isolation an exploratory laparotomy must be

usually a sequel to traumatic reticulitis or trauma in

contemplated.

adult cattle.

The most commonly prolapsed organ seems to be the

reticulum and the result is interference with the motil-

Treatment

ity and function of the rumen and reticulum. Colic signs

An exploratory laparotomy in the right sublumbar

will be noticed at the time of the rupture but they do

fossa should be carried out if the farmer is willing.

not persist. Signs similar to vagus indigestion may be

Failing this, casualty slaughter should be performed.

apparent, although low-grade pain in the posterior

Exploration of the abdominal cavity will reveal the *thorax/anterior abdomen region, rather like traumatic*

hard mass of the intussusception, although when it is

reticulitis, has been noticed. Respiratory signs may be

exteriorized it may not be recognizable as such. It may

apparent due to reduced thoracic space. A definitive

appear more like a bloodstained tumour. Normal gut

diagnosis is unlikely to be made without recourse to an

should be identified entering and leaving the mass,

exploratory laparotomy, although radiography may be

which should then be surgically removed and intestinal

useful.

anastomosis performed. If the mass is recognizable as

Successful response to surgical correction has been

an intussusception, as may be the case if diagnosis was

reported, particularly in Indian buffalo, although this

is only likely to be successful with relatively small

there is a reluctance to move and walking sometimes

ruptures and in cases where the vagus nerve is not

instigates grunting. Appetite and milk production are

damaged. The cow is positioned in dorsal recumbency *invariably depressed and rumination ceases.*

and the incision made in the xiphoid area. Having

retrieved the reticulum from the thoracic cavity the

Diagnosis

hernia is repaired with monofilament nylon or by the

use of a fine nylon mesh.

The diagnosis of peritonitis can be difficult and is based

on the history and clinical findings. However, the con-

dition should be suspected in all cows that are pre-

Fat necrosis (lipomatosis, peritoneal

sented with the above clinical signs and a thorough

fat necrosis)

examination may reveal which organ is responsible.

Lipomatosis or peritoneal fat necrosis occurs sporadi-

Ballottement of the lower right flank may reveal splash-

cally (annual incidence 1–5 per 100 000) in old cows

ing sounds, indicating the presence of fluid in the peri-

with a suggested predisposition towards Channel Island

toneum, and also may cause the animal to grunt. For a

and Aberdeen Angus breeds. Affected cows may not

more detailed description of the diagnosis of traumatic *present any signs and the condition is detected at reticulo-peritonitis see p. 837. The history may also be routine rectal examination. Advanced cases of the con- helpful in arriving at a diagnosis, e.g. recent dystokia or dition will show signs of weight loss, underperformance abdominal surgery. If metritis is suspected, a rectal or and inappetence. The diagnosis will be based on rectal vaginal examination will aid the diagnosis. Abdominal palpation findings when large hard masses can be pal- paracentesis should reveal the presence of peritoneal pated in the abdominal cavity. Occasionally, fat in the fluid, which will be foul smelling and contain a large pelvic canal will be affected and the canal will be almost number of white blood cells.*

completely occluded and it is nearly impossible to carry The severity and extent of the peritonitis are usually out rectal palpation because of lack of space.

reflected in the severity of the clinical signs. If the peri- There is no treatment and slaughter should be tonitis is generalized and acute, the animal groans on advised. On post mortem as much as 20–25 kg of *expiration. When only a limited area of the peritoneum*

hard necrotic fat may be present in the omentum and

is involved, as in traumatic reticulo-peritonitis, pain will

mesentery.

only be evident when the exact location is percussed.

It is important to attempt to determine the cause of

the peritonitis in order to give an accurate prognosis

***Peritonitis** (see also p. 141)*

and to determine the line of treatment that should be

followed.

Peritonitis is a local or general, acute or chronic, inflam-

mation of the peritoneal cavity. Peritonitis usually

Prognosis

occurs as an accompanying condition of other specific

diseases, e.g. traumatic reticulo-peritonitis (p. 837) or

Localized peritonitis has a favourable prognosis, pro-

metritis (pp. 519, 521). The most common cause of peri-

viding the offending organ can be identified and cor-

tonitis is traumatic reticulitis followed by peritonitis

rective action taken. However, in acute generalized

as a sequel to metritis, dystokia or retained afterbirth.

peritonitis the prognosis can be poor, particularly if the

However, peritonitis may be a sequel to abdominal

peritonitis is a sequel to abdominal surgery, dystokia or

surgery, a ruptured abomasal or intestinal ulcer, pene-

a ruptured abdominal viscus. The prognosis will be

tration of the intestinal tract by foreign bodies, pancre-

related to the severity of the clinical signs, the degree

atic necrosis, rupture of biliary or urinary tracts, an

of depression, the weakness of the pulse and the extent

infected umbilicus in calves, rupture of the rectum,

of the signs of toxaemia.

uterus or large intestine, tuberculosis, liver abscesses

and chronic right- or left-sided displacement of the

Treatment

abomasum. Peritonitis can also be associated with

septicaemic conditions such as anthrax and calf

Treatment may first be directed to correction of the

septicaemia.

initial problem. However, the peritonitis itself will be

treated with large doses of antibiotics administered

intraperitoneally, intravenously and intramuscularly.

Signs

An initial dose of 5 g of benzylpenicillin and 5 g of dihy-

The clinical signs include a raised rectal temperature,

drostreptomycin is administered into the peritoneum

which is frequently in the range 39–40°C (102.5–104°F),

via the right sublumbar fossa, using a 2-inch 16-gauge

respiration is frequently shallow and pulse and respira-

needle followed immediately by 5 g of procaine peni-

tory rates are increased. The back is moderately arched,

cillin G and 5 g of dihydrostreptomycin by intramuscu-

lar injection and every 12 hours for three to five days.

systemic disease or other signs present, the cow must be

Some workers have reported success using heparin by

removed from its present food source, isolated and

intramuscular injection at a dose of 50 000 iu twice daily

given only dry feed, such as hay, to eat. Treatment with

for three days in addition to antibiotic therapy

antibiotics such as streptomycin may be instituted,

(Breukink, 1980). The author can report successful

although the efficacy in these situations is not proven.

treatment using intraperitoneal injections of metron-

Spasmolytics may help and oral therapy with gut seda-

idazole (10 g daily for 3–5 days). However, metronida-

tives such as chlorodyne or adsorbents such as kaolin

zole cannot now be used on animals intended for

are frequently used but again their efficacy is not

human consumption.

proven. The addition of glycine/electrolytes to the

drinking water has more recently been suggested, but

in cases where severe dehydration is present intra-

Diarrhoea

venous administration of 20–40 l of balanced elec-

trolytes is indicated.

Diarrhoea in adult cattle is a frequent sign and is

If the whole herd or group is affected, one must

present in many diseases. It may occur sporadically,

remember that lush spring grass will produce diarrhoea

affecting only individual animals, or it may be present

as will wet autumn grass in the UK. Wet grass silage will

in a large number if not the whole of the group. If the

also produce fluid faeces. In some areas of the UK and *whole group is affected, one must consider the feed or*

in other countries molybdenum toxicity is common, e.g.

the possible presence of a virus infection as in winter

on the so-called teart pastures of Somerset, and this will

dysentery. Blood may be present, in which case dysen-

produce severe diarrhoea in the whole grazing herd but

tery is used to describe the sign. The diarrhoea may be

can be corrected by the administration of copper in the

very watery or even projectile as in redwater (pipe stem

form of copper sulphate to the diets.

diarrhoea). The colour and odour may be distinctive.

An infectious cause of a whole group of cattle to be

Dark, foul-smelling, liquid faeces would indicate the

affected with diarrhoea is winter dysentery (see p. 852);

presence of occult blood and haemorrhage in the upper

infection with Salmonella typhimurium, S. montevideo small intestine. Pale, pasty-coloured faeces may indicate

or S. goldcoast may spread rapidly through a herd but rumen acidosis. Diarrhoea with air bubbles is fre-the animals will also be pyrexic.

quently attributed to Johne's disease. Endotoxaemia

Thus diarrhoea is a sign of many disease conditions

from a coliform mastitis or metritis will produce dark, *of cattle but frequently enteritis will occur in individual*

watery faeces. Infections with agents such as Campy-

animals and the cause will remain undetermined. There

lobacter spp. or BVD/mucosal disease virus will also

remains a challenge for the bovine practitioner.

produce diarrhoea and Salmonella spp. often produce

dysentery. Intestinal parasitism will produce diarrhoea

of varying intensity depending on the severity of the

Salmonellosis

problem, although this more commonly affects growing

cattle than adults.

Infection of adult cattle with a variety of Salmonella

Non-inflammatory diseases, e.g. cardiac failure, lym-

spp. is frequently encountered in cattle practice (see

phosarcoma and systemic amyloidosis, also produce

Chapter 15). In the UK as many as 100–200 herds per

diarrhoea by increasing intestinal secretion into the

10 000 may suffer the disease each year where it affects

bowel lumen.

a considerable proportion of the herd. The incidence of

The clinician is frequently presented with an adult *sporadic salmonellosis, where only one or two animals*

bovine where the only sign is an afebrile diarrhoea.

in the herd are affected, may be as high as 500–1000 per

Clinical examination may reveal sluggish rumen move-

10 000 herds. These sporadic occurrences are usually

ments but no other signs of indigestion or of abomasal

abortions due to S. dublin. A variety of Salmonella spp.

disease. Many of these cases will be the result of inges-

have been known to affect cattle but the two most

tion of toxic plants if the cattle are grazing or being fed

prominent are S. dublin and S. typhimurium. Salmo-conserved fodder and frequently the cause may be a

nella newport, S. montevideo and S. goldcoast are less small batch of soiled or spoiled silage.

frequently reported and sporadic outbreaks with other

Some cows with such acute diarrhoea die rapidly and

species occasionally occur. The most serious problems

post-mortem examination reveals a severe enteritis, fre-

are associated with enteritis and septicaemia, but spo-

quently haemorrhagic, but the examination for infec-

radic outbreaks of abortion with no concurrent septi-

tions or parasite counts proves unrewarding. One *caemia or enteritis are frequently encountered due to*

usually assumes that the cause of death is poisoning but

S. dublin. Epidemiologically, abortion appears different frequently the toxic agent is not discovered. When pre-from the enteritis and septicaemia syndrome and will

sented with individual cows showing diarrhoea and no

be dealt with separately (p. 582).

Epidemiology and aetiology

Signs

The principal signs produced by Salmonella infections The aetiological agents S. typhimurium and S. dublin are acute enteritis and septicaemia with a sudden onset

are those most frequently encountered although other

of severe diarrhoea or dysentery. Frequently, the mucous

species are reported sporadically. The epidemiology of

membrane lining of the small intestine is passed with the

S. dublin appears to differ from that of S. typhimurium.

faeces and, occasionally, blood clots are present.

It has been known for some time that to establish S.

The rectal temperature is 40.5–41.5°C (105–107°F)

dublin carrier status in the adult cow there needs to and the cow is severely depressed. The severity of the *be damage to the liver and/or bile ducts. The most*

signs varies considerably. If the disease occurs at or

frequent cause of liver damage is liver fluke and in

near parturition, septicaemia sets in and mortality may

areas where liver fluke is endemic, the incidence of S.

be as high as 20 per cent of affected animals, particularly

dublin enteritis is more common. The source of

with S. dublin infections. Salmonella typhimurium pro-infection for S. dublin is therefore carrier cows, most duces morbidity varying from 10 to 70 per cent of the

of which are suffering liver damage from liver fluke

herd however mortality is generally not high, although it

and if liver fluke is endemic in a herd, S. dublin

will be higher if infection occurs at or around calving.

may spread rapidly. In areas where S. dublin infection If infection with S. typhimurium or S. dublin occurs is unusually high, the organism can frequently be

during late pregnancy, seriously affected animals will

isolated from rivers, streams and ditches. It is difficult

frequently abort. This is probably a result of the fever

to postulate the role this contamination has in

and septicaemia rather than the infection directly

the spread of the infection as one would expect the *affecting the fetus or placenta. Salmonella dublin will watercourses to be infected if carrier cows exist in the*

cause abortion without enteritis and septicaemia being

area.

present but the epidemiology and pathogenesis is dif-

The carrier status probably also exists with S.

ferent. This will be discussed under Salmonella dublin

typhimurium, but this is much less common than with

abortion (see p. 582). Animals that abort following sep-

S. dublin. The majority of S. typhimurium outbreaks in ticaemia and enteritis frequently develop acute septic

adult cattle are of sudden onset and indicate a recent

metritis and peritonitis and frequently die.

introduction of the infection into the herd. The most

common source of infection is probably purchased con-

taminated compound feeds. These feeds often used to

Diagnosis

contain processed animal protein, which was frequently

The diagnosis is confirmed by the isolation of Salmo-

infected with Salmonella spp. Cross-infection to cereals nella spp. from faeces of affected animals. The faeces of also occurs when common storage bins and mixing

all cattle presented with acute enteritis accompanied *equipment are used. Cross-contamination of animal*

with fever should be sampled and tested for Salmonella

feeds may also be caused by wild birds or rodents that

spp. by bacteriological isolation. Affected animals

may live in animal feed production premises. A further

should be kept in isolation until the result is known.

source of infection for S. typhimurium is rivers or

streams. In many rural areas public sewerage facilities

Treatment

do not exist and septic tanks or cesspits are used. If

these do not function satisfactorily, raw or part-treated

Antibiotics administered parenterally are used for the

sewage finds its way into rivers. Human infection has

treatment of salmonellosis. Due to resistance to some

also been the cause of infection when cattle have grazed

antibiotics an in vitro antibiotic sensitivity test should be fields in which human defecation is known to have

performed as soon as possible. Resistance to penicillin,

occurred or fields that are situated next to lay-bys on

streptomycin, the tetracyclines and ampicillin is wide-

busy main roads.

spread with S. typhimurium. Neomycin and framycetin
On occasions cows have been shown to be excreting
are frequently effective and resistance to chlorampheni-
S. typhimurium but yet not show signs of disease, i.e.
col and gentamicin is rare. The combination of trimetho-
they are carrier cows. The presence of a carrier cow
prim and sulphadiazine is also frequently used. There is
within a herd may go undetected and no problem exists
always some controversy regarding the use of antibiotics
with the rest of the herd. The reason why the infection
in treating salmonellosis in adult cattle. Septicaemic
does not spread in these situations is not clear. It may
cases and complications following abortion should
be that a minimum infective dose is required to estab-
always be treated with antibiotics. However, in a herd
lish disease or the immune system of the animals may
outbreak, some animals will be less severely affected
be depressed with a virus infection spreading within the
than others and will recover spontaneously without the
herd and this allows Salmonella infection to develop
use of antibiotics. Antibiotic therapy will need to be

into disease.

administered for three to five days.

Oral rehydration therapy is indicated where dehy-

majority of outbreaks of S. typhimurium the problem

dration is evident and if the dehydration is severe, intra-

rarely recurs. It is only very occasionally that a herd

venous administration of 30 l of balanced electrolyte

may become chronically infected and sporadic cases

solution will prove to be a valuable support to anti-

will continue to occur. More usually the infection is con-

biotic therapy. Recovery time can be quite variable.

fined to the calves in endemically infected herds. In the

Cattle with mild enteritis will recover within two days,

case of S. dublin enteritis the main thrust in control fol-whereas severe septicaemic cases may take one to two

lowing vaccination is to control liver fluke in the herd.

weeks to recover their previous appetite and will not

If this is successfully achieved, enteritis caused by S.

normally return to previous levels of milk production.

dublin will be infrequent.

Attempts to identify carrier cows within endemically

infected herds are sometimes recommended. This is

Control

achieved by faeces sampling the entire herd and cul-

Once the diagnosis has been confirmed, it is important

turing the samples for Salmonella spp. Unfortunately, to limit the spread within the herd. Isolation of affected

Salmonella spp. are excreted intermittently in carrier animals will help but by the time cows are identified

cows and animals need to be sampled on several occa-

with enteritis, Salmonella organisms will be isolated sions, probably as many as six or seven, to be reason-from any site on the farm frequented by the cattle. Vac-

ably certain all carrier cows are identified. This

cination of non-affected animals should be considered.

procedure has proved to be neither practical nor nec-

In the UK the live vaccine prepared from an avirulent

essary in most outbreaks.

strain of S. dublin is no longer available. A dead vaccine prepared from formalin-killed cells of S. dublin and S.

Prevention

typhimurium (Bovivac S, Intervet Ltd) is available and To prevent infection with S. typhimurium may be diffi-has been used to control outbreaks of S. dublin or S.

cult because of the frequency in which it is found in *typhimurium. The whole herd should be vaccinated*

animal feeds. Contamination of feed can also be caused

with two doses 21 days apart and booster injections

by rodents and birds. However, legislation has been

administered two to three weeks before calving to

implemented in the UK to supervise all protein

boost the passive immunity available to the calves. If

processing plants and to ensure the protein material is

exotic Salmonella species are identified consideration sterilized. In recent years infections entering the

should be given to the use of autogenous vaccines using

herd via purchased feeds have become less frequent.

the same protocol as stated above. Control measures

Preventing infection spreading from the human

should also include monitoring the environment,

population to cattle can be achieved to some extent by

including the wildlife, and husbandry measures put in

the supply of clean wholesome water for cattle to drink.

place to reduce the risk of spreading infection. Cattle

For the effective control of a variety of infections

slurry should only be applied on land to be ploughed or *cattle should not be allowed to drink from natural*

on grass for conservation at least three to four months

watercourses. Effective fencing of fields may also be

before the grass is cut.

required, particularly alongside main roads and lay-bys

If S. dublin is identified as the causal organism, a repto prevent humans using grazing fields as a lavatory.

resentative number of faeces samples (usually six to

twelve) should be examined for the presence of liver

Winter dysentery

fluke ova and if positive the herd should receive appro-

priate anthelmintic therapy.

As the name implies, winter dysentery occurs during the

It is essential when salmonellosis occurs on a farm

period of winter housing and affects cattle of all ages.

that the utmost care should be taken regarding personal

It is obviously an extremely infectious disease because

hygiene. All the staff should be made aware of the

when it enters a herd it rapidly spreads through all

zoonotic implications and should not consume farm

animals in the herd. Also, once infected and the animals

milk during the course of an outbreak. In the UK, Sal-
have recovered, the herd will not usually experience the
monella isolation must be reported to the relevant
problem for four or five years, thus indicating develop-
departments of agriculture, who monitor the infection
ment of a herd immunity.
nationally. Very little action is taken against the farmer
Moreover, once one herd in an area becomes
unless there is a perceived human health risk, e.g. fresh
infected, it appears to spread rapidly to other herds
milk is being used for yoghurt, cream or cottage cheese
nearby. Perhaps this is a disease that can be spread by
production, in which case the public health authorities
veterinary surgeons! However, it is interesting that
may insist on pasteurization of the milk prior to pro-
there has been very little mention of its occurrence in
cessing. The question is frequently asked: should recov-
the UK during the last 15–20 years, whereas during the
ered cases be kept and will they become permanent
late 1950s and early 1960s it was frequently encoun-
carriers? Practice experience would indicate that in the

tered. It has been reported to be present in several

countries in Europe and the northern States of the USA

However, a proportion of the cases are more severely

and Canada have experienced large outbreaks in past

affected and some may become weak enough to

years. Although the morbidity is almost 100 per cent,

become recumbent. Severely dehydrated animals will

mortality is normally absent. Milk production, however,

require intravenous administration of 20–30 l of bal-

may be reduced by up to 50 per cent and take up to two

anced electrolytes and electrolytes added to the drink-

weeks to recover and so it is of economic importance.

ing water should prove advantageous. Oral astringents,

such as 50 ml of 5 per cent copper sulphate administered

Aetiology

every 12 hours, may prove effective. Morphine and

chloroform (chlorodyne) reduce intestinal motility and

Campylobacter fetus var. jejuni was once thought to be absorbents such as kaolin or bismuth salts have also

the causative organism. But the speed of spread, the *been recommended. Oral sulphonamides have been*

short incubation period of around three days and the

reported to be useful by some practitioners.

inability to reproduce the disease using cultures of C.

jejuni lead one to suspect the aetiological agent is a virus, which to date has not been identified. However,

Prevention

coronaviruses have been encountered in several out-

This is an extremely infectious disease and when it

breaks and are now often considered to be involved in

occurs in an area cattle or unnecessary personnel

the causation of some outbreaks.

should not enter the farm. Veterinary surgeons should

take the utmost care in thoroughly disinfecting their

Signs

boots and protective clothing before entering and

leaving farms when this infection is present locally.

The main sign is of a severe, watery, dark brown

diarrhoea with a foul-smelling odour. The faeces may

be tinged with blood. The diarrhoea is sometimes

Bovine virus diarrhoea/mucosal disease

described as explosive or projectile. At first only one or
Bovine virus diarrhoea and mucosal disease are both
two cows in the herd are affected, but within three or
diseases caused by bovine virus diarrhoea virus
four days several cows will show signs and within two
(BVDV), which is similar to the viruses causing Border
weeks all the older cattle on the farm will have become
disease in sheep and swine fever in pigs. These three
affected. The rectal temperature is usually normal and
viruses are together classified as pestiviruses within the
appetite is reduced in only a small number of more
Flaviviridae. It is worth noting that all three pestiviruses
severely affected animals. However, milk yield may
can cross the placenta and damage the fetus.
be reduced by up to 50 per cent and such animals
In 1946, veterinary workers at Cornell demonstrated
may show signs of abdominal pain, e.g. colic, arched
that a virus was the cause of a transmissible bovine diar-
back or a ‘hunched up’ appearance may be apparent.
rhoea and thereby named BVDV. The virus has since
The course of the disease in most cows is two to three

been identified worldwide as a most serious cause of

days.

cattle disease, particularly reproductive disease.

Diagnosis

Aetiology (Figs 48.1 and 48.2)

The severity and speed of spread of the disease present

no real problems in diagnosis except with the initial

Infection with BVD virus is generally a mild or even

cases, which may be misdiagnosed as a poisoning

subclinical event, except on two occasions, i.e. infection

(Chapter 54) or non-specific enteritis. Once several

of the pregnant animal and in mixed infections, e.g. with

cows are affected and the disease is occurring during

other respiratory viruses such as respiratory syncytial

the housed period, diagnosis is based on the clinical

virus (RSV), infectious bovine rhinotracheitis virus

signs present.

(IBR) or parainfluenza virus (PI3). Recently a more

Bovine virus diarrhoea would involve fewer animals,

virulent BVDV type 2 has teen reported in North

which would have pyrexia and characteristic oral

America.

lesions. Coccidiosis (see p. 282) normally affects

Many isolates of BVDV occur but all appear to cross-

younger animals, but this can be differentiated by the

react with convalescent BVDV sera. There are two dis-

presence of tenesmus and the identification of oocysts

tinct biological forms of the virus called biotypes,

in the faeces.

distinguishable in tissue culture, cytopathic and

non-cytopathic. This distinction is important in the

pathogenesis and understanding of mucosal disease.

Treatment

Cytopathic virus in tissue culture causes severe damage

Most affected cattle recover spontaneously in two to

to the cells and complete destruction within 48–72

three days and treatments do not speed recovery.

hours. The non-cytopathic virus causes no cell damage

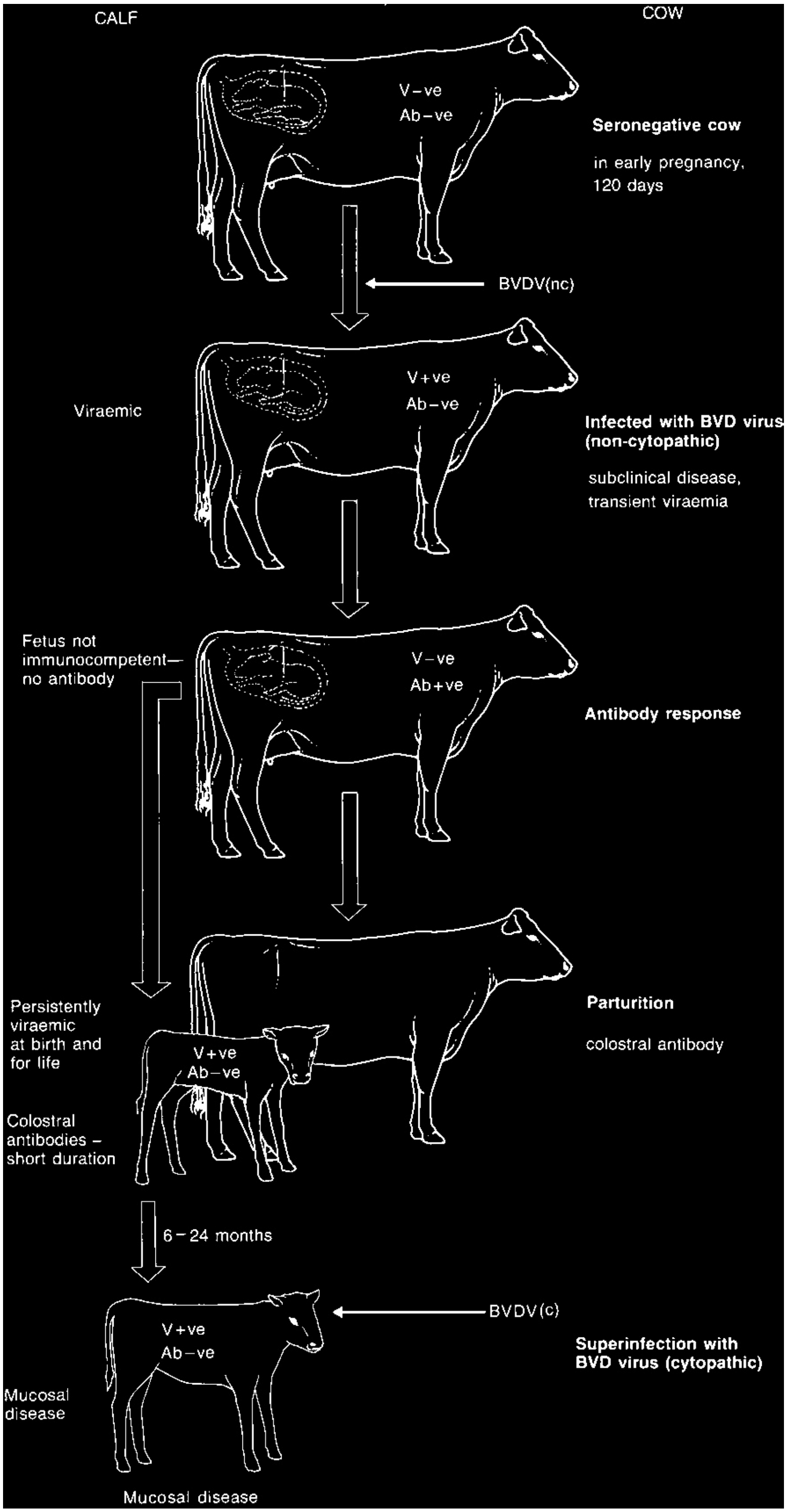

CALF
COW
V−ve
Ab−ve
Seronegative cow
in early pregnancy, 120 days
BVDV(nc)
Viraemic
V+ve
Ab−ve
Infected with BVD virus (non-cytopathic)
subclinical disease, transient viraemia
Fetus not immunocompetent— no antibody
V−ve
Ab+ve
Antibody response
Persistently viraemic at birth and for life
V+ve
Ab−ve
Parturition
colostral antibody
Colostral antibodies - short duration
6−24 months
BVDV(c)
V+ve
Ab−ve
Superinfection with BVD virus (cytopathic)
Mucosal disease
Mucosal disease

Fig. 48.1

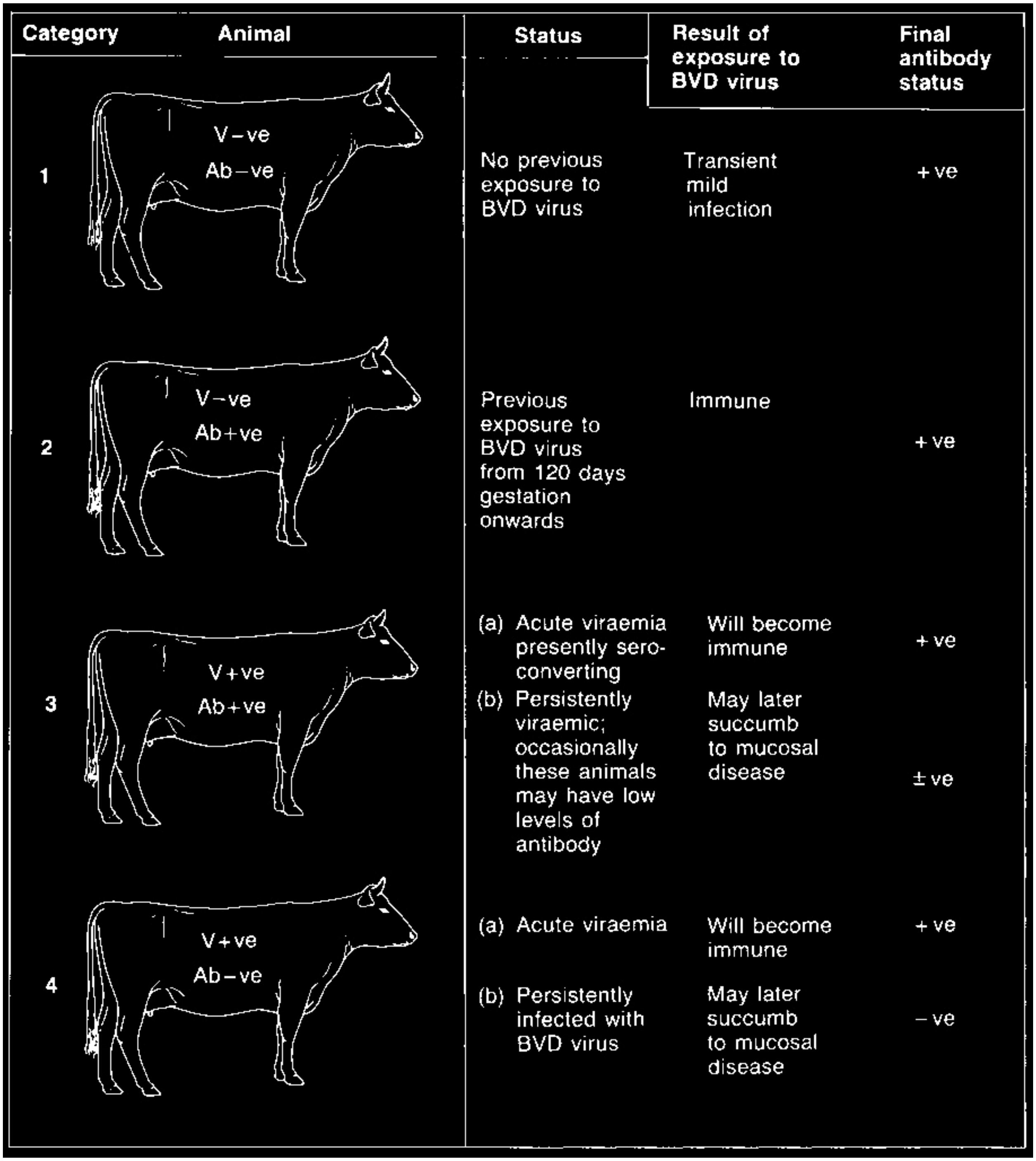
Hypothesis for the aeti-

ology of mucosal disease. V, BVD

virus; Ab, antibody to BVD virus; nc,

non-cytopathic; c, cytopathic (after

Brownlie, 1985).



Category	Animal	Status	Result of exposure to BVD virus	Final antibody status
1	V−ve Ab−ve	No previous exposure to BVD virus	Transient mild infection	+ve
2	V−ve Ab+ve	Previous exposure to BVD virus from 120 days gestation onwards	Immune	+ve
3	V+ve Ab+ve	(a) Acute viraemia presently sero-converting	Will become immune	+ve
		(b) Persistently viraemic; occasionally these animals may have low levels of antibody	May later succumb to mucosal disease	±ve
4	V+ve Ab−ve	(a) Acute viraemia	Will become immune	+ve
		(b) Persistently infected with BVD virus	May later succumb to mucosal disease	−ve

Alimentary Conditions • 855

Fig. 48.2

Combinations of BVD virus

and antibody in cattle and their signifi-

cance (after Brownlie, 1985).

and is identified by staining with fluorescein-labelled

and may result in abortion, mummification or early fetal

BVDV antisera.

death. If the fetus survives until neonatal life, it may

Non-cytopathic virus is the major biotype that causes

have developed a state of immune tolerance and then

disease, whereas cytopathic virus, isolated from field

the virus will persist for life. The fetus at birth will be

cases of mucosal disease, is usually only found as a

virus positive, but seronegative to the persisting virus.

superinfection of a pre-existing non-cytopathic

Infection after 120 days will still cause damage to the

virus infection. Bovine virus diarrhoea virus is shed

fetus, but it does not become immunotolerant and

in nasopharyngeal secretions and urine and perhaps

viraemic. Such damage would include cerebellar

by aerosol droplets. Faeces are a poor source of

hypoplasia resulting in ataxic calves (see p. 900).

virus.

Infertility: Infection of the cow in early pregnancy will cause infertility due to embryo or early fetal death. Evi-Pathogenesis

dence of this has been seen in North America, where

Postnatal infection of the young or growing animal with

an infected bull was used on two groups of heifers. One

non-cytopathic virus is usually a subclinical event. In

group was seropositive and the other seronegative. The

most herds where the virus is present there is no

seropositive heifers conceived normally (about 70 per

disease-related problem. However, infection of the

cent pregnancy rate) but the seronegative heifers suf-

seronegative pregnant cow prior to 120 days of gesta-

fered infertility (in the region of 33 per cent pregnancy

tion, before the immune system of the fetus has become

rate) that lasted several weeks. These heifers eventually

fully developed, can result in disease. When the virus

conceived when they had seroconverted some six to

has crossed the placenta, the fetus becomes infected

eight weeks after the initial infection.

Mixed infections: Bovine virus diarrhoea virus is

Diagnosis

immunosuppressive. Although infection of calves with

The diagnosis of mucosal disease will be based on the

BVD virus alone is generally subclinical if RSV, IBR or

clinical signs and laboratory tests. Pyrexia, diarrhoea,

P13 viruses are also present the pneumonia will be

erosions in the mouth and on the muzzle and recent

more severe than infection with respiratory viruses

weight loss in an animal six to 18 months old should be

alone (see Chapter 17).

highly suggestive of mucosal disease. In the live animal,

clotted and EDTA blood samples and a nasopharyn-

Mucosal disease: Mucosal disease occurs as a result of geal swab should be taken and must be submitted to the

a calf that was born viraemic and seronegative becom-

laboratory within 24 hours for both virus isolation and

ing superinfected with cytopathic virus. Mucosal

for BVDV antibodies. It is also helpful to submit fresh

disease is generally sporadic in nature affecting young

spleen, mediastinal lymph node, thymus and small in-

cattle six to 18 months old. It is usual to find only one, *testinal tissue (particularly with Peyer's patch tissue)*

two or three cases occurring on any one farm at the

for virus isolation. Bulk milk antibody levels can be

same time; however, larger outbreaks can occur. The

ascertained.

disease is characterized by weight loss, severe diarrhoea

and inevitably death. Death from mucosal disease

usually occurs two to three weeks after infection with

Differential diagnosis

cytopathic virus.

The main features of mucosal disease are mucosal ero-

sions, diarrhoea and death. Foot-and-mouth disease (p.

Signs

693), malignant catarrh (p. 953) and rinderpest (p. 707)

are the principal differential diagnoses. With foot-and-

The first signs to appear are anorexia accompanied by

mouth disease, morbidity is 100 per cent and vesicles

reddening and erosions around the dental pad, along

precede the mucosal ulcerations. With malignant

the gingival border and under the tongue. These are fol-

catarrh, corneal opacity is a feature; there is also gas-

lowed by reddening and erosion around the muzzle.

troenteritis and enlarged lymph nodes. Lymph node

The erosions are shallow, varying sizes and shapes and

enlargement is not a feature of mucosal disease. Rinder-

frequently coalesce. These are to be distinguished from

pest has vesicles preceding the erosions, morbidity is

ulcers following vesicular damage, e.g. in foot-and-

high and intestinal oedema and lymph node enlarge-

mouth disease (p. 693) or vesicular stomatitis (p. 710),

ment are common. Salmonella *(pp. 225, 850) enteritis*

which are deeper than mucosal disease erosions. Diar-

should not present a problem with differential diagnosis

rhoea then follows and sometimes lameness may be

as it generally affects either young calves or adult

apparent due to heat and reddening on the coronary

animals and there are no mouth lesions. Acorn poison-

band and erosions present in the interdigital space.

ing can look similar on post mortem, but biochemistry

Because of the sudden onset, diarrhoea is often the first

and histology of the kidney should distinguish it from

sign that is noticed although salivation is frequently *mucosal disease (see p. 951). Other poisoning events*

present. The animals are occasionally pyrexic. Weight

may also be considered as a differential diagnosis, but

loss is rapid and death inevitably occurs five to ten days

the characteristic oval erosions are generally absent.

later. Acute infections in adult cows can lead to diar-

rhoea and agalactia.

Treatment

Necropsy

There is no effective treatment for mucosal disease. If

the disease is suspected all efforts should be towards a

The post-mortem findings are usually strongly sugges-

diagnosis so that effective control measures may be

tive of mucosal disease. Oval erosions or shallow ulcer-

instituted.

ation may be seen in the buccal cavity, oesophagus,

abomasum, the small intestine beneath the Peyer's

Control

patches and in the colon. Oedema and erythema in the

intestinal epithelium may also be a feature. The prime

When a positive diagnosis has been made, the dam of

sites are the oesophagus, small intestine and abomasum.
the affected animal and all the animals in the same
Care must be exercised in opening the small intestine,
group as the affected animal should be blood sampled
which must be opened at the mesenteric attachment in
and the blood cultured for the presence of virus. Per-
order not to incise through the lesions. Tissue culture
sistently viraemic cows invariably give rise to viraemic
can be used to grow virus from all the lesions, as well
calves so all dams of viraemic offspring need to be iden-
as from mesenteric lymph nodes, spleen, thymus and
tified. If infection is a recent introduction then several
tonsil.
calves in the same age group as the affected one may

also be persistently viraemic. Most of these are likely to
'sweeper' bulls on breeding animals must include a
succumb to mucosal disease at some time in the future.
caution about the possibility of introducing BVDV into
When testing for BVDV, one should be aware of the
the herd.

possibility of sampling a calf that is only acutely

infected and not persistently viraemic. To differentiate

Johne's disease (paratuberculosis)

this possibility all virus-positive animals should be

retested at an interval of six weeks. Persistently

Johne's disease is a chronic, infectious enteritis that

viraemic calves should be slaughtered. In the USA and

results in progressive wasting and eventual death. The

elsewhere vaccines prepared from attenuated cyto-

disease has been reported worldwide wherever rumi-

pathic virus are available, but it is believed that these

nants exist and the causal organism is the acid-fast bac-

have occasionally caused disease. Inactivated BVD vac-

terium Mycobacterium johnei (paratuberculosis). This is cines are now available in the UK for injection in cows

now often called Mycobacterium avium var. paratuber-prior to pregnancy (p. 1011) and in calves for respira-

culosis (MAP). The prevalence of Johne's disease varies tory disease control (p. 1007).

between countries and within countries.

It is important to recall that surveys have suggested

There appear to be endemically infected farms on

that 1 per cent of adult animals in the national herd are
which the incidence can be as high as two or three con-
persistently viraemic. The retention of viraemic animals
firmed cases every year, yet in the same district there
in the herd is one strategy used to maintain herd immu-
will be many farms that do not experience the disease,
nity. However, there is always a risk that susceptible
except occasionally in a purchased animal. In some
cows in early pregnancy can become infected. There-
areas of the UK the incidence has declined consider-
fore, once persistently viraemic animals have been iden-
ably over the last 30 years, although the incidence in a
tified they should be slaughtered unless they can, with
number of northern European countries appears to be
certainty, be kept away from cows in early pregnancy.
increasing. Recently concern has been expressed at the
All newly introduced animals should be isolated and
similarity of Johne's disease and Crohn's disease in
screened for the presence of antibody and virus before
humans. The possibility exists that some cases of
mixing with the herd. Persistently viraemic animals

Crohn's disease may be caused by M. johnei.

should not be kept.

Pathogenesis

Control of BVD at herd level

Infection with M. johnei occurs in young calves usually Surveys have indicated that upwards of 60 per cent of

from their dams or contact with faeces of carrier cows.

UK cattle are seropositive to BVD infection and that

There follows a long incubation period of two to six

economic loss can be caused from infertility when

years during which lesions develop in the small intes-

seronegative animals are introduced into a seropositive

tine and the animals intermittently excrete the organ-

herd. This can be a common scenario with the introduc-

ism in the faeces. Not all infected animals progress to

tion of replacement heifers, whether home-bred or pur-

the disease state. Where the disease does develop, the

chased. Diagnosis of the seropositive status of the herd

organisms multiply and cause extensive lesions in the

can be achieved by testing bulk milk for antibody levels.

small intestine that produce overt clinical disease.

Recently, inactivated BVDV vaccines have become

available in the UK. The vaccines have proven excellent

Signs

efficacy in preventing the fetus becoming infected if

cows are vaccinated before they enter the breeding pro-

The usual presenting signs are profuse diarrhoea

gramme. Recent reports would suggest that significant

accompanied by gradual weight loss. Frequently, the

improvements in fertility can follow the use of vaccina-

stress of calving initiates the onset of signs and affected

tion. Therefore vaccination of replacement animals

cows are presented two to four weeks after calving.

before entering an infected herd is to be recommended.

Rectal temperature, appetite and ruminal contractions

Booster vaccination at yearly intervals will probably be

remain normal. Submandibular oedema is sometimes

required so in time the whole herd will require vaccina-

present. In advanced cases the weight loss leads to ema-

tion annually. The best control policy should be a com-

ciation and the diarrhoea remains profuse often with

bination of vaccinating breeding animals and *bubbles in the faeces.*

eradicating all persistently infected animals.

Special regard should be given to bulls as they can

Necropsy

transmit BVDV in semen. Any veterinary inspection of

bulls must include a blood test to ensure freedom from

The main pathological features are thickening of the

BVDV. Furthermore, any advice about the use of

lower part of the small intestine, the ileo-caecal valve

and sometimes the colon. The mucosal surface has a

stages of the disease. Antibiotics effective against

corrugated appearance. The organism may be present

Gram-negative bacteria, e.g. streptomycin, have been

on the mucosal surface or tissue sections of the intes-

used but without any long-term success. A short remis-

tinal wall may reveal both intracellular and extracellu-

sion of the diarrhoea is sometimes possible following a

lar organisms.

seven-day course of streptomycin and may be consid-

ered if for some reason it is not practical to cull the

Diagnosis

affected animal immediately. If dehydration is evident,

rehydration with intravenous fluid therapy may allow

Any debilitating disease that results in emaciation may

the animal to be sent for human consumption.

be confused with Johne’s disease. However, the profuse

diarrhoea, frequently containing bubbles, will distin-

guish the condition from weight loss caused by liver

Control

fluke (p. 276), liver disease, chronic traumatic reticulo-

As infection with the Johne’s disease organism occurs

peritonitis (p. 837) or malnutrition. Johne’s disease

in calfhood the main plank in any control programme

should always be considered as a possible diagnosis

is to separate the calves from their dams immediately

when a cow, four years old or more, and recently calved

after birth and rear them completely separate from the

is presented with weight loss and chronic diarrhoea. The

adult herd. They should not be allowed access to faeces

history of the prevalence of the disease on the farm will

from adult cows at any time during the growing period *also be helpful. Diagnosis is best confirmed by the*

and all drinking water should be from uncontaminated

demonstration of clumps of acid-fast bacteria in smears

sources, namely mains water.

of faeces stained with Ziehl–Nielsen stain. As excretion

In the UK and elsewhere a live vaccine (p. 1012) is

can be intermittent, repeat testing is sometimes neces-

available for use in endemically affected herds. The

sary. The faeces sample is best taken from the rectum

vaccine used is licensed by the Department of the Envi-

using a gloved hand, scraping faeces from the rectal

ronment, Food and Rural Affairs (DEFRA) and can

mucosal surface. Failure to detect the organism in faecal

only be used on farms where a positive diagnosis has

smears does not rule out the possibility of Johne's

been made from faeces or post-mortem material.

disease. PCR tests are now also used for the antigen,

Calves are separated from their dams at birth and the

but with the same provisos mentioned above. However,

vaccine administered subcutaneously in the brisket

the organism can usually be detected at post mortem in *area in the first seven days of life. A fibro-caseous*

stained impression smears of the mucosal surface of the

nodule 2–5 cm in diameter is produced at the injection

terminal ileum or in histological sections of the same

site and this remains for life.

area of ileum.

Vaccinated animals will produce positive reactions to

An ELISA test is now available which has a high sen-

both the avian and bovine tuberculin administered

sitivity and specificity in animals with clinical disease,

during tuberculosis testing. Usually, the avian reaction

although the sensitivity is reduced in animals infected

is greater than the bovine so differentiation from tuber-

but not showing clinical signs. PCR tests can be used on

culosis is possible if the comparative intradermal tuber-

milk and are a valuable herd screening test.

culosis test is used.

In some countries, Johnin is used as a diagnostic

Vaccination in endemic herds has met with consider-

test and can be administered intradermally or intra-

able success in reducing the incidence of disease in *venously. Injected intradermally, Johnin produces an*

them, but not necessarily infection. However, to be suc-

oedematous swelling at the site of injection in some

cessful separation of the calves from the adults and

cattle that are infected with Johne's disease. When

good hygiene is necessary in addition to vaccination.

injected intravenously, Johnin will initiate a rectal tem-

perature rise of at least 0.8°C (1.5°F) 4–8 hours after

injection. However, as with the complement fixation

Tenesmus

test, the use of Johnin as an accurate diagnostic indica-

tor is not to be regarded as reliable.

Tenesmus or ineffectual straining to defecate is com-

If a definite diagnosis is required, the organism can

monly a sign of disorders of the pelvic cavity, the rectum

be cultured from faeces, portions of terminal ileum or

and some diseases of the alimentary canal.

mesenteric lymph nodes, but positive results will not be

Tenesmus can be produced by profuse watery diar-

available for six to eight weeks.

rhoea or dysentery, constipation, parturition, prolapsed *vagina or rectum, vaginitis, urethral calculi, cystitis, lipo-*

Treatment

matosis of the pelvic cavity and coccidiosis. Tenesmus is

Treatment of Johne's disease is not to be recommended,

also an important sign of ragwort poisoning. Manual

as the clinical signs are only evident in the terminal

examination of the rectum or vagina will produce tenes-

mus, which will be all the more severe if diarrhoea is

faecal material will have entered the pelvic and abdom-

present. Rectal or vaginal lacerations as the result of

inal cavities. The judicious clinician will advise immedi-

sticks or broom handles being inserted into the vagina

ate casualty slaughter in such cases.

or rectum by sadistic individuals will also cause tenes-

mus. In practice, the most commonly encountered

reason for tenesmus is a cow that continues to strain

Recto-vaginal fistula

after calving. This can be due to a second calf in the

Recto-vaginal fistulae are invariably the result of severe

pelvic canal, a retained afterbirth or lacerations to the *dystokia, usually in first-calving heifers. Tearing of the vaginal wall. The most effective treatment in these sit- vulva can sometimes involve the anus or occasionally a uations is to remove the calf if one is present or admin- foot of the fetus punctures the roof of the vagina and ister a local epidural anaesthetic.*

the floor of the rectum and a fistula results. These

A thorough examination is essential in cattle exhibit- normally heal and the animal thereafter defecates via ing tenesmus. Vaginal examination should be carried the vagina. Attempts at surgical repair are sometimes out using a vaginascope to prevent further damage, recommended because pneumovagina or vaginal con- although frequently signs of vaginal damage may be tamination with faeces produces infertility. Although apparent by separating the vulval lips. A rectal exami- conception will not occur in cows so affected if natural nation will normally be necessary, particularly if consti- service is used, it may be successful using artificial pation is suspected, but a gloved well-lubricated arm insemination because the semen is deposited in the *should be used because this procedure may exacerbate*

anterior cervix or the body of the uterus, thus bypass-

the condition. Every effort must be made to identify the

ing the vaginal damage.

cause of the tenesmus so that corrective therapy can

then be applied.

References

Diseases of the rectum and anus

Breukink, H.J. (1980) The effect of heparin in the treatment of general peritonitis in cows. In Proceedings of the XIth Inter-

Rectal prolapse

national Congress on Diseases of Cattle, Tel Aviv, pp. 1442–5.

Rectal prolapse is less common in cattle than in other

Brownlie, J. (1985) Clinical aspects of bovine virus diar-

rhoea/mucosal disease complex in cattle. In Practice, ***7****, species. However, it may occur as a result of prolonged*

195–202.

tenesmus associated with vaginal lesions, or coccidiosis,

Gordon, P. (2001) A simple technique for correction of left dis-and it has been associated with laurel poisoning. The

placed abomasum. UK Vet, ***5,*** *33–5.*

condition appears to be more common in the Hereford

Jack, E.J. (1985) The cold cow syndrome – the Cornish ex-

than other cattle breeds.

perience. In Proceedings of British Cattle Veterinary As-

sociation Meeting, London, January 1985, p. 203.

Pinsent, P.J.N. (1977) The diagnosis of the surgical disorders Treatment

*of the bovine abomasum. Bovine Practitioner, **12**, 40–*

The rectum, if not excessively swollen, can be replaced

57.

under epidural anaesthesia and a pursestring suture

Pinsent, P.J.N. (1978) The diagnosis of the surgical disorders using umbilical tape inserted around the anal ring.

*of the bovine abomasum. Bovine Practitioner, **13**, 45–*

50.

In recurrent cases a submucosal resection may be

Stober, M. & Dirkson, G. (1977) The differential diagnosis of required.

abdominal findings (adspection, rectal examination and

*exploratory laparotomy) in cattle. Bovine Practitioner, **12**, 35–9.*

Rectal tears

Williams, E.I. (1975) The 'reticular grunt' test for traumatic Rectal lacerations are occasionally produced during

*reticulo-peritonitis. Bovine Practitioner, **10**, 98.*

rectal examinations. They may also be produced by *sticks or poles being inserted into the rectum by sadis-*

tic individuals. If the tear is completely through the

Further reading

rectal wall repair via a laparotomy may be possible,

although it is not easy to reach the pelvic cavity from a

Brownlie, J. (1985) Clinical aspects of bovine virus diar-

laparotomy incision. Also, to succeed the repair must be

rhoea/mucosal disease complex in cattle. In Practice, ***7****,* *effected immediately the laceration occurs, otherwise*

195–202.

Chapter 49

Respiratory Conditions

A.H. Andrews and R.S. Windsor

Acute exudative pneumonia

860

ing often at inspiration, particularly the latter. Cranio-

Aspiration pneumonia

860

ventrally, there may be moist sounds and there may be

Bovine farmer's lung

861

pleuritic rub (sandpaper-like) sounds in a few cases.

Bovine tuberculosis

862

Chronic suppurative pneumonia

864

Peracute pleuropneumonia

865

Necropsy

Diffuse fibrosing alveolitis

865

At post mortem there are dark areas of consolidation

Dusty feed rhinotracheitis

866

in the ventral parts of the apical and cardiac, and in

Fog fever

866

Thrombosis of the caudal vena cava

867

some animals, the thoracic lobes. The areas of pneumo-

Contagious bovine pleuropneumonia (CBPP)

868

nia may be small and scattered, but in more severe cases

there are large areas of consolidation and, in some

animals, abscess formation. Microscopically, there is

Acute exudative pneumonia

exudation and vascular congestion with the bronchioles

and alveoli showing infiltration with neutrophils and

Aetiology

macrophages (Pirie, 1979).

This is thought in many cases to be a primary bacterial

condition and usually Arcanobacterium (Actinomyces, Diagnosis

Corynebacterium) pyogenes (Gram-positive rods) can Diagnosis depends on the history of usually only a

be isolated, or in some cases Mannheimia (Pasteurella)

single animal being involved with pyrexia and respira-

haemolytica and P. multocida (Gram-negative short tory signs normally being evident.

rods) (Pirie, 1979).

Differential diagnoses involve chronic pneumonia but

normally the animals are less ill and several are affected.

Epidemiology

Inhalation pneumonia usually results in a very dull

animal and also there is often a history of drenching.

This condition is not uncommon and is usually seen as

respiratory disease in individual animals. It can be

present in cattle of any age, particularly when there has

Treatment and control

been chronic pneumonia in the housing period. In can

When treating, the affected animal should be isolated.

be seen in dairy-bred cattle as well as in suckler animals,

Antibiotic therapy with oxytetracycline, penicillin and

both indoors and at grass. Individual cases usually occur

streptomycin, ampicillin, amoxycillin, cephalosporins,

but outbreaks can follow some form of stress. The con-

sulphadimidine, and trimethoprim and sulphadiazine

dition is one of sudden onset and is mainly differenti-

for three to five days is usually successful. Most cases

ated from acute viral pneumonia by the fact that it

respond well to therapy, but a few cases relapse and some

usually affects individual animals.

ultimately develop chronic suppurative pneumonia.

Prevention is by trying to ensure adequate ventila-

Signs

tion when housed and to avoid chilling.

The animal shows signs of suddenly going off its feed

and is dull. There is an oculo-nasal discharge which may

Aspiration pneumonia

be mucoid or mucopurulent. The temperature is usually

40–41°C (104–107°F), respiratory rate is between 20

Aetiology

and 60/minute, usually with hyperpnoea. There is often

some coughing but this is not pronounced. On auscul-

This is also known as inhalation pneumonia and

tation there are usually squeaks, humming and wheez-

although not a common condition, it still occurs too

frequently. Obtaining an adequate history is important

Differential diagnoses include septicaemia, which has

and often the stockworker may realize what has hap-

fewer respiratory signs, enteritis but then diarrhoea is

pened, but will be reluctant to admit it or even that the

present, and acute exudative pneumonia, but in this

animal has been drenched. Obstruction or paralysis of

case there is no history of drenching and usually the

the larynx, pharynx or oesophagus may produce the

animal is less dull.

problem, as with parturient paresis, or the rupture of a

pharyngeal abscess or the products of laryngeal diph-

theria. The signs will depend on the nature of the fluid

Treatment and control

introduced, the quantity and the bacteria introduced. If

If there is to be a hope of effective therapy, it must be

a large quantity is administered into the lungs, then

administered as soon as possible after the drenching

instantaneous death may occur. If the substance given

incident. The use of antibiotics or a sulphonamide is

is soluble, then absorption into the body is rapid

indicated and it is best to give the first dose intra-

because of the highly vascular nature of the lungs, and

venously. Thus oxytetracycline, amoxycillin, ampicillin,

few, if any signs will occur. Less soluble products will

sulphadimidine, sulphamethoxypyridazine or sulpha-

result in a varying degree of toxaemia and respiratory

pyrazole can be used. In exceptional circumstances

signs, which are often fatal, after between one and three *where allowed chloramphenicol might be indicated.*

days.

Therapy should be continued in most cases for about

five days. In addition, fluid therapy may be required.

Signs

The animal should be encouraged to eat and drink. It

should be kept on its own in a well-bedded, airy pen.

In the peracute form death occurs rapidly after drench-

Control is by ensuring that all drenching and dosing

ing. However, in the acute form only one animal is

is undertaken slowly, allowing the animal time to

usually affected and there is a history of drenching.

swallow.

Signs develop rapidly and include a varying degree of

dullness and inappetence, a cough and tachypnoea. The

temperature is usually elevated to about 40°C (104°F)

Bovine farmer's lung

and on auscultation there are areas of dullness present,

normally in the cranio-ventral parts of the lungs, and

Aetiology

moist bubbling and crackles may be heard in the area.

There is often also a pleuritic rub sound and some

This is a form of chronic atypical interstitial pneumo-

degree of thoracic pain. If the condition progresses, the

nia. The condition appears to be a chronic reaction to

signs of dullness and anorexia become more pro-

certain fungi found in badly made hay, such as Micro-

nounced, and there may be a fetid odour to the breath.

polyspora faeni.

In the subacute form there are few signs present

except for episodes of coughing and tachypnoea fol-

Epidemiology

lowing the introduction of the fluid. Some animals will

survive the immediate episode and become chronic

The problem is quite common during the winter in

cases. These will show ill-thrift and intermittent bouts

housed cattle fed poor quality mouldy hay or straw.

of respiratory problems.

More cases occur in the wetter western parts of Britain

and in other countries with high rainfall. Where much

rain falls in the summer months, hay may need to be

Necropsy

baled at very high moisture contents. This allows over-

At post mortem there is often an acute exudative or

heating to occur and thermophilic microflora then pre-

gangrenous pneumonia of the ventral parts of the

dominate. Disease is often only seen in adult cattle and

apical, cardiac and usually also the diaphragmatic

in some cases the farmer will also have farmer's lung.

lobes. In some animals there is extensive suppurative

In Britain this is defined as an industrial injury and is

necrosis.

considered to be due to the inhalation of dust from

mouldy hay or other mouldy vegetable produce. It

results in a defect in gas exchange due to a reaction in

Diagnosis

the peripheral parts of the bronchopulmonary system.

Diagnosis is helped if a true history is obtained and is

In cattle the condition is usually a herd problem but

indicative that the condition is present. Usually only a

occasionally a farmer will consider that there is sudden

single animal is affected and the signs are of sudden

onset in one animal. In such cases the examination of *onset. The respiratory signs are severe and there is*

other animals will show varying lesser degrees of the

usually a leucopenia and neutrophilia present.

problem.

Signs

Control involves improving hay-making, which may

mean the use of hay additives to upgrade hay quality.

The acute signs follow housing and there is often a

Otherwise, the provision of silage might be useful but

sudden onset of dullness, a fall in milk yield and a

this does normally mean investment in new machinery

decreased appetite. The animal shows respiratory signs,

for producing the conserved roughage.

normally including some respiratory distress, and

coughing. On auscultation there are crackles over the

cranio-ventral parts of the lung. Although some cases

Bovine tuberculosis

are pyrexic, most animals will have a normal rectal

temperature.

Aetiology

In the chronic form there is progressive weight loss

and coughing, often with the production of green

This is infection with Mycobacterium bovis (Gram-

mucus, which tends to occur with each winter but

positive, acid-fast rods).

resolves during the summer months with outside

grazing. Occasionally, such animals will develop a

Epidemiology

sudden crisis following a stress such as calving, a sudden

At one time the condition was very common in many

heavy exposure to the antigen, unaccustomed exercise

countries. However, following tuberculin testing, pas-

or due to congestive heart failure. Usually there is

teurization of milk and adequate meat inspection the

obvious tachypnoea and hyperpnoea but no pyrexia or

disease is uncommon in most countries today, but is still

thoracic pain or alteration in the resonance of the

seen periodically mainly in dairy herds. In most cases

thorax. Auscultation may produce harsh crackles over

infection breaks out in the growing heifers or younger

the cranio-ventral aspects of the lung and in some cases *cows. The condition is still prevalent in south-west*

there are widespread whistles, squeaks and wheezing. It

England, but is now being increasingly seen in other

is uncommon for animals to die of the condition unless

areas including the south Midlands, north-west England

there are complications.

and Wales. In many regions infection has reappeared

and is associated with the finding of tuberculosis in the

Necropsy

European badger (Meles meles). However, in many

cases infection can follow the purchase of a carrier

At necropsy all lung lobes may be affected and there is

without overt signs. Infection of deer with M. bovis can often overinflation of the peripheral acini. Small grey-also spread disease and in New Zealand a problem

green foci tend to be present in the lobules. Histologi-

occurs with the brush-tailed possum (Trichosurus

cally, the alveolar walls show interstitial infiltration with

vulpecula). The organism is killed by sunlight, but is plasma cells, lymphocytes and macrophages. Another

resistant to desiccation and can survive in a wide range

change is bronchitis obliterans and also epithelial granu-

of acids and alkalis. It is also able to remain viable for *lomata can occur.*

long periods in soil that is moist and warm. In cattle

faeces, M. bovis can survive for as little as a week or as Diagnosis

long as eight weeks. Man can occasionally be infected

and the disease can occur in goats and pigs, and very

Diagnosis depends on a history of occurrence in wet

occasionally in horses and sheep. Very occasionally

areas and feeding poor quality mouldy hay in winter.

cattle can be infected with Mycobacterium tuberculosis, The problem improves in the summer. Signs include

usually because people tending or in close contact with

loss of weight with the respiratory disease. An intra-

the cattle are infected.

dermal skin test with Micropolyspora faeni produces a When infection is by inhalation, a lesion often occurs

reaction 4–6 hours after injection. On serological exam-

at the point of entry and the local lymph node. When

ination precipitating antibodies to Micropolyspora

ingestion is the route of entry, alimentary lesions are

faeni are found but they may also be seen in unaffected rare but lesions may be present in the tonsils, pharyn-cattle within the same herd.

geal or mesenteric lymph nodes. Lesions may then disseminate from the primary areas to others.

When the badger is involved, most infection is

Treatment and control

thought to be by ingestion, but a higher infection level

The use of long-acting corticosteroids may help reduce

is necessary to establish alimentary than respiratory

signs. Where mouldy hay or straw has to be fed or used

infection. In most cases the lesions are respiratory and

for bedding then it must be shaken out outside before

are thought to be due to the inhalation of ruminal gases.

being offered to the animals. As human problems can

The organism can be present in sputum, milk, faeces,

arise, a face mask should be worn.

urine, vaginal and uterine discharges and any discharg-

ing lesions. Entry is usually by inhalation (especially if

infection is active and if cases are ‘open’ and therefore

housed) or ingestion (when outside or badgers are the

likely to infect other animals. Active infection is desig-

source of infection). Drinking infected milk can infect

nated by lung infection with limited encapsulation and *the calf. Signs can occur in very young calves (under a*

hyperaemia. This categorization is now thought to be

month old). Intercurrent disease in the herd such as

erroneous and it is considered that most lesions are

BVD may exacerbate the problem (Monies, 2000).

potentially infective. Other organs often show small,

Once in a herd, infection probably spreads from cow to

transparent, shot-like lesions and these may also be

cow by inhalation. However, spread from cows to calves

present in the lymph nodes. Tuberculous cystitis and

may be via the milk. Occasionally, intrauterine infection

metritis tend to be open cases. Closed infection is seen

has resulted from a coital transfer.

as discrete lesions enclosed within well-developed cap-

sules. The enclosed pus tends to be caseous and yellow

or orange in colour. In tuberculin reactors the apparent

Signs

absence of gross lesions of tuberculosis – so-called non-

Various body systems can be infected. Often signs are

visible lesion (NVL) reactors – does not necessarily

few and usually are confined to the respiratory tract.

indicate that the animal is uninfected.

There is a soft, productive, chronic cough occurring

once or twice at a time. It can be elicited by pressure

Diagnosis

on the pharynx. If the condition continues there is a

marked increase in the depth and rate of respirations

Diagnosis depends on the history of an area where

as well as dyspnoea. In advanced cases, areas of dull-

tuberculosis occurs in cattle, badgers or other wildlife.

ness in the chest are heard on auscultation or percus-

The signs often result in chronic respiratory lesions with

sion. In other cases there are squeaks and whistles. A

loss of condition and a soft, productive, single cough.

snoring respiration can occur.

The comparative tuberculin test is useful. It uses avian

The alimentary form is unusual. There are few signs

(0.5 mg/ml) and bovine tuberculin purified protein

but occasional diarrhoea occurs. Bloat can arise

derivative (1.0 mg/ml) injected into the neck skin. There

through enlargement of the mediastinal and bronchial

is a greater skin thickness increase in bovine than avian *lymph nodes. Bone can be infected and meningitis*

tuberculin. Interpretation depends on whether there is

occurs in calves.

no history of reactions, one or more reactions without

Mammary involvement these days tends to be rare

confirmation at post-mortem examination or a herd with

but results in udder induration and the supramammary

a recent history of reactions confirmed post mortem.

lymph nodes are enlarged. The udder form can be a

Johne's disease (p. 857), skin tuberculosis (p. 886) or

serious potential source of spread to humans. The

avian tuberculosis can result in false positive bovine

uterine form is also uncommon. Swelling of various

tuberculin reactions but usually the avian reaction

lymph nodes can occasionally be seen, and abortion

increases more than the bovine. False negatives occur

may sometimes occur.

following protracted infection, desensitization follow-

A generalized form can occur with signs following

ing tuberculin testing, early cases of infection, old cows

calving. There is a progressive loss of condition with a *and those animals recently calved.*

variable appetite. There may be a variable rectal tem-

The single intradermal test is used in many countries.

perature but usually it is only about 39.7°C (103.7°F).

Its main disadvantage is that it will give reactions to

The animals are more docile than normal but still bright

avian tuberculosis, skin tuberculosis or Johne's disease.

and alert.

A short thermal test can be used by injecting tuberculin

subcutaneously and measuring the animal's tempera-

ture every 2 hours. A rise in temperature of 1°C (1.8°F)

Necropsy

is considered significant. Intravenous tuberculin also

A focus of infection occurs within a week of bacteria

results in a temperature rise. The Stormont test has

entering the cow and, after the third week, calcification

been used to detect disease in infected cattle. Various

can occur. Depending on the route of entry, and where

serological tests have been used and recently the

the condition becomes generalized, one or several

enzyme-linked immunosorbent assay (ELISA) test has *lymph nodes may contain tuberculous granulomas. In*

shown promise. A gamma interferon test can be used

the respiratory system it is the mediastinal or bronchial

to determine infected cattle.

lymph nodes that are involved, possibly with abscesses

in the lungs. The pus is thick, cheese-like and yellow or

Differential diagnosis

orange in colour. Sometimes the pleura and peritoneum

contain nodules.

Differential diagnosis includes enzootic bovine leuko-

In practice, an attempt is made to determine whether

sis (Chapter 43b) but this can be detected by serology.

Chronic lung abscesses can cause problems in diagno-

More usually the animal becomes progressively

sis. Traumatic reticulitis (p. 837) may produce similar

duller and thinner, with a fall in milk yield and inter-

signs but there is usually a history of an acute attack.

mittent pyrexia, up to 40°C (104°F). A cough is usually

Chronic pericarditis (p. 731) can present problems but

present with the production of mucus and there is a *will result in a jugular pulse and muffled heart sounds*

variable degree of tachypnoea. Thoracic pain may be

and endocarditis (p. 726) cases usually produce a

obvious by an abduction of the elbows and reluctance

murmur. Contagious bovine pleuropneumonia (p. 868)

to move, but in other cases it is only discernible on bal-

can cause problems but can be differentiated by a com-

lottement. On auscultation there are usually whistles,

plement fixation test. Lymph node enlargement due to

squeaks and wheezing sounds in the cranio-ventral part

actinobacillosis (p. 823) may be difficult to detect but

of the chest and there are often areas of dullness.

can be done with a tuberculin test.

Necropsy

Treatment and control

If the main lesion at post mortem is a bronchopneu-

monia, there is usually marked consolidation of the

Treatment is not usually undertaken because of the

cranio-ventral parts of the lung, with exudate filling the

chronic nature of the disease and its potential zoonotic

bronchi and bronchioles. On histological examination, *effects. Control in many countries, including North*

inflammatory cells pass the alveoli and bronchi. When

America and Europe, is by tuberculin testing and

the main problem is a bronchiectasis, often bronchi in

slaughter of reactors. Hygiene standards need to be

the cranial and middle lobes, with dilated air passage-

upgraded and efficient meat inspection and tracing

ways, contain mucus and fibrous tissue. In severe cases

back to the farm of origin is useful. Research work on

the histological sections show complete destruction of

vaccine production is being undertaken and may be

the alveolar tissue. When lung abscesses are the main

directed towards vaccination of wildlife such as badgers

feature, these are usually found in the ventral lung

and possums.

border. Necrotic tissues and pus-containing structures

are found within a fibrous capsular wall.

Chronic suppurative pneumonia

Diagnosis

Diagnosis is based on a history of a chronic loss of con-

Aetiology

dition with respiratory disease in a single animal with

Various initial causes may result in one or more

signs such as pyrexia, thoracic pain and cough.

pathological conditions such as bronchopneumonia,

Differential diagnosis needs to include acute pneu-

bronchiectasis and pulmonary abscesses. These are

monia (p. 860), which may be in a single animal or

often encompassed by the term chronic suppurative

several animals; salmonellosis (p. 850; Chapter 15), but

pneumonia.

at this age there is usually diarrhoea; infectious bovine

rhinotracheitis (IBR) (p. 289) infection, but this usually

results in a marked conjunctivitis. Inhalation pneumo-

Epidemiology

nia (p. 860) on the other hand has a specific history and

tuberculosis (p. 862) will probably have a history of

Most cases occur in adult cattle rather than those still

herd infection, whereas malignant catarrhal fever will

growing. It is, however, a very common cause of res-

involve ocular lesions and enlarged lymph nodes, etc.

piratory signs in the individual animal. Often there has *been an outbreak of acute pneumonia in the history.*

Treatment and control

Although most cases seem to progress slowly over a

period of weeks or months, the odd case will appear to

Often therapy is of limited use. Any treatment may

be of sudden onset, due to a rapid exacerbation of a

need to be prolonged for 10 days to two weeks or more.

suppurative area in the chest.

Antibiotic therapy with amoxycillin, ampicillin, oxytet-

racycline, penicillin and streptomycin, sulphadimidine,

or trimethoprim and sulphadiazine may be helpful.

Signs

Most cases that respond are likely to break down again

Severe signs of disease include a sudden marked loss of

and so infected animals should be slaughtered when

condition with dullness, obvious thoracic pain, pyrexia

convenient.

(40.5°C; 105°F). In some animals there is halitosis due

Control involves culling animals that have had pre-

to a necrotizing bronchopneumonia and pleurisy. Death

vious bouts of respiratory disease and ensuring all cases *in these animals often occurs within a few days.*

are treated early and thoroughly.

Peracute pleuropneumonia

Diagnosis

Small numbers are affected with severe disease, which

A respiratory problem was described in the 1990s in

is often fatal. There is no apparent precipitating factor

Great Britain which appeared to be a relatively well-

except for calving. Post-mortem examination allows

defined syndrome and which at post-mortem examina-

diagnosis.

tion showed a pleuropneumonia (Harwood et al. , 1995).

While it looked like contagious bovine pleuropneumo-

nia, the history and epidemiology were not right and

Differential diagnosis

Mycoplasma mycoides subspecies mycoides was not Contagious bovine pleuropneumonia (CBPP) is an

isolated.

obvious differential and in many countries, as in Britain,

CBPP is notifiable and so it will be necessary to report *cases to the authorities (see p. 873).*

Aetiology

Routine bacteriology of lungs when positive routinely

Treatment

isolated Mannheimia (Pasteurella) haemolytica, usually of serotype Al. Arcanobacterium (Actinomyces) pyo-Large doses of antibiotics, often with non-steroidal

genes has been isolated from the necrotic areas within anti-inflammatory agents, can help in a few cases.

the lung. No further consistent bacterial or viral syner-

gism has been recognized.

Control

At present there is no real advice to offer in herds

Occurrence

which for any reason have to buy in animals.

All problems appear to have involved adult animals

and calf respiratory problems on the farms did not

Diffuse fibrosing alveolitis

appear to be unusual or of high incidence. Usually one

or a small number of animals are affected and most of

Aetiology

these die. The remainder of the herd do not appear to *show any signs of disease. Animals in the immediate*

The cause is unknown but many cases occur in animals

post calving period were most commonly infected.

with chronic bovine farmer's lung and have precipitat-

There was a history of purchase of cows and/or heifers

ing antibodies to Micropolyspora faeni. However, it is within the last 12 months on all farms and in several

probable that there are other precipitating causes as

there were imports from Europe as well as from the

some cattle do not possess antibodies to this organism.

United Kingdom. There was no history of recent trans-

port or movement of the affected animals.

Epidemiology

The condition affects individual animals and is uncom-

Signs

mon although more frequently seen in herds with a

history of bovine farmer's lung. Both dairy and suckler

Severe respiratory problems are seen with dyspnoea,

cows are affected and cases can occur indoors or

hyperpnoea and tachypnoea. Most animals will die or

outside, particularly in animals older than six years. The *are humanely destroyed regardless of any antibiotic*

condition is usually a progressive problem and may

regime. There are variable lung signs, including pleural

actually start following a stress such as calving. The con-

rubs, etc.

dition has normally been present for weeks or months

before advice is sought and the animal will have lost

condition with coughing or respiratory signs when sub-

Pathology

jected to mild exercise. Congestive heart failure occurs

The thoracic cavity contains severe changes with very

in about 12 per cent of cases.

obvious fibrinous or fibrous pleurisy. There are strong

attachments between the thoracic wall and the lungs;

Signs

pleural deposits can often be 1 cm thick. There are

large amounts of pleural effusion and pulmonary

Affected cattle are bright and do not have a raised tem-

oedema. The lungs show marbling with severe inter-

perature or pulse rate. The appetite is good but there is

lobular oedema, with parenchymal congestion and *a progressive loss of condition. The respiratory signs*

consolidation.

tend to be quite severe, with a persistent cough always

present as well as tachypnoea and hyperpnoea present

Table 49.1

The fate of various-sized particles entering the

even in the resting animal. On auscultation of the chest,

respiratory system.

rhonchi (whistles, squeaks, wheezing) are heard over

both lungs and crackling sounds in the cranio-ventral

Particle Fate

size (mm)

chest. There is no thoracic pain.

Depression and inappetence only occur in the late

>10

Removed in nasal passages

stages of the condition with congestive heart failure

2–10

Deposited at varying levels in respiratory tract,

resulting in subcutaneous oedema and an increased *but above alveoli. The smaller the particle,*

heart and respiratory rate. The liver may be palpably

the further down the respiratory airways it is

enlarged and there may be diarrhoea.

deposited. Removed by mucociliary action

1–2

Deposited in alveoli

0.5–1

Exhaled with air

Necropsy

<0.5

Deposited in alveoli due to diffusion forces

At necropsy alveolar changes predominate but there

may be bronchitis with excessive thick mucus in the

bronchi. There is thickening and fibrosis of the alveolar

walls. Histologically, large numbers of mononuclear

Signs

cells are seen in the alveolar air spaces. There may be

Following feeding or bedding, there is the sudden onset

hyperplasia of type 2 pneumocytes or metaplasia of the

of coughing. The cough tends to be dry and can be *alveolar epithelium so that it contains ciliated and*

single or paroxysmal. Several cattle are normally

mucus-secreting cells. Pulmonary hypertension can

affected. The animals are otherwise bright and alert;

occur and this results in right-sided heart failure.

they eat well and there are no abnormal lower respira-

tory sounds. Respirations are normal in rate and extent,

Diagnosis

and temperature is normal. There is conjunctivitis and

usually a copious ocular and nasal discharge, which is

Diagnosis depends on the history, i.e. a single animal,

mucoid but sometimes slightly purulent.

with gradual loss of condition with respiratory signs

present at rest, coughing, no thoracic pain or fever and

a bright animal.

Treatment and control

Treatment involves replacing the feed or bedding used.

Treatment

Otherwise dampen down the feed before giving it, or

molasses can be added to it. In the case of bedding, new

As the cause is unknown, little can be done to alleviate *bales should be opened up outside before the cattle are*

the problem. However, corticosteroids can reduce the

bedded.

cellular changes in the lung. Casualty slaughter of the

Control is by not feeding dusty hay. If the feed is

animal should be undertaken before the loss of condi-

found to be dusty then 5 per cent molasses should be

tion is too severe.

added to it. Dusty bedding should not be used. As the

particles affecting the animals can affect humans, it is

advisable for workers to wear face masks.

Dusty feed rhinotracheitis

Aetiology

Fog fever

Particles of different sizes meet varying fates in the res-

Aetiology

piratory system following inspiration (see Table 49.1).

Most of the particles will be in the nasal passages or the

This is a form of atypical interstitial pneumonia.

trachea, bronchi and bronchioles. The condition results

Although not fully authenticated, the condition is con-

from the introduction of dry, fine-particled feed, or very

sidered to be a toxicosis following the ingestion of large

dusty bedding.

quantities of l-tryptophan.

The introduction of a dusty dry feed to animals

indoors causes the problem. The signs occur most fre-

Epidemiology

quently in the hour or two following feeding. Removal

of the feed causes recovery in a few days. The condition

The condition is seen in cattle over two years old, par-

occurs most commonly when the relative humidity is

ticularly those in suckler herds, and affects several cattle

low.

to a varying degree at the same time. Often the cattle

have been receiving little nutrition and are put onto

Cattle slaughtered in the later stages do not usually

a more lush pasture in the autumn (September to

show haemorrhages of the respiratory mucosa. There is

November). The field may have been top-dressed with

an overall pale pink colour with variable amounts of *a nitrogenous fertilizer. The condition is normally seen*

interstitial emphysema.

within two weeks of entry to the new pasture. The

Hereford and Hereford-cross breeds seem to be par-

Diagnosis

ticularly susceptible.

It is thought that l-tryptophan in the grass is ingested

Diagnosis involves the history of a group condition,

and metabolized in the rumen to indole acetic acid

mainly in suckler animals moved to a lush pasture in

(IAA), which is decarboxylated by Lactobacillus spp. to autumn. The signs help, particularly the acute respira-produce 3-methyl indole (3MI). This metabolite can

tory signs with little to hear on auscultation, no cough

enter the blood and is usually acted upon by the mixed

and the animals being more tranquil than usual. Post-

function oxidase system to produce indoles and other

mortem findings indicate the condition, with pulmonary

metabolites in the urine. 3-Methyl indole can cause the

oedema and emphysema.

destruction of pulmonary cells such as type 1 pneumo-

Differential diagnoses include husk (p. 272), but a *cytes and monociliated bronchiolar secretory cells,*

cough is present and there would be a history of no

resulting in various pathological changes. Mortality in

vaccination. Pneumonic pasteurellosis (p. 286) would

severely affected animals can be high (up to 75 per

produce pyrexia and a mucopurulent discharge. Nitrate

cent) but usually only a small number (5 per cent) are

poisoning (p. 950) would produce some signs but the

so involved.

blood would tend to be brownish and the urine contain

methaemoglobin. Infectious bovine rhinotracheitis (p.

289) would usually involve pyrexia and a loud explosive

Signs

cough. Thrombosis of the caudal vena cava (see below)

Several animals will show signs but the degree will vary

would usually involve a single animal and eventually

widely and often the farmer only notices one to be ill

haemoptysis would occur. Brassica spp. (p. 941) poi-

at the start. The cattle tend to be much quieter and

soning would have a different history of feeding and

more approachable than normal and to have a sleepy *would usually be later in the autumn.*

or tranquil expression. The respiratory signs are usually

of distress but vary in degree. Coughing is normally

Treatment and control

little heard.

In the severe form there is the sudden onset of dys-

Treatment is to remove the cattle from the incriminated

pnoea with a loud respiratory grunt, mouth breathing,

pasture. Most other treatment tends to be empirical.

and often the animal froths at the mouth. Auscultation

Interference with a severely distressed animal may

reveals little considering the severity of the illness,

result in its death. Atropine at 1 g/450 kg (990 lb) body

but it may produce soft, moist sounds and a few

weight intravenously acts as a bronchodilator and cor-

crackles. Death can occur as the result of excitement.

ticosteroids may be useful. Flunixin meglumine has

Less severely affected animals show tachypnoea (rate

been beneficial in experimentally produced acute

50–80/minute) with hyperpnoea and usually there is no

bovine pulmonary emphysema and in the field.

dyspnoea. The rectal temperature tends to be normal

Control means that if animals are hungry when they

and the animal is again quiet and tranquil. Coughing is

enter a new pasture in the autumn, restrict their feed by

only heard occasionally and in some recovering animals

only allowing grazing for short periods during the first

a subcutaneous emphysema may develop. Auscultation

two weeks. This should be for about 2 hours on the first

may reveal harsh sounds.

day, increasing by an hour a day so that the cattle can be

left out for the whole day after about 12 days. Otherwise

the area can be strip-grazed or initially grazed with a less

Necropsy

susceptible species such as sheep. If monensin sodium is

Dead animals have haemorrhages in the larynx, tracheal

given at the rate of 200 mg/head per day before and after

and bronchial mucosae. The lungs tend to be swollen,

entering the pasture, this can stop problems.

heavy and dark red in colour. The cut surface glistens, is

smooth and has a red appearance. Emphysema may be

Thrombosis of the caudal vena cava

present in the interlobular septa and pleura. Histologi-

cal examination reveals severe congestion and oedema

Aetiology

of the pulmonary tissue, hyaline membrane formation,

severe interstitial emphysema and moderate epithelial

The cause is a septic focus, usually in the liver, resulting

hyperplasia of type 2 pneumocytes.

in a septic thrombus in the caudal vena cava, from

which there is the haematogenous spread of infection

normally present within the pulmonary artery. In the

to the lungs.

lung itself there is usually embolic suppurative pneu-

monia, intrapulmonary haemorrhage, often concentric

and globular in shape, and multiple red areas where

Epidemiology

blood has been aspirated. When there is obstruction of

This is an uncommon condition affecting single animals

the hepatic veins then there is marked hepatomegaly

over one year old, although many cases occur in the

and ascites.

growing animal. A few cases of thrombosis of the

cranial vena cava have been recorded with similar signs.

Most cases result from a liver abscess. This causes a

Diagnosis

localized phlebitis, usually in the area of the vena cava,

Diagnosis involves the history of loss of condition and

adjacent to the liver. Septic emboli pass to the lungs

respiratory signs in a single animal. The signs help, par-

where they can produce chronic suppurative pneu-

ticularly haemoptysis with thoracic pain, and are almost

monia and multiple lung abscesses, or they can cause

pathognomonic. Post-mortem findings are relatively

pulmonary arterial lesions. Endarteritis, arteritis and

diagnostic with thrombosis of the vena cava, emboli

thromboembolism occur, resulting in aneurysms of the

in the pulmonary artery and intrapulmonary haemor-

pulmonary artery, which then rupture causing haemor-

rhage. Haematological examination shows the packed

rhage in the bronchi and alveoli. Usually, there is a

cell volume is often low (11.0–22.5 per cent).

history of sudden onset of respiratory disease, although

Differential diagnosis includes an accident, but signs

in some cases there is a history of chronic loss of weight

would be highly unlikely unless there is an immediate

and coughing. A few cases show obstruction of the

history of trauma. Tuberculosis (p. 863) could also give

hepatic venous return with chronic venous congestion

rise to some of the signs but is usually much slower and

of the liver, its enlargement and no access to the col-

the tuberculin test would reveal this.

lateral venous drainage. Bacteriological examination

often reveals little because of previous therapy. How-

ever, some cases reveal staphylococci, A. pyogenes and Treatment and control

Fusobacterium necrophorum spp.

There is no effective therapy. Cattle can be casualty

slaughtered if necessary after a course of four or five

Signs

days' antibiotic therapy using a broad-spectrum com-

pound and then leaving the required withdrawal time.

Peracute signs result in an animal dying suddenly with

Control is not possible, but any septic focus should be

no premonitory signs but usually there is a pool of *treated adequately as soon as it occurs. Make sure that*

blood in front of it. In the acute case, cattle with the

all changes in feeding are undertaken slowly so as to

condition show respiratory disease for a few days or

avoid the possibility of acidosis (p. 829).

some months, with tachypnoea and shallow breathing.

The animal develops haemoptysis and frothy blood can

be found in the nasal passages and mouth. There are

often blood stains around the animal and in many cases

Contagious bovine

there is melaena. There is a variable amount of thoracic

pleuropneumonia (CBPP)

pain with abduction of the elbows. On auscultation

there is a widespread whistle, with wheezing sounds.

Mycoplasma mycoides is the cause of contagious bovine The chronic form involves animals developing con-pleuropneumonia (CBPP), which now that rinderpest

gestive cardiac failure and ascites with an enlarged

has been controlled, is the cattle disease of greatest eco-

liver, which may be palpated on the right sublumbar

nomic importance on the continent of Africa. CBPP

fossa. This often occurs some time before haemoptysis *affects only cattle and the water buffalo (Bubalis*

is present.

bubalis). Claude Bourgelat, the great French veterinary Once animals start to show haemoptysis then death

surgeon and founder of the Lyons Veterinary School,

will ensue, usually within a week or two but occasion-

was the first person to differentiate rinderpest from

ally it may take up to 40 days.

CBPP (in the eighteenth century). It was thought the

disease was introduced into Europe from Asia in the

seventeenth century and that the wars of the eighteenth

Necropsy

and nineteenth centuries resulted in its spread through-

Following death, often one or more abscesses are found

out the continent. From Europe it was taken to the rest

in the liver, and usually the caudal vena cava thrombo-

of the world; South America is the only continent that

sis is in the area of the liver. Multiple septic emboli are

has never experienced the disease.

New techniques (PCR, DNA fingerprinting, ELISA, *among others) in manipulating mycoplasms have led to*

new thinking about the phylogeny of the group. Where

there were individual species, the organisms now

have been grouped into 'clusters'. Economically the

Mycoplasma mycoides cluster is the most important,

containing as it does, Mycoplasma mycoides subspecies mycoides, small colony type (M. mycoides), the large colony type that infects goats and to a lesser extent

sheep and M. mycoides capri, another of the agents that causes contagious caprine pleuropneumonia.

It has been possible to trace the introduction of the

infection into many countries. Indeed, in some cases the

identity of the infected animal is known! There is,

however, some dispute about the entry of the disease

into Africa. French workers believe that the infection

was introduced when Bos indicus crossed into the con-

tinent from Asia; it did not get to southern Africa in this

way and there is evidence that it did not exist in East

Africa before the invasion of General Napier into

Ethiopia in 1868.

The Dutch Ambassador to the Cape Colony, with the

Fig. 49.1

In 1995 most countries in Africa south of the Sahara

intention of improving the local stock, imported a bull

Desert reported CBPP.

from his country in 1853. The infection was rapidly dis-

seminated by trek oxen, particularly to the Transvaal

where in the space of two years it killed more than

100 000 animals. From South Africa the infection was

obic conditions. The organism requires a complex

taken to Namibia, Zimbabwe and Botswana. From

medium for growth, containing serum and yeast extract,

Namibia it was taken to Angola and from there to

and growth is slow taking up to 72 hours to reach a

Zambia and the Congo. By 1940, with the exception of

maximum. In broth cultures a swirling mucoid mist is

Namibia and Angola, the southern African countries

produced from the galactan which is attached to the cell

had eradicated the infection. The development of an

membrane.

efficient vaccine at Muguga (the T1 broth vaccine) and

Joint Project 16 (a research project to improve knowl-

Epidemiology

edge of epidemiology, diagnostic techniques and the

vaccine) resulted in CBPP being brought under control

Only cattle and water buffalo are susceptible to CBPP;

throughout west, central and east Africa by 1970.

the African buffalo has been infected under experi-

The failure of African governments to invest in vet-

mental conditions, but that same study found that

erinary services over the subsequent years has resulted,

natural transmission did not occur. There is some

as was seen with rinderpest, in a resurgence of the

debate as to whether Bos taurus or Bos indicus is the disease throughout the continent; by 1995 most coun-more susceptible to infection with M. mycoides. An

tries of Africa south of the Sahara reported the disease

understanding of the epidemiology has been bedevilled

(Fig. 49.1). It is said that the vaccine no longer works.

by an inability to reproduce the disease in cattle other

than by the cumbersome 'in contact' method, in which

cattle are artificially infected by having a culture ino-

Aetiology

culated directly into the bronchi and then these

Two types of M. mycoides subspecies mycoides are rec-artificially infected *animals are mixed with healthy sus-*

ognized: the small colony type (SC) which causes CBPP

ceptible animals. Normal transmission is by droplet

in cattle and the large colony type which occurs in goats

infection from actively infected animals to susceptible

and rarely in sheep. They cannot be differentiated in

animals in close proximity. However, indirect trans-

culture, biochemical or immunological tests; however,

mission has been demonstrated under experimental

they can be separated by PCR. They have a different

conditions.

pathogenicity in cattle, because only the SC types

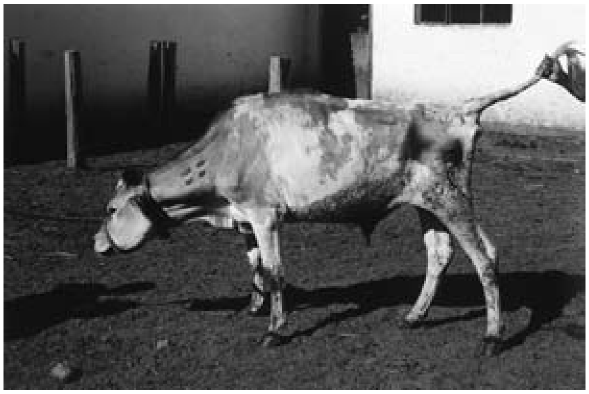
A second factor that hinders the understanding of

causes CBPP. M. mycoides is a micro-organism that

this disease is the potentiation of myths and statements

lacks a cell wall and will grow under aerobic or anaer-

of fact that have no basis in experimentation, e.g. 'There



is a prolonged incubation period'; 'lungers break down
infection passes down the respiratory passages there is
and the animal again becomes infective'. There is no
a bronchiolitis and alveolitis leading to pneumonia and
evidence for either of these statements but they are
pleurisy. It is thought that the galactan plays a part in
held to be true. In all the vaccine trials carried out
attaching the organism to the mucous membrane and
at the East African Veterinary Research Institute,
so preventing the body defences from eliminating the
Muguga, Kenya, control animals put in contact with dis-
organism. Some workers believe that hypersensitivity
eased animals showed signs of infection (either clinical
or autoimmune reactions are responsible for the lesions
or serological) at about six weeks (plus or minus 10

and there is some evidence for this. It is hoped that days). Under field conditions it may be that the animal by use of modern molecular techniques this will be has avoided infection for a long period of time. Work resolved. It has also been suggested that there is a dif- at Muguga failed to reactivate disease in recovered fusable toxin which stimulates the formation of the animals: stress, corticosteroid treatment and even fibrous capsule around the necrotic tissue. Some removal of the spleen were unsuccessful. Until proven workers believe that the galactan acts as an endotoxin otherwise, it is the actively diseased or the animal incu- and causes systemic reactions similar to those seen in bating the disease which must be considered as the infection by Gram-negative bacteria; this is not proven. main risk to susceptible animals.

Until recently it was believed that only one lung was CBPP is a disease of the older animal and calves rarely affected, which would support the suggestion of an show pneumonic disease. Infection in young animals autoimmune phenomenon. However, in recent out-

normally results in lesions in the joints. In consequence,

breaks lesions have been seen, in a very few animals, in

calves play little or no role in the spread of disease.

both lungs. This may be the result of antibiotic treat-

Although there is no experimental evidence to

ment. As can be seen from the foregoing, much needs

confirm the observation, it is generally believed that it

to be done to give a clear understanding of the patho-

is the weight of infection in a herd that determines the

genesis of CBPP.

clinical picture. Under natural conditions, there might

be a single animal infected in a herd and this animal will

Clinical signs

show only mild signs which may well pass unnoticed.

Nevertheless, the animal infects several more animals

At least these are clearly understood! In the hyperacute

and they in turn yet more. In this way the weight of

form the animal may be found dead, without premoni-

infection builds within a herd until widespread clinical

tory signs, but this is not common. The acute disease is

disease is seen. This picture may explain the long incu-

characterized by fever, lethargy, loss of appetite and bation periods referred to in the literature. pneumonic signs. The animal stands with elbows When the infection is introduced into a susceptible abducted and the neck stretched out, the mouth open herd there can be a great variation in response, from a and the tongue protruding (Fig. 49.2). From time to severe, massive, acute outbreak of disease involving up time it may emit a soft, moist cough. The pleurisy causes to 60 per cent of the animals in the herd with 40–50 per severe pain and the animal will grunt if the chest is cent of the affected animals dying, to a much less severe problem, involving less than half of the herd with few animals severely affected and a low mortality. Recovered animals are resistant to further infection. In many of these recovered animals sequestra may be seen: a sequestrum is a piece of diseased lung that has become separated from neighbouring healthy tissue and surrounded by a fibrous capsule. In a closed herd, in which no action is taken, it is not uncommon for the disease to die out. Recently there has been a move towards *treating clinically sick animals. The effects of this treat-*

ment on sequestrum formation are not known but it is

thought that it might prevent the animals from devel-

oping a proper sequestrum and so prolong the period

in which the animal can pass on the infection.

Pathogenesis

Fig. 49.2

Animal showing signs of acute CBPP – The animal

If little is known of the epidemiology of CBPP, even less

stands with elbows abducted and the neck stretched out, the

is known of the pathogenesis of the disease. When

mouth open and the tongue protruding.

touched. Because the chest is so painful it is uncommon

state that relapses occur, but there are no published

for an animal with the acute disease to lie down and it

reports of this actually happening.

will remain on its feet until almost the end. Filthy mucus

Although calves can develop the classical lung lesions

runs from the nostrils and saliva may drool from the

and show the same signs as the adult, this is uncommon.

mouth. Pregnant cows may abort and the fetal fluids

The more typical picture is one of swollen joints caused

contain vast numbers of mycoplasms. Despite the size

by a fibrinous bursitis (Fig. 49.3). For some unknown

and nature of the lung lesions, it is often difficult to

reason it is more commonly the forelegs that are affected.

identify the site of the lesions by percussion or auscul-

tation. Although there may be massive kidney infarcts

Post-mortem findings

present it is rare for an animal to show signs of renal

disease. If the animal survives the signs grow progres-

In the animal that has died from acute disease, the first

sively less pronounced, the nasal discharge may well

thing seen is the vast quantities of straw-coloured

become purulent, the animal will lose a considerable

pleural fluid in the chest cavity; 10 litres or more have

amount of flesh and become emaciated. The larger the

been reported (Fig. 49.4). The fluid may contain pieces

lesions, the slower the recovery.

of fibrin that have broken off from the pleural adhe-

There is a great variety of clinical manifestation from

sions, and up to 109 mycoplasmas per ml. A localized or *this dramatic picture down to almost no clinical signs at*

diffuse pleurisy may be present, appearing like an

all. What determines the size of the lesions and hence

omelette.

the clinical picture is not known. In any outbreak it is

Acute lesions vary in size from 1 to 2 cm in diameter

possible to see acute, subacute and chronic disease,

to those affecting the whole of the lobe. More than one

often all three pictures at the same time. Many workers

lesion may be present but they are usually restricted to

Fig. 49.3

A young calf with CBPP, showing swollen joints

Fig. 49.4

Carcass of an animal with acute CBPP, vast quanti-

caused by a fibrinous bursitis.

ties of straw-coloured pleural fluid in the chest cavity; 10 litres or more have been reported. Note that one lung is diseased but the other appears normal.

Fig. 49.5

Lungs of an animal with acute CBPP. The char-

Fig. 49.6

Lung of animal 27 months after infection, showing a

acteristic lesion is 'marbling', identical to that seen in acute walled-off sequestrum. Thomas Walley, likened the sequestrum

pasteurellosis.

to an 'Egyptian mummy in its case'.

one lung. The characteristic lesion is 'marbling', iden-

thought to be caused by emboli from the lung settling in *tical to that seen in acute pasteurellosis (Fig. 49.5).*

the kidney. They can be of any size and number and one

Interlobular oedema and fibrin deposits highlight the

or both kidneys may be infected; the colour of the infarcts

structure of the lung. The lung tissue itself may be dark

varies from white to red to black. Lesions affecting

red or changing to grey and thrombi may be seen in the

the joints of calves are normally bilateral, serofibrinous

vessels. These thrombi result in infarction of the portion

tendosynovitis or occasionally arthritis. Lesions are

of the lung supplied. The tissue dies, separates from the

mostly seen in knees and lower joints of the forelegs. A

healthy surrounding tissue and becomes walled off

valvular endocarditis has been reported in calves.

into a sequestrum. The nineteenth century Dean of

the Edinburgh School, Thomas Walley, likened the

Diagnosis

sequestrum to an 'Egyptian mummy in its case' (Fig.

49.6). Small sequestra will disappear over time, to be

A presumptive diagnosis should be based on the

replaced by scar tissue, but the larger ones can remain *history, the clinical signs and the post-mortem findings.*

for life. M. mycoides has been isolated from the tissue However, it is essential that the presence of M.

in a sequestrum up to 27 months after the animal was

mycoides be confirmed. The isolation and identification infected. It was rare for these sequestra to become sec-of the mycoplasma gives a certain diagnosis; growth

ondarily infected by other bacteria, but in recent out-

inhibition or immunofluorescent antibody tests can be

breaks such infection has been seen. This may be a

used to identify the organism once it has been isolated.

result of antibiotic treatment.

Under African conditions this may not always be pos-

Histological examination is not very useful in making

sible, particularly if the outbreak occurs at a great dis-

a diagnosis as the lesions are not pathognomonic. The

tance from the laboratory. In such cases samples of

lesion commences with a severe hyperaemia of the

pleural fluid can be taken onto blotting paper and then

affected lung and associated pleura with effusion of ery-

dried. These papers can then be examined by an agar

throcytes, neutrophils and macrophages. There is a *gel diffusion test (AGT) or the newer polymerase chain*

massive serofibrinous effusion into the alveoli and the

reaction (PCR).

interlobular septa. Vasculitis and thrombosis of arteries

In the live animal serological tests are required to

occur in the affected parts of the lung. This results in

confirm a diagnosis. The simplest crush-side test is

the necrosis of that area supplied by the vessel and the

the slide agglutination serum or blood test (SAST or

onset of sequestration. This commences with a layer of

SABT) using a stained antigen. It is cheap to produce,

inflammatory cells separating the infarcted area from

easy to carry out and has therefore been discarded!

the surrounding healthy tissue. Granulation and fibro-

False positive results to this test occur, but they do to all

sis separate the infarct from the healthy tissue.

serological tests. The complement fixation (CF) test

Lesions resembling sequestra may be seen in the

is the test approved by the Office International des

mediastinal and bronchial lymph nodes and they are

Épizooties (OIE) as the definitive test for the confir-

always enlarged and oedematous. Infarcts in the kidney
mation of CBPP. This workhorse was developed in Aus-
are common in animals with acute disease, and they are
tralia and has been used successfully throughout Africa

for the control of the disease. It does not require expen-
but caused many adverse reactions and some deaths;
sive equipment or reagents but it is a complicated test
however, the broth vaccine gave good protection
to perform, although once mastered, the technique can
without producing too many adverse reactions. Labora-
produce excellent results on a regular basis. The com-
tory and fieldwork showed that it produced a solid
plaint is that CF antibodies do not persist in animals
immunity for more than a year. The T1 broth vaccine was
with sequestra. If these animals play no part in spread-
then lyophilized, but it was too expensive to test this new
ing the disease, then this is of no importance. The tech-
vaccine and so it was assumed that since it was a T1
nique has been modified to be carried out in the African
vaccine it would work! By passage in the presence of

bush, but apart from Zambia, this field test is no longer

streptomycin, a streptocmycin-resistant variety of the T1

in use in Africa. After vaccination some cattle develop

strain was produced. This enabled the vaccine to be

CF antibodies but by 12 weeks these antibodies have

mixed with the rinderpest vaccine and so reduce the

gone and at present there is no satisfactory way of deter-

delivery costs. Again this new vaccine was not tested.

mining whether or not an animal has been vaccinated.

Perhaps this is why the new T1 does not work very well!

The new enzyme-linked immunosorbent assay (ELISA)

suffers from the same deficiencies. In the absence of

Control

post-mortem evidence, it would be a brave veterinarian

who diagnosed CBPP on serological findings alone.

CBPP is a disease of cattle movement; stop movement

and the spread of disease is halted. Many countries

freed themselves from infection by prohibiting move-

Differential diagnosis

ment and slaughtering infected animals or herds. When

Acute pasteurellosis (p. 286) is the condition with which

CBPP was introduced into Botswana in 1995, the

CBPP is most likely to be confused, but the former reg-

disease was eradicated by preventing animals from

ularly affects both lungs. A cultural examination of the

moving and a stamping-out policy. The price of freedom

lesions should identify the cause. Pneumonic lesions of

from CBPP was in excess of $200 million and there are

east coast fever (ECF) (p. 750) could be confused with

few African countries that can afford such an expense.

those of CBPP, although pleurisy is not normally a

For Botswana this was an economically sound policy

feature of ECF and there are concurrent lesions in the

because it protected their markets in Europe.

spleen and lymph nodes of animals with ECF. Exami-

In almost all African countries CBPP is a notifiable

nation of Giemsa-stained preparations of smears from

disease and there are official controls on the import of

spleen or lymph node should confirm the diagnosis of

cattle. However, in many countries there are nomadic

EFC.

people who have moved from country to country before

Sequestra can be mistaken for the cysts of parasitic
the borders existed, e.g. the Fulani in west Africa and
infestations, particularly echinococcus (p. 281), or aber-
the Maasai in east Africa. A recent outbreak of CBPP
rant liver flukes (p. 276).
in Tanzania resulted from the theft of two animals in
Kenya by Tanzanian Maasai who moved the animals
across the unmarked ‘border’. Lack of appropriate
Vaccination (see p. 1011)
action by the Tanzanian authorities has resulted in the
There is no treatment for this disease and so vaccination
disease spreading the length and breadth of the country.
is an important means of protection of the animals. At
Wars, famine and inadequate financing of veterinary
the turn of the last century, pleural fluid or diseased lung
departments have resulted in CBPP running riot in east
was injected under the skin of the tail to protect the
and central Africa. Unless something is done to stop the
animals. Rider Haggard in his novel ‘King Solomon’s
spread it will not be long before the disease topples over
Mines’ refers to this technique for protecting cattle from

into Malawi and Mozambique, two of the countries

the 'lungsick'. He points out that this often resulted in

in sub Saharan Africa which have never experienced

the animal losing its tail, which he considered preferable

CBPP. From there the whole of southern Africa is at

to losing its life. Throughout the twentieth century

risk. Early warning of the arrival of the disease is impera-

workers have looked for vaccines. It appears that only

tive for adequate control. To this end, it is essential that

live vaccines produce protection. The Australian

all animals that are slaughtered, be it in an abattoir, on

workers developed the V5 vaccine, which was accept-

a slaughter slab or in the bush, and are examined by a

able in Australia, because there farmers considered that

trained member of the veterinary department to ensure

if a few animals did not die after vaccination, then the

that they are not carrying lesions of CBPP.

vaccine had not worked. Such a vaccine could not be

Rinderpest has almost been eradicated from Africa;

used in Africa. In the Sudan the KH3J vaccine was used;

it is time that the international community turned its *although it caused no reactions it also failed to protect*

attention to the control of CBPP on the continent. To

cattle. The T1 vaccine was first used as an 'egg vaccine',

this end research into vaccines, epidemiology and diag-

nostic methods are required. Strangely enough these

Further reading

were the topics of investigation for Joint Project 16 over

thirty years ago.

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Chapter 50

Skin Conditions

L.R. Thomsett

Warble fly

875

Bacteria and viruses play a minor role except when skin

Dermatophytosis (ringworm)

878

signs are associated with systemic infection by these

Parasitic skin disease

880

organisms. Allergic disorders are also uncommon and

Lice (pediculosis)

880

genetic diseases rare.

Mite infestations: mange, scabies

881

Warts (viral papillomatosis)

882

Urticaria

883

The effect of skin disease on the livestock industry

Pruritis/pyrexia/haemorrhagic syndrome (PPH)

884

Photosensitization

884

Where animals are reared to provide food and other

Bovine farcy

885

byproducts, skin disease, although clinically not in itself

Atypical mycobacteriosis

886

serious and rarely life-threatening, may cause signifi-

Dermatophilosis (bovine streptothricosis)

886

cant losses to the agricultural industry through the

Horn cancer

887

following effects:

Lumpy skin disease and pseudo-lumpy skin disease

887

Lumpy skin disease

887

• The debilitating effect of pruritus on the affected

Pseudo-lumpy skin disease

888

animals. Heavy louse infestations or infestation by

Other conditions having skin signs

888

sarcoptic mites causes irritation, restlessness and

weight loss.

The skin of the ox shows general conformity with the

• Damage to hides from self-trauma or the migration

anatomical characteristics of the large domestic animals

of parasitic larvae.

(Fig. 50.1). Approximately 7 mm in thickness, it consists

• Damage to tissue from bacterial infection or larval

of epidermis and dermis and their adnexa. The hair

migration resulting in condemnation or trimming of

follicles are simple and carry a single hair, the colour of

meat at slaughter.

which, depending on body site and breed, may be black,

• Limitation of sale value or show potential of

white or a wide variety of variants of brown or grey.

infected animals and their danger as vectors of

Single hairs leave the skin surface at an angle, each

disease to other stock.

follicle having an erector pili muscle allowing the hair

to be raised to a more upright position.

Hair growth and replacement is a cyclic process of

Warble fly

active growth (anagen) when the hair follicle is pro-

ducing a new hair, and a period of rest (telogen) when

The insect is also known as warbles, cattle grubs, gad fly

the mature hair, which now has a constricted bulb and

or Hypoderma infestation and is due to the migrating

is referred to as a ‘club’ hair, is held in the hair follicle

stages of a parasitic insect (see p. 740). Two species of

before being shed.

warble fly are recognized in many countries of the

Sweat and sebaceous glands are distributed over the

northern Hemisphere, namely Hypoderma lineatum

body surface and show specialization in certain areas,

and Hypoderma bovis and they differ little in their

e.g. the mammary gland, naso-labial glands of the

territorial distribution. These parasites are not found in

muzzle. At the extremities of the limbs and on the head

the southern hemisphere as they have not become

of horned breeds the skin is specially modified to form

established, despite importation of infected cattle.

the hooves and horns.

Cattle, particularly young stock at pasture, are the

definitive host for the parasitic stages of the life cycle *although other species are recorded as occasionally*

Skin diseases of cattle

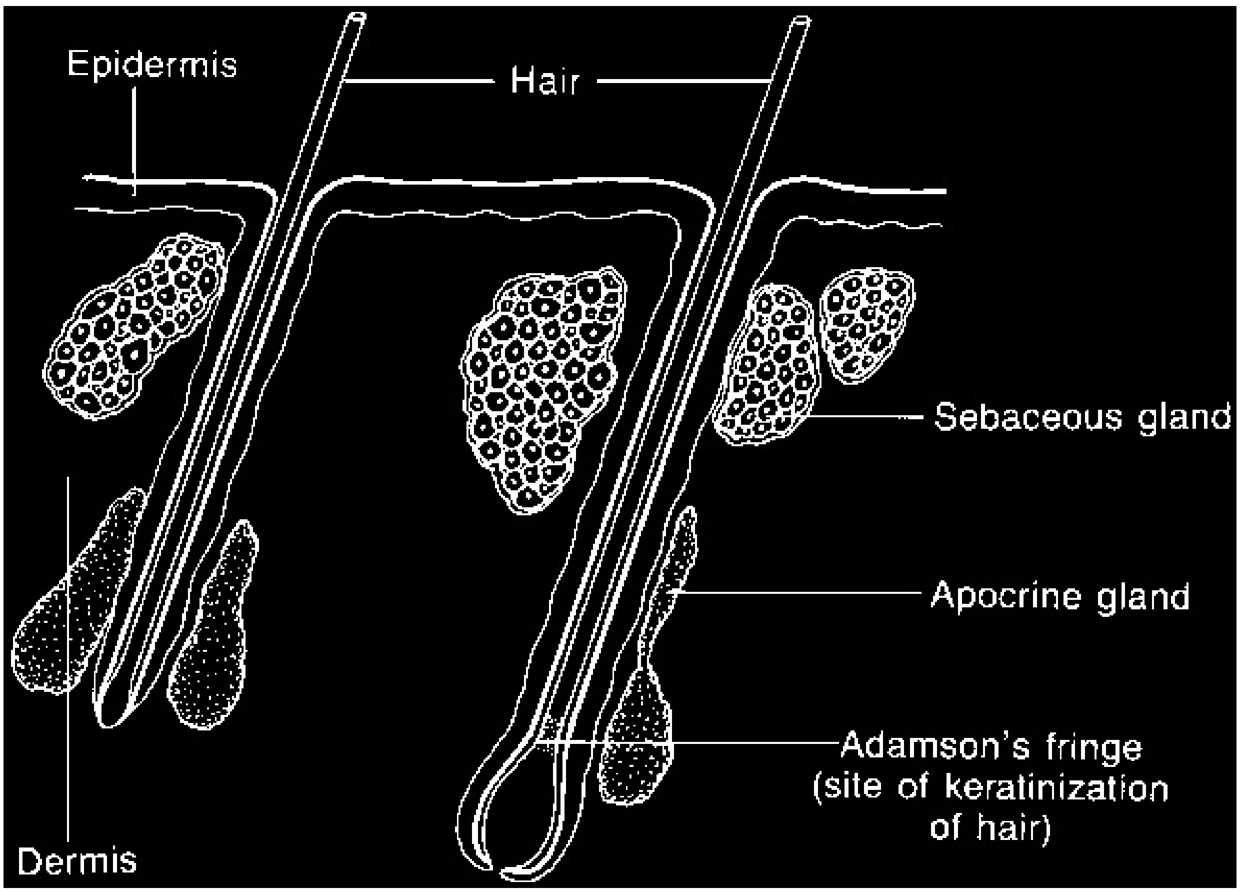
being infested, such as horses, deer, goats and even man.

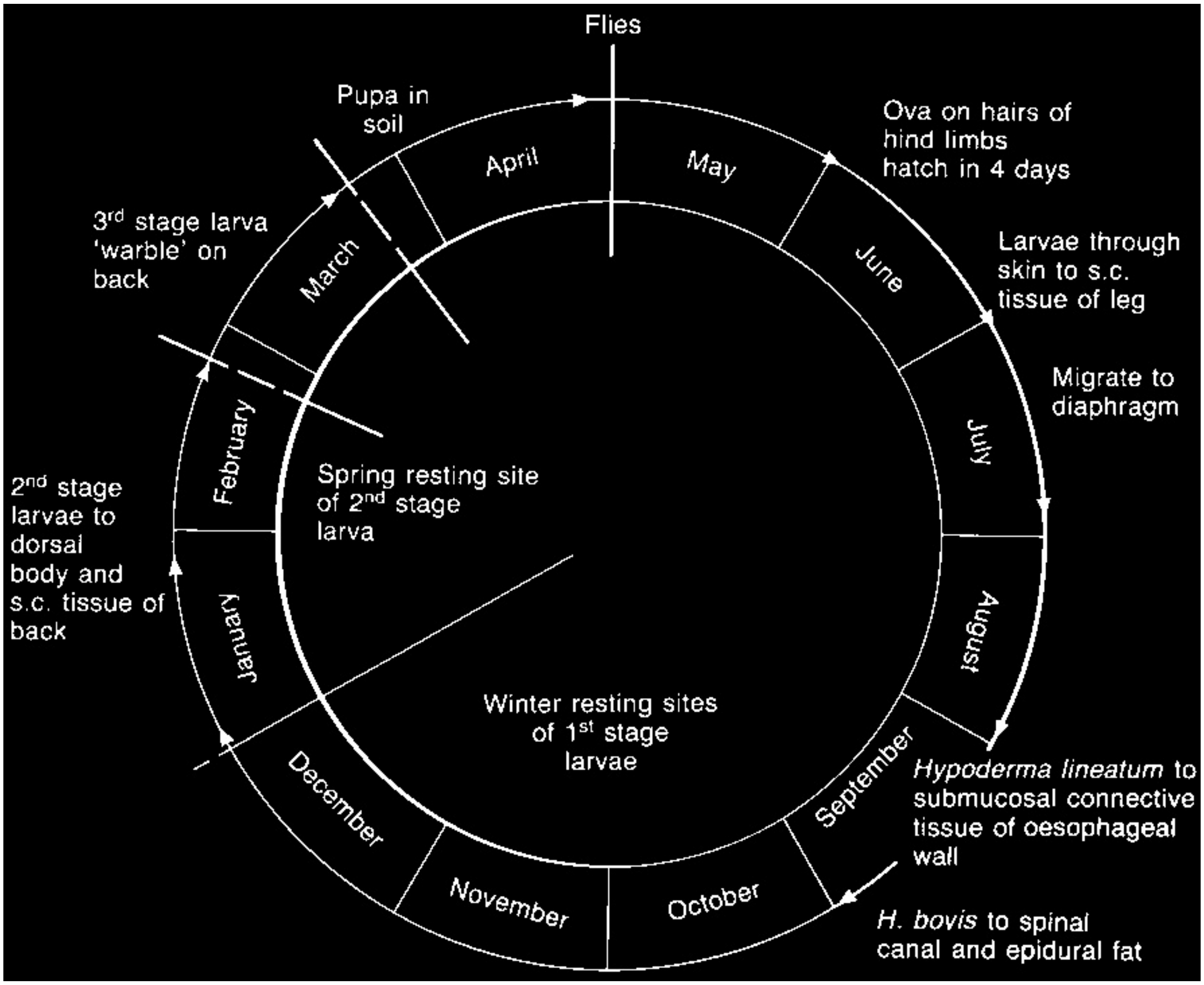
Primary disease of the skin of cattle is more commonly

In species other than cattle the life cycle is rarely, if ever, attributable to parasite infestation or fungal infection.

completed.

875





apprehension among a group or an individual animal,

Life cycle (see Figs 50.2 and 50.3)

followed by suddenly taking flight at a gallop, tail in the

Warble flies become active in the spring and on warm

air, suddenly turning and repeating the movement in an

days in the summer months adult females (up to 15 mm

effort to shake off the pursuing flies. This is known as *long) home in on grazing cattle and alight on the hairs*

‘gadding’.

of the lower limbs, on which they lay their eggs. Hypo-

Once ova are attached to the hairs they hatch in four

derma bovis lays its eggs singly while H. lineatum lays days and larvae crawl to the skin surface, through which

a row of six or more on a hair. The egg-laying behav-

they penetrate to the connective tissue and wander for

iour of the flies causes irritation and restlessness to

four to five months. Migratory patterns within the host

cattle and attempts are made to avoid the flies by

differ: H. lineatum moves to the submucosal connective running away. Characteristically, this is seen as initial

tissue of the oesophageal wall while H. bovis goes to the region of the spinal canal and epidural fat. At these

sites they remain for the autumn and winter. As second-

stage larvae they migrate towards the back of the host

where further maturation takes place.

Large domed nodules are formed under the skin

within 30–45 cm (12–18 inches) on either side of the

spine, in which the now third-stage larva produces

a ventral breathing pore. Grubs within the nodules *progressively increase in size to 25–28 mm in length, depending on species. In the spring the larva emerges from its cyst, falls to the ground and pupates. After a period of four to six weeks the adult fly emerges.*

Effect of Hypoderma larvae on the host

Fly attacks: Considerable 'worry' is caused to cattle when approached by these flies; this results in restlessness that interferes with grazing and may result in poor

Fig. 50.1

Diagrammatic representation of bovine skin.

weight gain. Milking cattle show a fall in milk yield.

Fig. 50.2

Hypoderma spp. life cycle.

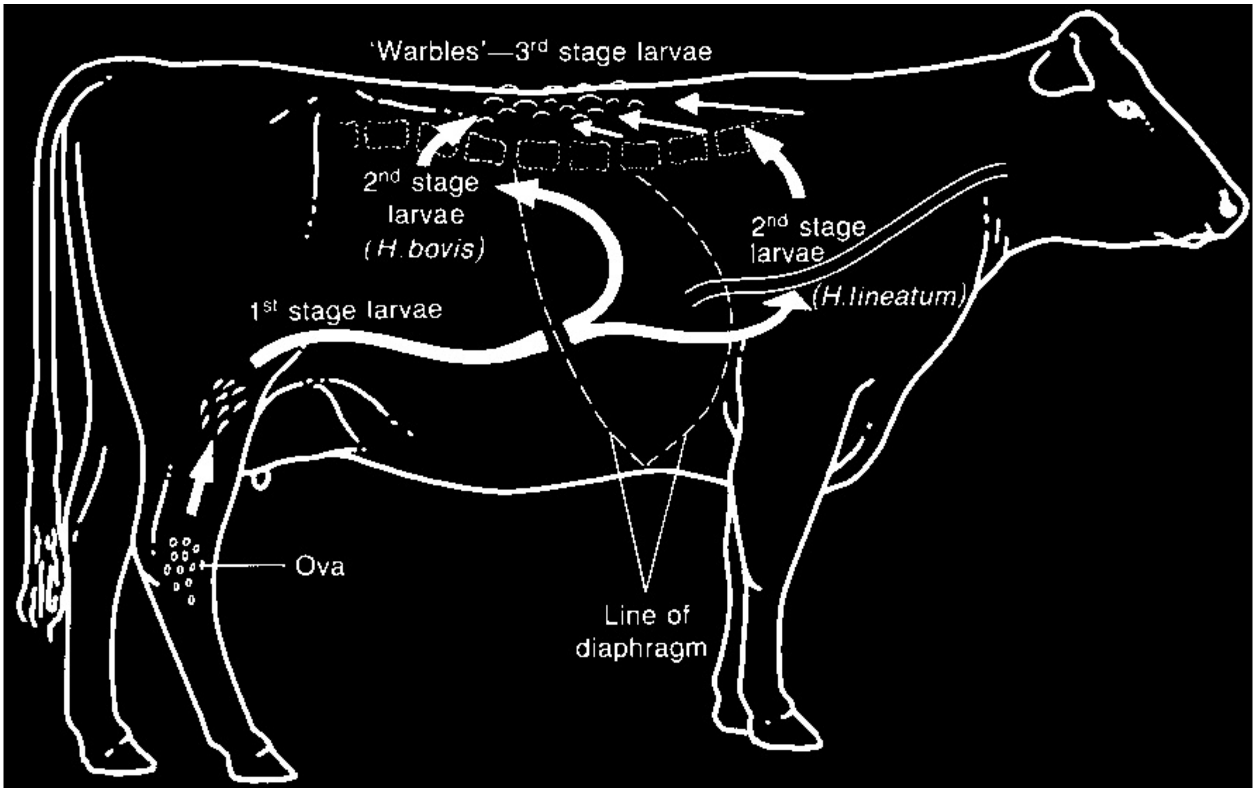


Fig. 50.3

Migration of warble fly larvae

within cattle.

Damage by larvae

Table 50.1

Dose rate for pour-on treatment using Phosmet

13 per cent w/v.

• Carcasses. The presence of grubs may necessitate

trimming of meat at slaughter or, in some cases,

Weight of animal (kg)

Dose (ml)

condemnation. Trimming makes the carcass less

aesthetically acceptable and so it can dispropor-

Up to 130

20

tionately reduce the price when meat is plentiful.

131–200

30

• Hides. Maturation of warble fly grubs to the stage

201–260

40

where they make breathing pores causes serious

261–330

50

damage to the dermis and results in downgrading

Over 330

60

of affected hides.

• Rupture of larvae. This occasionally precipitates an

immunological reaction.

When migrating in the earlier stage of the life cycle, *Preparations used include phosmet, trichlorfon,*

H. lineatum larvae may cause an oesophagitis when

fenchlorphos, coumaphos and fenthion. All are

they reach the oesophageal wall; H. bovis larvae can

cholinesterase inhibitors and knowledge of their

result in posterior paralysis.

actions, in particular their toxic effects and antidotes,

is essential before using them for warble treatment

(see p. 940).

Treatment and control (see p. 1031)

Organophosphorus preparations have been

Treatment of lesions associated with the maturation of

employed by dip, spray and wash. The most satisfac-

the migrating larvae has now been superseded by

tory method of application has been shown to be the

preventive measures.

'pour-on' procedure. An example of pour-on treatment,

Since the range of activity of Hypoderma flies is

using Phosmet 13.3 per cent w/v solution, is shown in

limited to 5–14 km (3–9 miles), control of infestation by

Table 50.1.

eradication is feasible provided neighbouring stock-

Cattle should be treated in autumn (15 September to

keepers treat their animals.

30 November) or in the spring (15 March to 31 June).

Organophosphorus preparations. Organophosphate

Best results are obtained by autumn treatment and

systemic insecticides have been found to be the most

prevent skin nodule formation by the third-stage larvae

effective agents for the eradication of Hypoderma

in the spring. No treatment should be given between 1

larvae, the aim being to destroy them early in the in-

December and the following 14 March because of

festation before they reach resting sites near the neural

possible reactions at the winter resting sites due to

canal or are themselves very large.

the death of the warbles.

Animals being treated on the above regimen should

The incubation period of the disease is generally connot be given organophosphorus anthelmintics, lev-

sidered to be approximately one week although four *amisole or diethylcarbamazine citrate at the same time.*

weeks has been suggested as the period in some out-

Special precautions regarding the use and handling

breaks. Once in contact with the skin surface of a sus-

of organophosphorus preparations, particularly with

ceptible animal, the fungus invades the anagen hairs

regard to wearing protective clothing, are applicable

(telogen hairs are not affected) by enzymatic destruc-

and reference to the manufacturer's data sheet is

tion of keratin. Hyphal growth extends only as far as

essential before their use.

the point at which keratinization of the hair takes place

In Great Britain warble fly infestation is a notifiable

(Adamson's fringe).

disease. The efficacy of control measures aimed at

The hair, so weakened, breaks off, leading to the

eliminating warble infestation can now be monitored

partial alopecia seen on clinical lesions of dermatophy-

serologically.

tosis. A generally mild inflammatory reaction accom-

panies the infection; only occasionally is this severe

Ivermectin: The systemic parasiticides based on iver-

in cattle, leading to excess production of skin scale,

mectin are also effective in destroying warble grubs. One

folliculitis or furunculosis.

per cent ivermectin injection may be used according to

the manufacturer's recommendations after the end of

Signs

the period of fly activity and before the larvae reach their

resting sites. The milk of treated cattle may not be used

The disease is usually non-pruritic in cattle. Lesions are

for human consumption, or manufacturing purposes or

characteristically greyish-white and have an ash-like

within 60 days prior to parturition. Meat animals must

surface. Their outline is circular and they are slightly

not be slaughtered within 35 days of their last treatment.

raised due to the accumulation of many layers of scale

and the swelling of tissues beneath due to a moderate

inflammatory reaction. Some lesions may show areas of

Dermatophytosis (ringworm)

mild exudation and yellow crust formation where the

skin reaction is more severe. Removal of hair tufts or

The infection of hair and skin keratin with the der-

some of the accumulated crust will often leave a raw

matophytes Trichophyton verrucosum, and less com-

bleeding surface. Broken hairs remain as hair stubble

monly T. mentagrophytes, causes lesions commonly

encased in scale and crust (Plate 50.1).

referred to as ringworm. This disease has a worldwide

The size of lesions varies, 3–5 cm (1–2 inches) dia-

distribution, the incidence of which is considered to be

meter being common; in the more severely affected

high although an accurate figure for its occurrence is

animals lesions become confluent to form extensive

not known. It is particularly common in young stock

areas of infection (Plate 50.2).

between two and seven months of age and during the

The distribution of lesions in calves commonly

autumn and winter months of the year. Adult cattle are

involves the periorbital skin, ears and back, while in

also quite frequently affected.

adult cattle the thorax and limbs are the more favoured

Animals kept in close contact with one another, e.g.

sites. In show cattle subjected to grooming, multiple

under intensive management systems, are particularly

small lesions develop over the whole of the body and

at risk. Other species may also be infected, including

limbs following the spread of infective spores by con-

horses, sheep and also man in whom it may cause

taminated grooming brushes. Very occasionally the

serious skin lesions. Although not giving rise to serious

udder can be affected (Plate 27.29).

systemic debilitating symptoms, the effect of ringworm

is on the value of the animal or its hide.

Duration of the disease

Show animals with the disease may not be shown or

Ringworm infection is generally considered to be self-

sold, infected stock carry a depreciated market value

limiting and the course of the disease to be one to four

when offered for sale and the hides of animals slaugh-

months, although in some cases a period as long as nine

tered show defects that render them less valuable for

months has been necessary for resolution to take place.

top-quality leather manufacture.

These periods may be shortened by implementing the

appropriate therapeutic measures.

Epidemiology

Diagnosis

The spores of ringworm fungi survive for many months

and in some cases years in the farm environment. They

Diagnosis is made on the clinical signs of classic lesions

may be transmitted either by fomites or by asympto-

of dermatophytosis confirmed by the laboratory exam-

matic carrier animals to susceptible hosts.

ination of hair and crust samples.

Collection of samples

may only succeed in moderately reducing the duration

of the disease) has brought the therapy of ringworm in

(1)

By forceps epilation of hair from areas of active

cattle into question. Scott (1988) refers to ‘a sea of anti-

infection.

fungals’ for the treatment of animal ringworm, many of

(2)

Scrapings of crust, hair and scale using a scalpel

which are of questionable efficacy. The choice of

blade.

therapy depends on the availability of appropriate

antifungal agents.

Using either of these procedures the material obtained

is collected in a paper envelope (ensuring that the quan-

tity of sample is adequate for the diagnostic procedures

Systemic treatment

to be carried out), sealed and labelled for transmission

to the laboratory.

(1)

Griseofulvin. An oral feed supplement given at

If culture is contemplated, swabbing the area with

a dose of 10 mg/kg body weight for 7–14 days. In

70 per cent alcohol prior to collection of material may

the USA an alternative routine of 15–35 mg per kg

reduce contaminants in the specimen.

body weight for 18–30 days is considered more

effective. Pregnant animals should not be treated

Laboratory diagnosis: Arthrosporic hyphae on hairs *with this preparation. Milk from treated animals*

can be demonstrated using the microscope.

should not be used for human consumption until

48 hours after the last treatment. Cattle should not

(1)

Wet preparation of suspect material on a micro-

be slaughtered for human consumption until five

scope slide with coverglass mounted in 20 per cent

days after the last treatment. It is no longer avail-

potassium hydroxide solution and gently warmed.

able for cattle in the UK.

(2)

Wet preparation in lactophenol cotton blue on a

(2)

Sodium iodide. A dose of 1 g/14 kg body weight as

microscope slide under a coverglass.

a 10–20 per cent aqueous solution is given by

(3)

Wet preparation on a microscope slide under a

intravenous injection, followed by a repeat injec-

coverglass mounted in potassium hydroxide/Super *tion seven days later. Pregnant cattle should not*

Quink solution.

be treated with iodide therapy. Cattle so treated

In all procedures using the microscope for the exami-

may show signs of iodism (pp. 261, 302, 823).

nation of wet preparations care is necessary in adjust-

ing the microscope illumination in order to visualize

arthrosporic hyphae. This is equally applicable to the

Topicals

examination of portions of cultured material.

Imidazoles: A wide range of imidazole preparations

Definitive diagnosis of the species of fungus may be

have been formulated for the treatment of fungal skin

obtained by culture techniques using Sabouraud's agar,

infections.

mycobiotic agar, or dermatophyte test medium (DTM),

Enilconazole (Imaverol, Janssen Animal Health)*:*

and observing the characteristics of the organism, i.e.

Cattle may be treated by spray or wash using a 0.2 per

colonial morphology and that of the hyphal growth. In

cent w/v emulsion of enilconazole in water. It is rec-

order to arrive at a conclusive answer culture time may

ommended that excess scab and crust be removed by

need to be extended, i.e. for as long as three weeks.

scrubbing with a stiff brush soaked in the antifungal

Using Sabouraud's agar, rapid identification of T. ver-

emulsion. Subsequent treatments by spraying or wash

rucosum may be achieved by culture at 30–37°C (34°C), are made on three to four occasions at three-day

when the colony shows long chains of chlamydospores

intervals.

characteristic of the organism.

The DTM may be used to suggest a positive diag-

Other preparations:

nosis of a pathogen by observation of the indicator

***Natamycin (Mycophyt, Intervet UK Ltd)**: A dry*

colour change.

powder for the preparation of a 0.01 per cent suspen-

Definitive diagnosis is only by identification of cul-

sion in water is available for application to cattle by

tural characteristics.

spray or wash. Special care is necessary in reconstitut-

ing the powder, for the final suspension reference

should be made to the manufacturer's data sheet. Fol-

Treatment

lowing an initial treatment a repeat application may be

Owing to the difficulty in eliminating the organism from

made four to five days later. Subsequent treatments can

the environment in which many cattle are kept, and the

follow at 14 day intervals. Following treatment with

number of animals involved, the reward for treating the

natamycin suspension animals should be sheltered from

disease with such preparations as are suitable (these

direct sunlight for several hours.

Copper naphthenate (Kopertox)*: A topical prepara-*

formaldehyde. The wearing of appropriate protective

tion presented as an aerosol containing 2.19 per cent

clothing in conformation with health and safety regula-

w/v copper naphthenate. Lesions to be treated should

tions is essential.

be thoroughly soaked with a solution. A repeat treat-

ment may be given after an interval of 10 days if *necessary. The product is now not available in some*

Parasitic skin disease

countries.

***Iodine**: A liquid made up of equal parts of tincture*

***Lice (pediculosis)** (Plate 50.3)*

of iodine and glycerin has been used for the treatment

of individual lesions of ringworm on cattle.

Lice are somewhat dorso-ventrally flattened insects up

***Note**: Special precautions are necessary in the appli-*

to 6 mm in length that are host-specific parasites.

cation of topical preparations. Care should be taken to

The distribution of lice is world-wide. The species

avoid sensitive areas, the eyes in particular and also the

infecting cattle are the biting louse Bovicola (Dama-

transfer of topical applications to other animals in

linia) bovis, and the sucking lice Haematopinus eurys-contact with those under treatment.

ternus, Linognathus vituli, and Solenopotes capillatus.

The biting lice feed on tissue debris while the sucking

species suck blood and tissue fluid (see p. 741).

Prophylaxis

Griseofulvin at a dose of 7.5–60 mg/kg per day for five

Life cycle

weeks has been suggested as a prophylactic against der-

matophyte infection. Pregnant animals should not be

The entire life cycle of approximately three to six

treated. However, animals so treated will not be

weeks' duration is spent on the host. Adult females lay

immune to disease and so may become infected at a

their eggs and attach them singly to hairs. These appear

later date.

as pearly or opalescent bodies (nits) 1–2 mm long. From

the egg immature nymphs emerge, and pass through

several moults before becoming adult. Survival off the

Immunity

host is short, usually less than one week. However,

The role of immunity in the epidemiology of outbreaks

under certain conditions lice have been recorded to

of cattle ringworm remains unclear. Re-infection after

survive for periods up to three weeks.

natural infection appears to be uncommon.

On the host, populations of lice vary seasonally, being *highest in colder seasons when the coat is long and*

Vaccination (see p. 1017)

transmission by contact from animal to animal readily

occurs. Lower populations in the warmer seasons are

The immunization of cattle against Trichophyton ver-

due to the higher environmental temperature of the

rocosum infection has been practised in Russia and

skin and coat in which lice cannot survive.

Norway and a vaccine is now available in the United

In spite of these factors, small populations may

Kingdom (Ringvac Bovis LTF-130, Intervet Ltd).

survive in protected areas, i.e. the ears, axillae, jowl, tail, Freeze dried material prepared from an attenuated

ready to multiply when environmental conditions

non-pathogenic stain of T. verrucosum is reconstituted become beneficial.

for the inoculation of young calves at two weeks of age.

Two inoculations are recommended at an interval of

Distribution of infestation on the host

10–14 days by intramuscular injection into the neck.

Biting lice occur mainly on the neck, withers and tail

Disinfection

head. Sucking lice are commonly found as a more gen-

eralized infestation, occurring on the head, neck,

Viable spores of ringworm fungi may remain in build-

withers, down the brisket, tail, axillae and groin.

ings and particularly on porous surfaces, e.g. wood,

brick, for months or years, making disinfection difficult.

Signs

Cleansing with high pressure water jets, scrubbing

down with hot detergent solutions or disinfectants (e.g.

The cardinal sign is pruritus, the resulting restlessness

benzalkonium chloride) or alternatively, disinfection

leading to poor feeding and poor weight gain. The coat

with 2 per cent formaldehyde solution after prior scrub-

is poor in condition, often with alopecia and excoriation

bing can remove infection. When using disinfection

due to self-trauma, with loss of coat lustre and excess

procedures, i.e. spraying and scrubbing walls, doors, etc.,

dandruff as well as hide damage. Animals in milk may

special precautions should be taken to prevent contact

show lowered production. Infestations with sucking lice

with the preparation used, e.g. on the skin, in the eyes *may give rise to anaemia and consequent increased sus-*

and by inhalation, particularly when using solutions of

ceptibility to concurrent disease.

Diagnosis

panied by secondary infection with bacteria (Plate 50.6).

The persistent intense pruritus causes debility, loss of

This depends on the demonstration of lice and eggs

condition, poor food conversion, hide and skin damage

within the coat. Because of pruritis, the only major

and in dairy cattle a reduction in milk yield. Workers in

disease to be differentiated is mange.

close contact with affected animals may show papular

skin lesions.

Treatment (see p. 1030 onwards)

Diagnosis: Physical examination,

history,

possible

Louse infestations of cattle may be controlled by the

human involvement, demonstration of S. scabiei in skin application of
antiparasitic sprays, powders, washes,

scraping material examined microscopically all help

'pour-ons' and certain injectable preparations. The use

the diagnosis. In exceptional cases skin biopsy may be

of these should be complemented by attention to man-

helpful.

agement and husbandry aimed at eliminating reservoirs

The main differential diagnosis is with

of infection and improving nutrition.

psoroptic/chorioptic mange.

Antiparasitics for louse control, of which there are

many, are based mainly on organochlorine, organophos-

phorus and synthetic pyrethroid active principles, e.g.

Treatment and control (see also p. 1030)

Gamma BHC powder (0.625 per cent), Coumaphos

(1)

Organophosphorus pour-ons, dips, sprays.

powder (1 per cent), Diazinon wash (2 per cent),

(2)

Gamma BHC 7.5 per cent (not milking cows) 5–

Phosmet 'pour-on' (13.3 per cent) and Permethrin

25 ml in 6 l water.

'pour-on' (4 per cent).

(3)

Diazinon 2 per cent wash, 28 ml in 4.5 l water.

Ivermectin 200–300 mg/kg subcutaneously is effective

(4)

Phosmet 20 per cent pour-on.

against sucking lice but of variable efficacy against the

(5)

Permethrin 4 per cent pour on.

biting species. Before use reference should be made to

(6)

Ivermectin 200–300 mg/kg by subcutaneous

the manufacturer's data sheet for details of special pre-

injection.

cautions to be observed, e.g. milk withholding times of

(7)

Amitraz (Taktic, Intervet Ltd). A 0.025 per cent

dairy cattle, permissible intervals between treatment

solution in water is applied by spray at 5 to 10

and slaughter of meat animals.

litres per animal to wet the whole body. This *should be repeated after an interval of 7 to 10 days*

Mite infestations: mange, scabies

in severe cases. Further applications if necessary

Infestation of the skin of cattle with parasitic mites may

may be made at two to three month intervals.

be by any of four species: Sarcoptes scabiei, Psoroptes Special precautions apply to operatives using this

communis, Chorioptes bovis or Demodex. The inci-preparation in respect of the wearing of protective

dence of disease due to these shows variation in differ-

clothing for which reference should be made to

ent parts of the world in respect of the species of mite

the manufacturer's data sheet. The milk withold-

and pathogenicity (p. 742).

ing time for milking cattle treated with amitraz

solution is 48 hours after the last treatment.

(8)

In circumstances where the above preparations

Sarcoptic mange, sarcoptic scabies

are not readily available, lime/sulphur dips can be

Sarcoptes scabiei (bovis) (Plate 50.4) has a life cycle of effective. The disadvantage associated with this

10–17 days and may infest cattle of any age, breed or

treatment is that repeat applications at 7 to 10 day

sex. Infection takes place by direct contact with infected

intervals may be required on as many as six

cattle or with environmental fomites, although survival

occasions.

of the mites in the environment is limited to a few days.

(9)

Synthetic pyrethroids.

These are examples of preparations available. Applica-

Signs: Sarcoptes scabiei causes an intensely pruritic tion routines may vary and response to treatment will

papular dermatitis due to the burrowing activities of

determine how many applications may be required.

the female mites within the superficial epidermis and a

Reference to the appropriate data sheet is essential for

concurrent hypersensitivity reaction. This results in a

information on special precautions and withdrawal

non-follicular papular response, exudation and crusting

times to be observed (see for lice, above).

with self-trauma in an attempt to relieve the itching.

This produces excoriation, alopecia and thickening of

the skin (Plate 50.5).

Psoroptic mange, psoroptic scabies

Lesions commonly commence about the head and

spread to become generalized with gross thickening of

Psoroptes mites are non-burrowing and have a two-

skin folds. In some animals these lesions may be accom-

week life cycle. Survival off the host may be as long as

three weeks. Transmission of infection is by direct or

Three species of Demodex mites have been identified

indirect contact.

in cattle, the life cycle of which, as in other hosts, is

obscure. Transmission of infection occurs from dam to

Signs: Infection commences over the withers and

calf by contact during suckling. No age or sex predilec-

spreads to the rest of the body. Lesions are papules

tion has been established, nor is it clear why an organ-

accompanied by severe pruritus leading to extensive

ism living as a commensal should suddenly become

serous exudation and crusting with alopecia and *a pathogen by its rapid unpredicted multiplication;*

lichenification. Irritability and consequent debility may

immunodeficiency has been suggested as one cause.

result in unthriftiness, poor weight gain, hide damage

and reduced milk yield in lactating animals.

Signs (Plate 50.7): Multiple nodules, sometimes sec-

ondarily infected, result in folliculitis and furunculosis

Diagnosis: The diagnosis is by demonstration of mites

of the face, neck and shoulders, occasionally becoming

by microscopic examination of wet preparations of skin

generalized. The disease is usually non-pruritic but nev-

scrapings. Differential diagnosis is with sarcoptic

ertheless results in severe hide damage and consequent

scabies, and chorioptic scabies.

economic loss.

Treatment: Treatment is the same as for sarcoptic

Diagnosis: With skin scrapings, wet preparations of

scabies, although care is needed to ensure that infection

expressed nodule contents examined microscopically

has been eradicated. Resistance to treatment has been

show caseous sebaceous masses and large numbers of *recorded.*

mites.

Histology of skin biopsy shows distended hair folli-

Chorioptic mange, chorioptic scabies

cles packed with mites. Secondarily infected lesions

show folliculitis, furunculosis and dermal granuloma

Chorioptes bovis is a superficial, non-invasive inhabi-formation.

tant of cattle skin. Living on epidermal debris, it has a

Differential diagnosis is with dermatophytosis (p.

life cycle on the host of two to three weeks. It survives

878) and dermatophilosis (p. 886).

only a few days off the host under natural environ-

mental conditions although under experimental condi-

Treatment: Demodicosis is often difficult to treat and tions it may live as long as 10 weeks.

prognosis is always guarded. Organophosphorus 'pour

Transmission of infestation is usually by contact. Out-

ons' have in some cases been found to be beneficial.

breaks among housed dairy cattle are higher in the

winter time when mite populations are greatest.

Warts (viral papillomatosis)

Signs: Non-follicular pruritic papules result in self-

trauma accompanied by erythema, excoriation, exuda-

Bovine papillomatosis is commonly thought of as an

tion, alopecia and the formation of crusts. These mostly

infectious disease of the skin of mainly young cattle,

involve the limbs, particularly the hindlimbs, the udder,

usually self-limiting, widely distributed about the world,

scrotum, perineum and tail. The neck and flanks may

posing little difficulty in diagnosis, prognosis or treat-

also be involved.

ment. The causal agent of the condition is a virus.

This is not, however, the whole story of bovine in-

Diagnosis: Diagnosis is by the microscopical demon-

fection with DNA papovaviruses of which the bovine

stration of causal mites in wet preparation of skin scrap-

papilloma virus has certainly five, if not more, strains.

ings. The differential diagnosis is with infestations with

Cross-reactivity between strains does not occur.

lice (p. 880) and other parasitic mites.

Papilloma virus appears to be host specific and trans-

mission of bovine warts to humans handling infected

Treatment: Treatment is the same as for sarcoptic

cattle and cattle products has not been proven.

scabies. Apparent spontaneous regression may occur

Of the strains of virus isolated, it appears that each

in the summer months when infestation appears to be

has an anatomically determined predilection site of

confined to the distal limbs.

infection.

(1)

BPV type I causes frond-like lesions on the nose,

Demodicosis

teats or penis: fibropapillomas in young cattle

Demodectic mites are considered to be normal resi-

(Plate 27.31).

dents of the skin of many species of wild and domestic

(2)

BPV type II causes papillomatosis of the skin of

animals. They are apparently host specific and live

the face, head, neck and dewlap, eyelids and occa-

mainly within the hair follicles and sebaceous glands.

sionally legs of young cattle.

(3)

BPV type III causes atypical warts, small smooth

rule. Occasional cases of generalization may be en-

white sessile lesions on the udder and teats (p. 367;

countered and are likely to be due to a failure in cell-

Plate 27.32).

mediated immunity.

(4)

BPV type IV causes alimentary tract and urinary

Autogenous vaccines (p. 1014) for the treatment of

bladder papillomas and ocular lesions possibly

bovine papillomatosis are of doubtful value. Where

progressing to squamous cell carcinoma.

large, persistent growths are present, e.g. on the neck,

(5)

BPV type V causes non-regressing rice-grain warts

removal by cryosurgery or cold steel surgery may be

on the teats.

attempted.

For the prevention of infection with BPV I and II, *Interdigital fibropapillomatosis, although wart-like in*

commercial and autogenous vaccines are claimed to be

character, has no proven viral aetiology.

effective. The use of lithium antimony thiomalate 6 per

cent w/v solution by deep intramuscular injection, 15 ml

Epidemiology

on each of four to six occasions at 48-hour intervals is

claimed to aid enucleation and necrosis of peduncu-

Infection may be spread either by direct contact with

lated warts.

infected animals or indirectly by fomites, e.g. from

fences by trauma through minor abrasions or by direct

or indirect effects of ectoparasitism. Following infection

Disinfection

lesions appear after a two to six-month incubation

While control of infection by disinfection is not

period.

commonly undertaken, where recurrent outbreaks of

disease have occurred in housed cattle attempts at dis-

Signs

infection may be justified. Solutions of formaldehyde *or caustic soda in appropriate dilution may be used,*

Viral papillomatosis is commonly seen in young cattle

hosing down all treated surfaces well with water after

and once established lesions will resolve in a period of

these solutions have been allowed to act and prior to

one to twelve months. Commencing as small, smooth,

restocking.

hairless, firm, button-like elevations projecting slightly

above the skin surface, they may be from 1 mm to

several centimetres in diameter (Plate 50.8). They may

Urticaria

develop to become coarse and cauliflower-like (Plate

50.9), sessile or pedunculated and single or multiple in

The physical manifestation of urticaria in the form of

number. Lesions are commonly sited on the head, neck

oedematous skin plaques or of angioneurotic oedema

and brisket and extensive generalization may occur.

may be caused by a wide variety of factors. These may

be immunological, as in Coombs' type I and II reac-

Diagnosis

tions, or non-immunological associated with injected *irritants or non-immunological histamine release.*

On clinical grounds the lesions are characteristic as is

Some non-immunologic factors that may precipitate

their distribution pattern on the skin and also the age

urticarial responses or intensify an already established

group affected.

reaction are pressure, sunlight, heat, exercise, drugs,

Histological examination shows epithelial prolifera-

chemicals, even psychological stress. Certain genetic

tion with or without connective tissue proliferation:

disorders have also been implicated in the aetiology of

BPV I and II produce epithelial and fibrous prolifera-

urticarial reactions.

tion; BPV III, IV and V produce epithelial proliferation.

Urticaria is usually seen as an acute onset disorder

having no age, breed or sex predilection, which runs an

Prognosis

acute or chronic course. It mostly affects a single indi-

vidual or, on occasion, a small group.

In infection with BPV I and II, spontaneous regression

within one to twelve months is the rule, while in the case

Signs

of BPV III, IV and V and 'interdigital papillomatosis',

lesions tend to be persistent.

In cattle, urticarial reactions are associated with insect

and arthropod bites and stings, infection, the adminis-

tration of antibiotics, vaccines or other biological prod-

Treatment and control (see also p. 1030 onwards)

ucts, some feedingstuffs as well as stinging plants.

With uncomplicated cases little treatment is required

Lesions of urticaria may vary in size, often being

since spontaneous regression in young animals is the

plaque-like wheals, localized or generalized over the

neck, body and upper limbs in particular. They are

Signs

usually cold to touch and may pit on pressure. Pruritus

The systemic response is of a high fever (40–41°C;

is variable as is the tendency for serum leakage onto the

104–106°F) with petechiation of the conjunctiva and

skin surface or for there to be haemorrhage. Urticarial

visible mucous membranes, with general dullness. An *lesions commonly show a well-defined shape or pattern,*

extensive papular to exudative dermatitis with pruritus

e.g. being ovular, serpiginous or arciform, or in the case

of variable intensity develops over the head, neck, per-

of angioneurotic oedema involve certain structures with

ineum, udder, back and tail-head (Plate 50.10). These

extensive oedematous swellings.

signs are accompanied by self-trauma (rubbing, kicking

Acute onset angio-oedema has been seen in the UK

and licking), which leads to excoriation with bleeding

on turning out housed cattle onto spring pasture, mani-

and hair loss over a period of days to several weeks.

fest as oedematous swelling of the periorbital skin,

Although the dermatitis may subside, the febrile

muzzle, perianal and perivulval tissue and occasionally

response may persist for four to seven weeks.

the udder and teats. The condition is usually transient

Seriously affected animals may die, while those

and apparently causes little distress. More severely

less so are unthrifty and ultimately have to be

affected animals may show evidence of respiratory *destroyed.*

distress.

In the USA a form of auto-allergic urticaria has been

described in Jersey and Guernsey cattle. Affected indi-

Diagnosis

viduals are believed to have a genetic predisposition to

The blood picture shows leucopenia followed by leuco-

an allergic response when there is unusual engorgement

cytosis. Skin biopsy shows superficial and deep perivas-

of the udder or undue retention of milk. Clinical signs

cular dermatitis with eosinophils and mononuclear cells

are of allergic urticarial skin rash and, in some individ-

predominating.

uals, respiratory distress.

The post mortem reveals generalized petechiation

particularly subserosal, with some cases showing free

Diagnosis

blood at external orifices.

Diagnosis is mainly on history and lesions of rapid

The differential diagnosis is with other acutely febrile

onset. Urticarial-like plaques with superficial exudation *diseases of dairy cattle, such as anthrax (p. 717), and*

and crusting closely resemble the discrete active lesions

exudative dermatitis with severe pruritus of parasitic

of dermatophytosis (p. 878).

origin.

Treatment

Treatment

Treatment is with subcutaneous or intramuscular

This is non-specific and usually there is little response.

injection of 3–5 ml of 1/100 adrenaline solution. Cattle

A few cases have improved following prolonged use of

with milk allergy should be milked out. In urticaria

injectable corticosteroids.

spontaneous resolution is often rapid and may have

commenced or taken place by the time a visiting

veterinarian arrives to attend the case.

Photosensitization

Pruritus/pyrexia/haemorrhagic

Aetiology

syndrome (PPH)

This biophysical phenomenon occurs when skin *becomes sensitized to certain wavelengths of sunlight,*

A disease of cattle, the pathophysiology of which is

particularly within the ultraviolet range of the spec-

unclear, was first reported in cattle in the UK and in The

trum, in the presence within skin cells of specific

Netherlands in the late 1970s. In The Netherlands the

photodynamic agents (see also pp. 370, 943).

outbreaks were associated with the feeding of concen-

Photodynamic agent in circulation Æ skin Æ irradiation

trates containing a urea compound, diureidoisobutane.

by sunlight Æ cell death Æ necrosis Æ sloughing

In the UK this compound was not implicated and the

causal factor has not been identified. Most cases were

Substances giving rise to these reactions in cattle may

on self-fed silage, often after the introduction of a dif-

be porphyrins originating from defective haemoglobin

ferent silage additive to the farm. All cases were in

metabolism, e.g. congenital porphyria, bovine proto-

cows, with a morbidity of 10.9 per cent and up to 25 per

porphyria, or they may be substances of plant origin,

cent mortality, although almost all cases are culled due *e.g. hypericin, which is found in the plant St John's wort*

to loss of condition.

(Hypericum perforatum). This process of photosensi-

tivity is often referred to as primary or direct light Lesions on the muzzle and udder may suggest a differ-sensitization.

ential diagnosis of bluetongue *(see p. 691).*

Alternatively, another set of circumstances can lead

to photosensitization, referred to as secondary or

Prognosis

hepatogenous light sensitization. Although the final

outcome, skin necrosis and sloughing, is the same as in

In the primary form of the disease, provided the under-

the primary form, the process by which this is brought

lying cause is not genetic, then removal to housed,

about differs.

well-ventilated, shaded and cool conditions should be

Where liver damage (of diverse aetiology) interferes

adequate to allow resolution of the lesions. Where

with the metabolism of the chlorophyll metabolite,

severe liver damage is confirmed, prognosis is poor and *phylloerythrin, this latter substance enters the circula-*

may well be terminal.

tion. As with other porphyrins, it initiates a light sensi-

tivity response when present in the skin.

Treatment

Both of these manifestations of photosensitivity are

systemic in origin. A third, localized, form of skin reac-

Cool, shaded, fly-free housing to avoid myiasis is nec-

tion to sunlight may on rare occasions be induced by

essary. Where necrosis and sloughing has taken place

contact with the sap of certain plants containing pso-

lesion hygiene is essential to prevent fly strike and

ralens. Localized lesions are more likely to be found on

the application of powder dressing to that end is bene-

the distal limbs, muzzle or ventrum.

ficial. Resolution in severely affected animals is often a

In order for photodynamic cell destruction to take

long process. Antibiotics to limit secondary infection

place, the following circumstances are necessary:

may be justified, as may the short-term administration

of corticosteroids in certain cases. In secondary photo-

(1)

The photodynamic agent must be present in the

dermatitis, the justification of therapy will be deter-

skin at the time of exposure to sunlight.

mined by the acuteness or chronicity of the underlying

(2)

The exposed skin will be non-pigmented (the

disease.

greater the density of melanin pigmentation, the

greater is the protection against ultraviolet solar

radiation).

Bovine farcy

(3)

The density of hair cover should be such that sun-

light can penetrate to the skin surface.

A chronic nodular and ulcerative disease of the skin of

Photosensitization leading to photodermatitis is

cattle, the causal organisms of which may be either

essentially a physical process. The activation of por-

Nocardia farcinica or Mycobacterium farcinogenes.

phyrins within skin cells by ultraviolet irradiation

The disease is only found in Africa, Asia and South

releases energy that causes cell death, the clinical signs

America.

of which are erythema, oedema and necrosis of exposed

non-pigmented areas of skin. In some animals vesica-

Aetiology

tion is present prior to necrosis, sloughing and ulcera-

tion of affected areas. Pruritus and pain may also be

Nocardia farcinica is a soil saprophyte that becomes

shown.

inoculated into wounds by contamination or enters the

Sites most likely to be involved in cattle are those

skin by inoculation via tick vectors, which themselves

most exposed to direct sunlight, e.g. the head, neck,

carry the organism for long periods of time.

back and lateral aspects of the body, udder and teats

(more extensively when the photosensitive animal is

Signs

lying down) (Plates 27.23, 50.11 and 50.12).

Once inoculated, slowly developing painless nodules

appear more commonly over the head, neck, shoulders,

Diagnosis

limbs, perineum and groin. Infection may give rise to

The dramatic lesions of skin necrosis and sloughing

mastitis and whilst following the lymphatics cause

should not present diagnostic difficulty in the estab-

cording of these vessels as well as lymphadenopathy.

lished case. The presence or absence of systemic signs

Ulceration of lesions occurs with the discharge of thick,

of illness, e.g. jaundice, positive blood screens for

grey/yellow material.

hepatic disease, should determine whether the condi-

Infection may be protracted and confined to the skin

tion is primary or secondary.

but generalization, particularly to the lungs and viscera,

Very localized lesions on distal limbs, ventrum or

can occur with a progressive loss of condition leading

muzzle would suggest a topical plant contact aetiology.

to death.

Diagnosis

tous bacterium. Infection with D. congolensis is con-

fined to the epidermis where the motile zoospore stage

Diagnosis is dependent on the clinical signs. The organ-

of the organism, activated under suitable conditions of

ism may be demonstrated in smears of exudate (acid-

climate and skin damage, grows to form a filamentous

fast filaments, which are beaded). Culture of Nocardia

mycelium within the epidermis. In dry conditions the

farcinica is also possible.

spore stage of the bacterium may remain dormant in

Histopathology shows the presence of pyogranulo-

dry crust, scab and hyperkeratotic skin debris for many

matous dermatitis.

months.

The differential diagnosis is with so-called skin tuber-

A number of factors influence the incidence of the

culosis due to acid-fast bacilli, particularly nodules

disease, of which high temperature and humidity play

found on the lower limbs or cording of lymphatics of

an important role. Similarly, breed susceptibility is of

forelimbs (see below).

importance, indigenous cattle being more resistant to *infection than imported exotic breeds.*

Treatment

The initiation of lesions requires skin damage, albeit

superficial, by abrasion, e.g. thorn scratches, insect bites

Inorganic iodides have been used but the advice given

(biting flies or ticks may themselves carry the infective

is usually to have the affected animals destroyed.

organism).

The incubation period may be as short as two weeks.

Atypical mycobacteriosis

Signs

Skin infections with environmental mycobacteriaceae

Bovine cutaneous streptothricosis commences as a cir-

are recognized worldwide. Lesions arise from the intro-

cumscribed moist patch, often with raised or matted

duction of organisms through sites of skin trauma.

hairs, giving a characteristic 'paint brush' appearance.

Infection gives rise to nodular lesions on the distal

Discrete lesions occur in the initial stages which coa-

limbs, sometimes discrete, otherwise in chains following

lesce to form large areas of hyperkeratotic scab and *the course of the superficial lymphatics. Nodules occa-*

crust (Plates 50.13 and 50.14). In severe infections as

sionally rupture to exude creamy pus. The condition is

much as half the skin surface may be involved. Scab

commonly referred to as 'skin tuberculosis'.

may be of variable thickness and on removal show a

Diagnosis is by the demonstration of acid-fast organ-

concave underside coated in thick, yellowish exudate,

isms in the smears of pus or by histopathology of biop-

leaving a raw, bleeding epidermis.

sied lesions. The importance of this infection is its role

in inducing a non-specific reaction to the intradermal

tuberculin test (see p. 863). There is no treatment.

Diagnosis

Impression smears of the exudate, fixed and stained by

Gram's method or methylene blue, reveal numerous

Dermatophilosis

rows of cocci formed into branching filaments. Organ-

(bovine streptothricosis)

isms may not be readily demonstrable in material taken

from old lesions or those affected by secondary infec-

This is a chronic or acute exudative dermatitis that may

tion. Dermatophilus congolensis may be cultured on

affect many species of animals and is of world-wide

blood agar under microaerophilic conditions.

distribution. It also occurs in humans.

Differential diagnosis is with dermatophytosis (p.

The disease in cattle is of particular importance in

878) and sarcoptic scabies (p. 891).

Africa, where it is thought to have been known since

the nineteenth century, in America, the Middle East and

Treatment

Mediterranean Europe.

In cattle the disease is of importance for its role in

Antibiotic therapy using penicillin and streptomycin as

causing economic loss through down-grading of hides

a single dose regimen (70 000 iu penicillin and 70 mg/kg

and skins, reduced milk yield, marked debility in

body weight streptomycin intramuscularly) will prevent

severely affected animals with dehydration and death.

epidermal invasion by zoospores as well as re-infection.

Alternatively, five daily doses of 5000 iu penicillin and

5 mg/kg body weight streptomycin may be given (Lloyd,

Aetiology

1981). Long-acting oxytetracycline by deep intramus-

The agent responsible for infection is the actinomycete,

cular injection at 20 mg/kg body weight has also been

Dermatophilus congolensis, a Gram-positive filamen-

found to be effective (Lloyd et al., 1990). Topical appli-

cation of solutions of cresols and copper salts in appro-

has a world-wide distribution amongst all types of

priate dilution may have a preventive effect.

cattle.

Prevention

Lumpy skin disease (see p. 768)

Since predisposition to the disease is due to skin trauma

A seasonal disease that occurs particularly at times of

from vegetation, ectoparasite infestation with poor hus-

high insect population and can affect cattle of any age,

bandry resulting in malnutrition and/or the presence of

breed or type.

concurrent disease, many of these factors are difficult to

The mode of transmission of infection has not been

control. Efforts directed towards the establishment of

fully determined although the association with periods

herds of breeds resistant to D. congolensis may be of of high insect population and proof that Stomoxys

long-term benefit.

calcitrans can carry the virus suggests that the organism The quest for an effective vaccine continues but is

is insect-borne. The incubation period is one to four

still in the experimental stage of development (Lloyd,

weeks.

1984). A combination of improved husbandry with

Lumpy skin disease causes high economic loss

vaccine therapy may eventually be the effective means

through decreased milk production, abortion, loss of

of control.

condition and hide damage.

Signs

Horn cancer

The initial viraemia is associated with a febrile

This disease, which results in neoplasia of the horn core,

response, nasal discharge, excess salivation and possibly *is usually an extension of squamous cell carcinoma that*

lameness. After a period of one week the first signs of

arises from the mucosa of the frontal sinus. Involve-

skin lesions may be seen as papules/nodules with

ment of the horn core causes loosening of the horn,

enlargement of the superficial lymph nodes.

which drops off leaving the tumour exposed. While

Skin lesions can be localized or generalized, circum-

metastases occur in such conditions as squamous cell

scribed firm and flattened intradermal nodules up to

carcinoma of the eye, they do not occur in horn core

5 cm in diameter. While lesions can be confined to the

lesions.

skin of the chest, neck, back, limbs, perineum, udder and

scrotum, more severely affected animals may show

involvement of the nasal and turbinate bones. Oedema

Diagnosis

of the ventral chest and abdomen, also the limbs, may

This is by biopsy and clinical examination.

occur.

Skin lesions may well ulcerate and be slow to resolve, *persisting for months to years in some cases. In most*

Treatment

instances the skin lesions necrose, passing through

Treatment has been found to have variable degrees of

phases of ulceration and scarring before resolution in a

success and recurrence is common following surgery.

period of one to three months.

Cryotherapy, surgical excision, radiodiathermy and

Morbidity is usually around 50 per cent but may be

immunotherapy have all been tried.

as high as 90 per cent with mortality in the region of

10 per cent.

Lumpy skin disease and

Prognosis

pseudo-lumpy skin disease

This is always guarded. Those animals that progress to

(see also p. 768)

respiratory tract involvement may well die.

Two forms of lumpy skin disease are recognized:

Diagnosis

• *True ‘lumpy skin’ disease, the causal agent of which*

History, clinical examination, skin biopsy and virus

is the Neethling pox virus, infection with which

isolation are all helpful. Apart from other histopa-

gives rise to acute or subacute disease among cattle

thological changes present, eosinophilic intracyto-

in parts of Africa.

plasmic inclusion bodies may be found in keratinocytes,

• Pseudo-lumpy skin disease due to infection with

and glandular and ductal epithelium of the skin

Allerton virus, bovine herpes virus type 2, which

glands.

Table 50.2

Other conditions referred to in the text which also show skin signs.

Actinobacillosis

Chronic granulomatous lesions as an extension from infected soft tissues and lymph nodes (see p. 823) Actinomycosis

Chronic granulomatous lesions eroding skin from underlying bone infections (see p. 824) Alopecia

Congenital baldness. Baldy calf syndrome (see p. 181)

Albinism

Congenital oculocutaneous absence of pigment (see p. 182)

Bacterial infections

• of the teat – blackspot; F. necrophorum (see p. 370)

• of the udder – folliculitis, impetigo, Staph. aureus (see p. 371) Besnoitiosis

Gross thickening of skin, lichenification, hair loss (see p. 756) Claw conditions

(See Chapter 31)

Congenital

Epitheliogenesis imperfecta (see p. 181)

Epitheliokeratogenesis imperfecta (see p. 181)

Copper deficiency

Poor coat, change in black coat colour (see pp. 254, 298)

Digital disorders see also Claw disorders (p. 427)

Ichthyosis

Congenital hair loss, accumulations of scaly epithelium (see p. 182) Interdigital dermatitis

See also Claw disorders

Onchocerciasis

Multiple parasitic nodules within the skin (see p. 774)

Selenium poisoning

Hoof cracking, rough coat, hair loss (see p. 305)

Stephanofilariasis

Thickened skin, papules, crusts, ulcers possibly on the udder and teats (see p. 774) Viral diseases

Cowpox

Rare, erythema leading to pustule formation on teats (see p. 365) Foot-and-mouth disease

Vesicles on teats, muzzle, in addition to coronary band and mouth (see p. 700) Herpes mammillitis

Irregular vesicles on skin of udder and teats, discoloration, ulceration (see p. 363) Papillomatosis

Warts on teats (see p. 365)

Pseudocowpox

Common, erythema, papules, vesicles and scabs on teats (see p. 364) Rickettsial disease

Jewbrana disease, petechiation, bleeding through the skin (see p. 766) Treatment

neck, back, udder, perineum and scrotum showing

superficial raised plaques having a central depression

None is effective. Antibiotics may be given to combat

and superficial necrosis.

secondary infection. Measures to minimize the possi-

bility of fly strike and subsequent myiasis should also

be taken.

Diagnosis

History, physical examination, virus isolation and skin

Prevention

biopsy are helpful. Skin biopsy shows, among other *changes, eosinophilic intranuclear inclusion bodies in*

Some protection is gained by vaccination with modified

keratinocytes of the stratum spinosum.

Neethling virus vaccine. Vaccination with sheep pox

virus has also conferred some protection.

Other conditions having skin signs

Pseudo-lumpy skin disease *(see p. 768)*

See Table 50.2.

A much milder condition than 'true' Neethling virus

lumpy skin disease and due to infection with bovine

herpes virus type 2. The organism is also responsible for

References and further reading

outbreaks of herpes mammillitis (p. 363).

General

Signs

Scott, D.W. (1988) Structure and function of the skin. In Large Animal Dermatology, pp. 2–28. W.B. Saunders & Co., There is absence of a systemic response or superficial

Philadelphia.

lymphadenopathy with a clinical course similar to

herpes mammillitis, resolution occurring in two to three

Warble fly

weeks. In exceptional cases lesions may persist for con-

siderably longer.

Fadok, V.A. (1984) Parasitic diseases of large animals. Veteri-Skin lesions have a similar distribution and appear-

nary Clinics of North America: Large Animal Practice, **6**, *ance to those of lumpy skin disease, with limbs, body,*

3–26.

Scott, D.W. (1988) Parasitic diseases. In Large Animal Der-

Bovine farcy

matology, pp. 245–8. W.B. Saunders & Co., Philadelphia.

Soulsby, E.J.L. (1982) Helminths, Arthropods and Protozoa of Lloyd, D.H. (1981) Bovine farcy. In Current Veterinary

Domestic Animals, 7th edn, pp. 432–7. Baillière Tindall, Therapy, Food Animal Practice (ed. by J.L. Howard), London.

p. 1136. W.B. Saunders & Co., Philadelphia.

Dermatophytosis

Dermatophilosis

Scott, D.W. (1988) Large Animal Dermatology, pp. 179–82.

Lloyd, D.H. (1981) Streptothricosis. In Current Veterinary W.B. Saunders & Co., Philadelphia.

Therapy, Food Animal Practice (ed. by J.L. Howard), pp. 1134–5. W.B. Saunders & Co., Philadelphia.

Lloyd, D.H. (1984) Immunology of dermatophilosis: recent

Parasitic skin diseases

developments and prospects for control. Preventive Medi-

*cine, **2**, 93–102.*

Blood, D.C., Radostits, O.M. & Henderson, J.A. (1983) Veteri-Lloyd D.H. & Sellers, K.C. (1976) Dermatophilus infection in nary Medicine, 6th edn, p. 964. Baillière Tindall, London.

animals and man. Symposium Proceedings, Ibadan. Acade-

Fadok, V.A. (1984) Parasitic skin diseases of large animals. Vet-mic Press.

*erinary Clinics of North America, Large Animal Practice, **6**, Lloyd, D.H., Hawkins, J.P. & Pragnell, J. (1990) Efficacy of 3–26.*

long-acting oxytetracycline in the treatment and control of

*Linklater, K.A. & Gillespie, I.D. (1984) Outbreak of psorop-bovine dermatophilosis. Veterinary Dermatology, **1**, 78–*

*tic mange in cattle. Veterinary Record, **115**, 211-12.*

82.

Scott, D.W. (1988) Parasitic diseases. In Large Animal Dermatology, pp. 207–30. W.B. Saunders & Co., Philadelphia.

Horn cancer

Warts

Bastianello, S.S. (1982) A survey of neoplasia in domestic

species over a 40-year period from 1935 to 1974 in the

Gibbs, E.P.J. (1984) Viral diseases of the skin of the bovine teat Republic of South Africa. I. Tumours occurring in cattle.

and udder. Veterinary Clinics of North America: Large

Ondersterpoort Journal of Veterinary Research, ***49***, *195–*

Animal Practice, ***6***, *187–202.*

204.

Hunt, E. (1984) Infectious skin diseases of cattle. Veterinary Pachauri, S.P. & Pathak, R.C. (1969) Bovine horn cancer.

Clinics of North America: Large Animal Practice, ***6***, *155–74.*

Therapeutic experiments with autogenous vaccine.

Scott, D.W. (1988) Epithelial neoplasms. In Large Animal Der-American Journal of Veterinary Research, ***30***, *475–7.*

matology, p. 420. W.B. Saunders & Co., Philadelphia.

Lumpy skin disease and pseudo-lumpy

Pruritis/pyrexia/haemorrhagic syndrome

skin disease

References to outbreaks are all prior to 1980, since which time Martin, W.B. (1986) Bovine mamillitis. In Current Veterinary there have been no reports in the scientific literature.

Therapy: Food Animal Practice II (ed. by J.L. Howard).

However, a few outbreaks still occur each year.

pp. 472–3. W.B. Saunders & Co., Philadelphia.

Blood, D.C. & Radostits, O.M. (1989) Veterinary Medicine, 7th Njoku, C.O. (1986) Lumpy skin disease. In Current Veterinary edn, p. 1300. Baillière Tindall, London.

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Photosensitization

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St George, T.D., Uren, M.F. & Melville, L.F. (1980) A gener-Veterinary Clinics of North America: Large Animal Practice, alised infection of cattle with bovine herpes virus 2. Aus-6, 176–9.

*tralian Veterinary Journal, **56**, 42.*

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Chapter 51

Neurological Disorders

P.R. Scott

Introduction

890

ical examination. A methodical neurological examina-

Development, structure and function of the nervous system 891

tion allows the lesion to be localized to specific areas of

Development

891

the brain (Braund, 1985). The common diseases and

Structure and function

891

conditions which affect those areas of the brain can

The nature and causes of signs of neurological disorder

891

then be listed and further investigated. This approach

Endogenous biochemical causes

891

is much more preferable than the undergraduate

Exogenous biochemical causes

892

student or practitioner attempting to memorize long

Genetic causes

892

Micro-organisms

892

lists of clinical signs for every neurological disease. A

Neurological examination

895

logical approach to neurological examination of cattle

Cerebral syndrome

895

highlights discrepancies when new diseases arise

Cerebellar syndrome

896

because it does not limit the differential diagnoses to

Vestibular syndrome

896

known diseases.

Pontomedullary (brainstem) syndrome

896

Such a methodical approach (Scott et al. , 1989a, 1995) Collection of CSF

896

was not adopted when a vague neurological disease,

General principles of treatment for CNS infections

897

bovine spongiform encephalopathy (BSE),

first

Summary

900

appeared in United Kingdom dairy herds during the

Specific diseases

900

mid 1980s. The clinical findings were not consistent with

Cerebellar hypoplasia/hydranencephaly

900

any recognized bovine neurological disorder and led to

Bacterial meningoencephalitis

901

Brain abscess

902

spurious diagnoses such as brain tumours, chronic

Cerebellar abiotrophy (postnatal degeneration)

903

hypomagnesaemia, listeriosis, hepatic encephalopathy,

Unilateral middle ear infections/vestibular syndrome

903

etc. The lack of a methodical approach to suspected

Polioencephalomalacia (cerebrocortical necrosis, CCN)

903

cases of BSE resulted in a correct clinical diagnosis in

Listerial encephalitis

904

only 85 per cent of slaughtered cattle. Indeed, many of

Lead poisoning

906

these cattle were examined twice some weeks apart,

Thromboembolic meningoencephalitis (TEME)

907

which should have excluded many acute neurological

Aujeszky's disease

907

diseases. Despite over 15 years' experience of BSE, the

Rabies

908

clinical diagnosis remains only 85 per cent correct.

Bovine spongiform encephalopathy (BSE)

909

Despite data collected from over 20 000 suspected cases

Idiopathic brainstem neuronal chromatolysis of cattle

911

of BSE which were negative on histopathological ex-

Sporadic bovine encephalomyelitis (SBE, Buss disease)

911

Spinal cord lesions

amination of brain tissue, no summary of these clinical

cases has appeared in the veterinary literature. This lack

of data indicates the absence of a standard logical

Introduction

approach to neurological disease by many veterinari-

ans. Too often the clinical signs are fitted to a limited

Many of the neurological disorders of cattle such as

number of known diseases and it is therefore inevitable

lead poisoning, botulism, hydranencephaly caused by

that new diseases will not be recognized.

congenital bovine viral diarrhoea/mucosal diarrhoea

Cerebrospinal fluid (CSF) analysis is the most useful

(BVD/MD) or Akabane virus infections present as

laboratory test in the clinical investigation of neurolog-

outbreaks. It is essential therefore that an accurate

ical diseases in cattle (Scott & Penny, 1993; Scott 1995a, diagnosis is reached in order to expedite preventive

1996) but such samples are rarely undertaken in prac-

and control measures. The investigation of possible

tice. However, lumbar CSF samples can be obtained *central nervous system (CNS) involvement in a disease*

from affected animals under local anaesthesia on the

process necessitates a detailed assessment of the

farm with immediate results available on visual exami-

animal's history and a complete physical and neurolog-

nation, ensuring an accurate diagnosis and specific

treatment without further delay (Scott & Penny, 1993).

the conducting system for neural impulses. The neu-

For example, animals may present with neurological

roglia are also of two types; the oligodendroglia are

signs indicative of cerebellar dysfunction where a neu-

responsible for the formation and maintenance of the

trophilic pleocytosis and increased CSF protein con-

myelin sheaths of the axons and astrocytes which

centration indicate focal meningitis (Scott et al. , 1994a) provide the supporting scaffold of the CNS and also

while normal CSF parameters in another case do not

contribute to the blood–brain barrier. In the peripheral

indicate an infectious cause and indirectly support the *nervous system the Schwann cell is the homologue of*

diagnosis of a developmental abnormality causing dys-

the oligodendrocyte.

function (Scott et al. , 1993a).

The nervous system is heavily dependent upon

In many situations in practice the clinical examina-

glucose and oxygen to sustain functional activity; con-

tion is incomplete and fails to yield sufficient informa-

sequently there is a rich capillary network, especially in

tion to make a specific diagnosis. Consequently, in the

regions of high neuronal density. Even brief disruption

field situation response to treatment has often been

of blood supply will interfere with membrane function

used as an adjunct to diagnosis (Morgan, 1992), despite

with accumulation of toxic metabolites, such as lipid

numerous treatments being administered simultane-

peroxides, resulting in swelling or cell death. When a

ously (Power et al. , 1985), thereby limiting interpreta-nerve cell is lost it cannot be replaced and the circuit

tion of the outcome.

containing it is diminished. If substantial numbers of

There are specific changes in antibody titre, serum nerve cells are lost, functional deficits will result. ion, metabolite or enzyme concentration in only a small Infectious agents, toxic incidents and traumatic percentage of bovine neurological diseases and a spe- events may damage not only the neurone but also the cific diagnosis is often reached only in fatal cases which glial components of the nervous system. Following are examined in detail at necropsy (Jeffrey, 1992). injury astrocytes can proliferate to produce an as- However, for cost reasons few cattle are subject to a troglial scar, which itself may distort the tissue and fur- detailed post-mortem examination. Histopathological ther interfere with neural function. Oligodendroglia can examination of the CNS is expensive and multiple sec- also be regenerated from stem cells, but in the mature tions are cost-prohibitive. Accurate lesion localization CNS the ability to replace myelin is to a large extent by the clinician is therefore essential before euthanasia dependent upon the viability of the neurone. is carried out, otherwise discrete lesions may not be sec-

tioned at necropsy and an incorrect diagnosis reached.

The nature and causes of signs

Development, structure and

of neurological disorder

function of the nervous system

Endogenous biochemical causes

Development

(see also Chapters 21, 46, 54)

Development of the nervous system of mammals takes

This group of conditions includes those metabolic dis-

place as a sequence of intensely active events that occur

eases that are associated with the stresses of production

from early embryogenesis and continue in cattle into

and systems of management and includes milk fever,

postnatal life. During these phases cells undergoing

hypomagnesaemic tetany and acetonaemia. These dis-

rapid division and differentiation are susceptible to a

orders produce no specific pathological changes in

wide variety of physical, chemical and infectious agents.

the CNS and the clinical condition in most instances can

The physical factors include extremes of temperature, *be readily reversed by rapid correction of the specific*

especially maternal hyperthermia, and direct or indirect

deficiency.

trauma. Chemical factors include organic, inorganic and

Inborn errors of metabolism are usually considered

plant poisons, nutritional imbalances and toxic products

to be heritable, mainly with an autosomal recessive

of microbial activity in the maternal or external envi-

mode. A gene may control a specific enzyme or enzyme

ronment. The direct invasion of the fetus by micro-

system and a defect therein will block the normal meta-

organisms presents a further hazard and inherited

bolic pathway. In some cases, however, there may be

defects or spontaneous errors in nucleic acid templating

alternative pathways to modulate or minimize the con-

may produce effects at all stages of development.

sequences and these may influence the time of onset

and rate of progress of clinical disease.

In inherited congenital myoclonus in the polled

Structure and function

Hereford (Harper et al. , 1986), affected calves, although Structurally, the nervous system of higher vertebrates

bright and alert, are unable to stand from birth and

comprises neurones and neuroglia. The neurones form

show stimulus-responsive myoclonic spasms. A second

genetically mediated disorder, neuraxial oedema, also

teristic neuropathology. The clinical signs of hepatic

occurs in Herefords and possibly other breeds. Affected

encephalopathy, e.g. ragwort poisoning, may be inter-

calves appear normal at birth but within a day or two

mittent and slowly progressive or acutely fatal, depend-

they become dull and recumbent with opisthotonus.

ing upon the severity and duration of hepatic overload

The significant pathology is in the CNS and consists of

by nitrogenous compounds. There are behavioural

vacuolation at all levels of the neuraxis.

changes, with compulsive walking, circling, twitching of

Lysosomal storage diseases comprise an important

ears and eyelids, blindness and, in severe cases, recum-

group of genetically-mediated diseases whereby the

bency with opisthotonus (see p. 945).

products of faulty degradation accumulate in lysosomes

and the cell bodies swell. The cells of the heterozygote

Genetic causes

contain approximately half the normal concentration

of enzyme, but the animal itself appears normal, whilst

The plurality of genetic neurological disorders in cattle

the diseased animal is homozygous for the defect and

(Table 51.1) is possibly a reflection of intensive selec-

the enzyme is absent. Heterozygote recognition by

tion for particular production traits from within small

appropriate enzymatic assay offers a means of control-

populations of superior animals and is facilitated by

ling the disease within a population. Examples of lyso-

artificial breeding techniques.

somal storage diseases include lipidosis GM1

gangliosidosis in the Friesian, glycoproteinosis man-

Micro-organisms

nosidosis in the Angus, Murray Grey and Galloway

and ceroid lipofuscinosis, which has been described

Neurological disorders in cattle can result from the

in Beefmaster cattle. The clinical signs of GM1 gang-

activities of all types of infective agents. Some invade

liosidosis are reluctance to feed, dullness, progressive

the nervous system, usually causing inflammation of

ataxia and ill-thrift, and appear one to three months

the brain (encephalitis), spinal cord (myelitis) or the

after birth (see p. 179). Clinically, mannosidosis

membranous coverings (meningitis).

Others that

(pseudolipidosis) presents as wasting, altered behaviour

may be present in the alimentary tract or external

with aggression and progressive ataxia (see p. 179).

environment produce neurotoxins or antimetabolites,

which cause degenerative encephalopathies and

myelopathies.

Exogenous biochemical causes

There is a wide range of exogenous biochemical causes

Viruses

of neurological disorder. Some compounds, e.g.

organophosphorus compounds, organochlorides and

Viruses form an important group of neural pathogens.

carbamates, are specific neurotoxins whose mode of

The oronasal route is the most common portal of entry,
action is known. However, a great many toxicants
but some viruses gain access via the conjunctiva or
whose primary targets appear to be gut, liver or the
percutaneously by the bite of an insect vector or in-
cardiovascular system also cause neurological distur-
fected animal. Initial replication at the site of infection
bances. In the early phases these usually take the form
and in local lymphoid tissues is typically followed by
of excitement, muscle fasciculations, tachycardia and
viraemia with fever during which the virus penetrates
hyperpnoea, whilst convulsions and coma frequently
the blood–brain barrier and invades the neural
characterize the terminal phases. The mechanisms of
parenchyma. Typical inflammatory responses are focal
this toxic stimulation and depression of the nervous
and diffuse proliferations of microglial cells and
system are poorly understood (see Chapter 54).
perivascular and meningeal infiltrations of lympho-
In cattle, intoxication by chemical compounds is not
cytes. As the CNS is normally impermeable to circulat-

uncommon for reasons that include their innate curios-

ing immunoglobulins, synthesis of antibody by B cells

ity, considerable appetite and non-selective habits of

in the perivascular cuffs may play an important role in

grazing and licking. Lead, the organophosphorus com-

the recovery of the individual. Other virus infections,

pounds, ragwort, copper, urea and sodium chloride are

e.g. bovine virus diarrhoea/mucosal disease (Trautwein

known to cause neuropathological changes. Lead is by

et al. , 1987) and Akabane disease (Inaba et al. , 1975), far the most important
and is considered in detail later.

generally cause mild or inapparent disease in the adult,

Organophosphorus compounds used as insecticides

but cause severe transplacental infections of the fetus.

and herbicides are variably potent inhibitors of

Fetal meningoencephalitis or gross intracranial malfor-

cholinesterase (see p. 940). The clinical signs of acute

mations from destruction of the granuloprival elements

intoxication, miosis, salivation, polyuria, muscle fascic-

of the developing fetal brain may be the result,

ulations, apprehension and ataxia are the consequences *depending upon the stage of fetal development at*

of cholinergic overstimulation, but produce no charac-

infection.

Table 51.1

Inherited neurological diseases of cattle.

Disease

Mode

Breed(s)

Age at

Clinical features

Pathology

Reference

R/D

onset

Cerebellar abiotrophy

R

Holstein

3–8 months

Progressive spastic

Degeneration of

White et al. (1975)

ataxia, dysmetria.

cerebellar neurones

(p. 178)

Loss of menace

sparing the vermis

response

Hereditary congenital

R

Jersey

Birth to 3

Ataxia and intention

Hypomyelination and

Saunders et al.

ataxia 'jittery'

months

tremor

oedema of

(1952)

cerebellar white

matter

Cerebellar ataxia

R?

Shorthorn

1–3 days

Rapidly progressive

Spongy

Hulland (1957)

Hereford

ataxia with

transformation of

(p. 178)

recumbency

cerebellar white

matter, shrinkage

and loss of neurones

Familial cerebellar

R

Hereford

Birth

Recumbent,

Narrow disorganized

Innes et al. (1940)

hypoplasia and

stuporose,

cerebellar folia.

degeneration

intermittent rigidity

Paucity of

cerebellar cortical

neurones

Familial convulsions

D

Aberdeen

Birth to 6

Recurrent seizures

Swelling and

Barlow (1980)

and ataxia

Angus

months

with gradual

vacuolation of

(p. 178)

development of

Purkinje cells and

spastic ataxia and

Purkinje cell axons

hypermetria

Doddler

R

Hereford

Birth

Muscular spasms and

Calcification of

High et al. (1958)

convulsions,

cerebellar and

nystagmus,

medullary neurones

respiratory

difficulties

GM1 gangliosidosis

R

Friesian

1 month

Reluctance to feed,

Cerebrospinal

Donnelly et al.

dullness and

lipidosis with

(1973)

progressive ataxia

ballooning of

(p. 179)

neurones by

accumulations of

glycolipid

Mannosidosis

R

Angus,

Birth

Wasting, aggression

Vacuolation of

Hocking et al.

Murray

onwards

and progressive

neurones and fixed

(1972)

Grey,

ataxia,

macrophages, renal

(p. 179)

Galloway

lymphadenopathy

epithelial cells and

exocrine pancreas

Neuraxial oedema:

R

Hereford

1–3 days

Dullness, recumbency

Raised urine ketones.

Healy et al. (1986)

maple syrup urine

and

and opisthotonus:

Vacuolation

(p. 180)

disease

polled

nystagmus. Urine

throughout neuraxis

Hereford

smells of burnt sugar

especially white

matter

Inherited congenital

R

Polled

Birth

Stimulus-responsive

Contusions of

Harper et al. (1986)

myoclonus

Hereford

myoclonic spasms

coxofemoral joint

(p. 180)

with fractures/

deformity of

articular cartilage

contd.

Table 51.1

Continued

Disease

Mode

Breed(s)

Age at

Clinical features

Pathology

Reference

R/D

onset

Bovine generalized

R

Shorthorn

12 months

Muscular weakness,

Accumulation of PAS-

Richards et al.

glycogenosis

incoordination,

positive and Bests

(1977)

deficiency of a-1,4-

carmine plus

glucosidase or acid

granules in

maltase

neurones of

midbrain,

medullary and

cerebellar roof

nuclei

Chediak–Higashi

R

Hereford,

Young

Partial albinism (ghost

Yellow pigmented

Padgett (1968)

syndrome

Brown

adults

pattern colouring).

PAS, LFB and

Swiss

Susceptibility to

Sudan black B-

infection. Premature

positive inclusions

ageing

in nerve cells of

brain, cord,

myenteric plexuses.

Similar to lipofuscin

granules

‘Weaver syndrome’:

R

Brown

8–12

Motor dysfunction

Axonal degeneration

Stuart & Leipold

progressive

Swiss

months

with swinging gait

predominantly in

(1985)

degenerative

progressing to loss

spinal white matter,

(p. 179)

myeloencephalopathy

of movement and

axons in some brain

inability to stand

stem nuclei and

Purkinje cells of

cerebellar cortex.

Paramembranous

densities and synaptic

junctions

Neuronal lipodystrophy

R

Beefmaster

12 months

Blindness, circling,

Neuronal

Read & Bridges

recumbency and

multilamellar and

(1969)

coma

curvilinear

inclusions. Similar

structures may be

found in fixed

macrophages in

spleen and lymph

nodes.

Progressive ataxia of

R?

Charolais

8–24

Progressive weakness

Segmental

Palmer et al. (1972)

Charolais

months

and ataxia

demyelination of

(p. 179)

terminating in

CNS with retraction

recumbency

of internodes,

formation of

eosinophilic plaques

from oligodendroglial

processes

Recumbent calf

R?

Red Danish 6 weeks

Progressive ataxia,

Degeneration of

Hansen et al.

syndrome

milk

paresis and

neurones in ventral

(1988)

breed

immobility

horns of spinal cord

R, recessive; D, dominant; PAS, periodic acid shift.

Bacteria

conditions which affect those areas of the brain can

then be listed and further investigated. The most useful

Bacteria, with possibly Listeria monocytogenes as the and cost effective ancillary test is lumbar cerebrospinal

sole exception, do not invade the neuroparenchyma as

fluid analysis (Scott, 1992, 1995a, 1996). For example,

a primary event. Infection of the neuraxis usually arises

the clinical presentation in a young calf of depression,

from a bacteraemia causing meningitis, which may be

lethargy, cortical blindness and dorsomedial strabismus

purulent or non-purulent depending on the organism

is consistent with diffuse cerebral dysfunction; CSF

involved. Infection of the meninges may also arise

analysis reveals a markedly elevated protein concen-

directly following local trauma. Subsequent invasion of

tration and neutrophilic pleocytosis. These clinical signs

the neuroparenchyma, however, depends upon damage

are consistent with a diagnosis of bacterial meningoen-

to the blood–brain barrier, such as may occur following

cephalitis which is then confirmed on gross CSF inspec-

rupture of a meningeal abscess, devitalization of the

tion and laboratory findings (Scott & Penny, 1993).

tissue by toxic products or infarction due to infective

There is no need to consider an endless list of obscure

emboli as in thromboembolic meningoencephalitis

differential diagnoses when the neurological findings

(Ames, 1987).

and lumbar CSF tap yield pathognomic results. The

Other manifestations of bacterial involvement in

methodical clinical examination explores all aspects of

neurological disease include those caused by the exo-

the animal's presentation rather than attempting to fit

toxins of clostridial infections occurring elsewhere in

the clinical signs to a recognized condition/disease. For

the body, e.g. focal symmetrical encephalomalacia

example, the clinician may believe the calf described

(Buxton et al. , 1981) and tetanus, which are discussed above is suffering from bacterial meningoencephalitis

elsewhere. Also in this category are the thiaminolytic

because it is four days-old, dull and depressed – this

organisms that proliferate in rumen contents and are

description may equally apply to enterotoxigenic E.

implicated in polioencephalomalacia.

coli, starvation/hypothermia, polyarthritis, etc. The *diagnosis is not confirmed until a lumbar CSF tap is*

Protozoa (see p. 284)

taken and examined, when all potential diagnoses

except bacterial meningoencephalitis can be excluded.

Protozoan infections with Toxoplasma gondii and

Considerable confusion arose with the clinical recog-

Sarcocystis species have been implicated in neonatal

nition of bovine spongiform encephalopathy in the

necrotizing non-suppurative encephalomyelitis in

United Kingdom during the mid 1980s because practi-

calves (O'Toole & Jeffrey, 1987). Congenital sarcocys-

tioners could not assign the clinical findings to any

tosis infestation has been recorded as a cause of recum-

known disease and spurious diagnoses such as tumour,

bency in newborn calves. Severe coccidiosis in calves is

hepatic encephalopathy and chronic hypomagnesaemia

uncommonly associated with neurological disorder in

were commonplace. The accuracy of clinical diagnosis

Britain, although more widely reported in North

was approximately 85 per cent with a wide range of dis-

America. Pelvic limb paresis in yearling cattle pro-

eases incorrectly reported as BSE, including listeriosis.

gressing to tetraparesis over two to three days has

Bovine spongiform encephalopathy presents with clin-

been reported,

caused by Sarcocystis zurnii

ical signs of cerebral and cerebellar dysfunction with no

encephalomyelitis.

intrathecal inflammatory response (Scott et al. , 1989b); listeriosis shows the classical presentation of the

Nematodes

pontomedullary syndrome with an elevated protein

concentration in CSF and increased white cell concen-

The intermediate stage (Coeneurus cerebralis) of the

tration with predominance of large mononuclear cells

dog tapeworm Taenia multiceps may occasionally occur

(Scott, 1996). A methodical clinical examination should

in cattle in well-defined regions of Britain, but is much

readily differentiate these two common neurological

less common than the disease in sheep. The clinical

disorders of adult cattle in the UK.

signs are of a slowly progressive, space-occupying lesion

While the brain can be conveniently divided into six
in one cerebral hemisphere, circling to the affected side,
areas, each with a recognized neurological ‘syndrome’
proprioceptive deficits and contralateral blindness.
(Braund, 1985) only four syndromes concern the
veterinary practitioner: cerebral, cerebellar, ponto-
medullary (brainstem) and vestibular.

Neurological examination

Cerebral syndrome

A methodical neurological examination allows central
nervous system lesions to be localized to specific area(s)
Diffuse cerebral disease is common in ruminants, asso-
of the brain (Braund, 1985). The common diseases and
ciated with metabolic disease in adults and bacterial

meningoencephalitis in neonates. The cerebrum is con-
brainstem disease which is attributed to a lesion involv-
cerned with mental state, behaviour and, in conjunction
ing the ascending reticular activating system. Circling,
with the eye and optic (II) nerve, vision. Clinical signs
ipsilateral hemiparesis and proprioceptive defects are

which suggest cerebral dysfunction include blindness,

also common. Circling can be observed in diseases

but with normal pupillary light reflexes (II, III), com-

affecting the brainstem caused by involvement of the

pulsive walking, circling, constant chewing movements,

vestibulo-cochlear nucleus. Involvement of the facial

severe depression, dementia, yawning, head pressing,

nucleus results in ipsilateral facial nerve paralysis.

hyperaesthesia to auditory and tactile stimuli, and

Facial palsy is evident as drooped ear, drooped upper

opisthotonus. It is important to note that the clinical

eyelid (ptosis) and flaccid lip. Involvement of trigemi-

signs change as the disease condition progresses; for

nal nerve or the trigeminal motor nucleus results in

example, calves with bacterial meningoencephalitis

paralysis of the cheek muscles and decreased facial skin

may present with different clinical signs depending

sensation. Listeriosis is the classical brainstem lesion.

upon the duration of CNS infection.

Ipsilateral compulsive circling, sluggish gait, postural

deficits, deviation of the head (not a head tilt) and

Collection of CSF

depression with contralateral blindness are variably

seen in animals with unilateral cerebral lesions.

Collection of CSF forms an integral part of the clini-

cian's detailed neurological examination. Lumbar CSF

can readily be collected under local anaesthesia from

Cerebellar syndrome

cattle of all ages (Scott & Penny, 1993; Scott et al. , 1995).

The cerebellum is primarily concerned with fine coor-

While it may be preferable to collect cisternal CSF for

dination of voluntary movement. In cerebellar dys-

a more representative sample, this technique is inher-

function limb movements are spastic (rigid), clumsy and

ently more difficult to perform and is not without risk

jerky. Initiation of movement is delayed and may be

to the patient. Numerous studies in ruminant species

accompanied by intention tremors. Cerebellar disease

(Scott, 1992, 1995a, 1996) have shown that lumbar CSF

is characterized by a wide-based stance and ataxia

samples provide meaningful data which assist the clini-

(incoordination), particularly of the pelvic limbs but

cian in formulating a more specific diagnosis. Lumbar

with preservation of normal muscle strength. In addi-

CSF can be collected under local anaesthesia in the

tion to the ataxia, dysmetria may be observed with

standing animal. Cisternal CSF collection requires ap-

hypermetria the more common form observed in cere-

propriate restraint and, in many situations, either deep

bellar disease. Opisthotonus can occur in animals with

sedation or general anaesthesia.

severe lesions of the rostral cerebellum.

Collection of lumbar CSF is greatly facilitated when

the animal is positioned in sternal recumbency with

the hips flexed and the pelvic limbs extended alongside

Vestibular syndrome

the abdomen. In adult cattle that are ambulatory the

In growing cattle unilateral peripheral vestibular

lumbar CSF sample is collected from the standing

lesions are not uncommon. The major clinical signs

animal which must be suitably restrained in cattle

include ipsilateral (to the same side) head tilt, leaning

stocks which prevent lateral movement. The site for *and drifting sideways when walking. Circling may also*

lumbar CSF collection is the mid point of the lum-

be observed. Positional nystagmus may be depressed or

bosacral space which can be identified as the mid line

absent in animals with a vestibular lesion. There is spon-

depression between the last palpable lumbar dorsal

taneous horizontal nystagmus with the fast phase

spine (L6) and the first palpable sacral dorsal spine

directed away from the side of the lesion. There is fre-

(S2). The site must be clipped, aseptically prepared and

quently ipsilateral ventral strabismus (eye drop) which

1–2 ml of 2 per cent lignocaine solution injected subcu-

is exaggerated when the head is raised. Facial nerve

taneously. Sterile surgical gloves should be worn. A

paralysis is common in peripheral vestibular disease

guide to needle length and diameter (Scott, 1996) is

since both facial and sympathetic nerves fibres pass

included in Table 51.2.

close to the middle ear. In central vestibular disease the

nystagmus may be horizontal, vertical or rotary.

Table 51.2

Guide to needle length and gauge for lumbar CSF

sampling in cattle.

Pontomedullary (brainstem) syndrome

Calves <80 kg

1 inch 20 gauge

As most of the cranial nerve nuclei are present in the

Calves 100–200 kg

2 inch 19 gauge

brainstem, dysfunction is characterized by multiple

Cattle >200 kg

4 inch 18 gauge + internal stylet

cranial nerve deficits. Depression is also a key sign of

When the lumbosacral site has been surgically pre-

arachnoid space. The normal flow rate is one drop of

pared the needle is slowly advanced at a right angle to

CSF every 2 to 3 seconds. A steady flow of CSF is

the plane of the vertebral column or with the hub

obtained immediately following puncture of the arach-

directed 5–10° caudally. It is essential to appreciate the

noid mater in calves with meningoencephalitis, indicat-

change in tissue resistance as the needle point passes

ing increased CSF pressure. The use of a manometer

sequentially through the skin, subcutaneous tissue,

has no practical application in farm animal practice.

interarcuate ligament then the sudden 'pop' due to the

The analysis of lumbar CSF from a range of

loss of resistance as the needle point penetrates through

neurological disorders, and other conditions which

the ligamentum flavum into the epidural space. Once

present with abnormal mental state, is presented in

the needle point has penetrated the dorsal subarach-

Table 51.3.

noid space, CSF wells up in the needle hub within 2–3

seconds. There is no justification whatsoever in collect-

ing CSF from the ventral subarachnoid space. Between

General principles of treatment for

2–3 ml of CSF is sufficient for analysis and can be col-

CNS infections

lected by free flow from the needle hub or by gentle

syringe aspiration. Care must be taken not to dislodge

The important factors to consider in the treatment of *the needle point from the dorsal subarachnoid space*

central nervous system infections include:

when the syringe, with the seal already broken, is

• Bacterial pathogen;

attached to the needle hub. Sedation of the animal is

• Duration and extent of the disease process;

not usually necessary but intravenous xylazine (0.05–

• Ability of the selected antibiotic to penetrate the

0.1 mg/kg bodyweight) or diazepam (0.04 mg/kg body-

blood–brain barrier and achieve concentrations 10

weight) can facilitate positioning of the pelvic limbs in

to 30 times the minimum bactericidal concentration

recumbent animals. It is not necessary to compress the

in order to sterilize the CSF (Prescott & Baggot,

jugular veins to facilitate CSF collection.

1988; see also Chapter 61).

Samples of CSF are collected into EDTA containers.

The specific gravity value is determined using a

Supportive treatments include corticosteroids,

hygrometer. Many cerebrospinal fluid samples have

diuretics, dimethyl sulphoxide and non-steroidal anti-

first to be concentrated before CSF protein concentra-

inflammatory drugs (NSAIDs) e.g. flunixin meglumine,

tion can be determined using the pyrogallol method.

carprofen, meloxicam and ketoprofen. In addition,

White cell concentration in CSF is determined using a

certain situations necessitate appropriate intravenous

haemocytometer. Cytological examination of CSF is

and oral fluid replacement therapy to correct second-

facilitated when the sample is first concentrated by

ary acid–base and fluid disturbances.

cytospin. The sample is then air-dried and stained with

For an antibiotic to be effective in bacterial meningi-

Leishman stain and the differential white cell count

tis, it must penetrate into the CSF in sufficient concen-

based on a minimum of 20 cells. Further laboratory

tration to be bactericidal to the invading organism

testing, such as protein electrophoresis (Scott, 1993b),

(Lambert & Wall, 1991) and achieve CSF concentra-

adds little additional information and is rarely under-

tions 10 to 30 times the minimum bactericidal concen-

taken for cost reasons.

tration to sterilize the CSF (Sande, 1981; Prescott &

An assessment of CSF pressure can be made by

Baggot, 1988). Even with successful CSF antibiotic

determining the rate of CSF flow from the needle hub

penetration, the intrathecal defence mechanisms are

once the needle point has penetrated the dorsal sub-

inadequate to control bacterial infection and treat-

Table 51.3

Lumbar CSF results (median, range) for some common bovine CNS diseases.

Disease	**Number**	**Specific gravity**	**Protein (g/l)**	**White cells (¥109/l)**
Control	31	1.007 (1.006–1.011)	0.28 (0.06–0.73)	0.0125 (0.012–0.25)
Meningitis	17			

1.010 (1.007–1.017)

2.5 (0.5–7.1)

2.0 (0.012–12.6)

Listeriosis

12

1.009 (1.008–1.017)

1.69 (0.39–10.4)

0.3 (0.012–1.7)

Bovine viral diarrhoea

5

1.007 (1.006–1.010)

0.22 (0.09–0.24)

0.0125 (0.012–0.1)

Septicaemia

11

1.009 (1.007–1.011)

0.77 (0.19–2.04)

0.05 (0.01–0.2)

Acidosis

5

1.009 (1.007–1.011)

0.35 (0.2–1.3)

0.012 (0.012)

ment necessitates the use of bactericidal antibiotics

monocytogenes (Tuazon et al. , 1982). It is strongly (Landesman et al. , 1981; Del Rio et al. , 1983).

recommended that the first penicillin treatment is

The blood–brain barrier can be divided into the

administered intravenously. The minimum inhibitory

blood–brain and blood–CSF barriers, although some

concentration (MIC90) of penicillin G for L. monocyto-

researchers consider them functionally synonymous

genes has been quoted as 0.02 mg/ml (Prescott &

because extracellular fluid of the brain is in equilibrium

Baggot, 1988). While lumbosacral CSF penicillin G con-

with CSF. Morphologically, the blood–brain barrier

centrations between 0.09 and 1.02 mg/ml were achieved

comprises the continuous tight junctions (zonulae occlu-

in three cases of bacterial meningitis 48 hours after the

dens) of the endothelial cells which form the brain cap-

commencement of treatment of 44 000 iu/kg procaine *illaries. The permeability of the blood–brain barrier is*

penicillin b.i.d. (Scott & Sutton, 1992), the median CSF

dramatically increased by the inflammatory process,

protein concentration in those animals was higher than

whatever the cause (Oldendorf, 1975). The increased

values encountered in listeriosis cases (2.5 g/l compared

permeability of the blood–brain barrier in experimental

to 1.7 g/l), suggesting greater disruption of the blood–

meningitis models was in part caused by the separation

brain barrier. However, it is possible that the CSF peni-

of intercellular tight junctions of the cerebral micro-

cillin G concentrations achieved in brain tissue were

vascular endothelium which was augmented by the

considerably higher than those achieved within CSF.

presence of CSF leucocytes (Quagliarello et al. , 1986).

High dose penicillin G or oxytetracycline treatments

Few broad-spectrum bactericidal antibiotics are

have been reported to give a good prognosis for liste-

capable of penetrating the intact blood–brain barrier,

riosis cases provided the cattle are still ambulatory

but it has generally been assumed that the disruption of *when treatment commences (Rebhun & deLahunta,*

the blood–brain barrier, which occurs in bacterial CNS

1982). High dose penicillin treatment (44 000 iu/kg pro-

diseases, increases the degree of antibiotic penetration

caine penicillin b.i.d.) of cases of ovine listeriosis, where

(Barlow, 1991). Such increased permeability may be

the clinical diagnosis was supported by characteristic

sufficient to allow passage of antibiotics which achieve

lumbar CSF analyses, gave a 24 per cent success rate

minimum inhibitory concentrations within the CSF

(Scott, 1993a). It is possible that the optimum daily dose

(Rings, 1987), but few studies have been undertaken

rate of penicillin G to treat acute CNS infections could

in animals with naturally-occuring CNS infections to

be as high as 300 000 iu/kg; approximately 15 times the

support such assumptions.

normal dose rate. This dose rate is prohibitively expen-

Antibiotic penetration of the blood–CSF barrier

sive in most cattle except for the first day of treatment.

depends upon lipid solubility; the greater the degree of

The high cost of appropriate antibiotic therapy for

ionization of an antibiotic in plasma, hence reduced
infectious diseases of the CNS further emphasizes the
lipid solubility, the lower the penetration through
necessity of an accurate diagnosis before commencing
the blood–CSF barrier. Antibiotic penetration also
therapy. The use of conventional dose antibiotic
depends upon the degree of protein binding. Large
therapy is unlikely to prove effective in the treatment
molecular weight antibiotics, such as aminoglycosides,
of bovine listeriosis. Reports of successful treatment of
achieve very poor CSF concentrations even in the pres-
listeriosis with certain antibiotics administered at con-
ence of meningeal inflammation (Stone & Wise, 1991).
ventional dose rates raise doubts over the clinical diag-
As well as the selection of antimicrobial agent, there
nosis and whether the cattle were indeed suffering from
is considerable disagreement regarding the duration
a vestibular lesion, which would have responded well to
of treatment for CNS infections. Prescott and Baggot
such therapy.
(1988) quote the experimental findings of Tauber et al.

Active removal of penicillins from the CSF can be

(1987), that the single most important factor in achiev-

inhibited by probenicid. In horses the elimination half-

ing a favourable outcome for streptococcal meningitis

life of ampicillin was increased, and total body clear-

is the peak concentration of antibiotic in the CSF. Con-

ance reduced, following treatment with probenicid

versely, Rebhun and deLahunta (1982) recommended a

(Sarasola & McKellar, 1992). The extent to which

six week course of antibiotic treatment for bovine lis-

probenicid affects the clearance of penicillin from

teriosis. In farm animal practice the cost of antibiotic

bovine CSF is not known and requires further study

treatment is an important limiting factor in the animal's

before its use can be recommended as an adjunct to

treatment and high dose/short duration therapy is

penicillin therapy.

perhaps the best compromise in many situations.

Aminoglycosides

Penicillins

Gentamicin is rapidly bactericidal against many poten-

In man, penicillin and ampicillin are usually considered

tial Gram-negative organisms causing neonatal menin-

the antibiotics of choice for meningitis caused by L.

gitis but, as a polar antibiotic, is unable to cross the

blood–brain barrier, even during meningitis. This lack

Anti-inflammory agents

of penetration into the CSF led to intrathecal and

In certain neurological diseases, particularly polio-

intraventricular administration of aminoglycoside anti-

encephalomalacia and bacterial meningoencephalitis,

biotics for the treatment of meningitis in infants and

the control of cerebral oedema is an important factor

children, but this technique was associated with an

affecting prognosis (McGuirk, 1987). The increased

increased mortality rate. Intrathecal injections of gen-

intracranial pressure in bacterial meningoencephalitis

tamicin in the lumbosacral region failed to result in sig-

results from cerebral oedema, which may be a factor

nificant concentrations in ventricular CSF (Moellering

contributing to death, brain infarction and altera-

& Fisher, 1972) and, as a consequence, this technique

tions in CSF hydrodynamics. The development of

has not been practised for the treatment of bacterial

potentially-serious increased intracranial pressure is

meningoencephalitis in cattle.

indicated by coma, seizures, abducens nerve palsy, per-

sistent bradycardia and respiratory depression. The rec-

Chloramphenicol

ommended treatment for the control of cerebral

oedema is either 1–2 mg/kg dexamethasone given

Until withdrawal from the veterinary market in many

intravenously, 1–2 g/kg of dimethyl sulphoxide as a

countries, chloramphenicol was stated to be the anti-

10 per cent solution given intravenously or frusemide

biotic of choice for the treatment of bacterial menin-

1–2 mg/kg given intravenously (McGuirk, 1987).

goencephalitis (Rings, 1987) as it is capable of crossing

There are no comparative field investigations of cor-

the intact blood–brain barrier. In field studies 30 per cent

ticosteroid treatments in bovine CNS disease. While the

of calves responded to chloramphenicol and showed a *potential benefits of the concurrent use of dexametha-*

marked improvement within 24 hours and no relapses

sone with cephalosporin antibiotics have been demon-

occurred after five consecutive days' treatment (Scott

strated for the treatment of bacterial meningitis in

& Penny, 1993). There are no published studies of the

children, it is reported that there may be a number of

usefulness of florfenicol, a closely-related molecule, in

potential deleterious effects including a reduction in

the treatment of bacterial meningoencephalitis.

cellular immune function and reduced penetration of

antibiotics into CSF (Scheld & Brodeur, 1983).

Metronidazole

Metronidazole is highly lipid-soluble and capable of

Non-steroidal anti-inflammatory drugs (NSAIDs)

penetrating the blood–brain barrier and into brain

The potential application of NSAIDs such as flunixin or

abscesses. Unfortunately, this antibiotic is not licensed

ketoprofen in the treatment of LPS-induced intrathecal

for use in veterinary medicine in Britain and there are

reaction in bovine meningoencephalitis has not been *no data regarding its use in cattle with CNS infections.*

reported. Bacterial meningoencephalitis is commonly

In medicine, brain abscesses are frequently mixed

associated with septicaemia where intravenous NSAID

aerobic and anaerobic infections and in such situa-

administration would be of benefit in the treatment of

tions metronidazole is administered in conjunction with

septic shock. The analgesic properties of NSAIDs may

either penicillin or chloramphenicol.

also prove of benefit in the treatment of bacterial infec-

tions of the CNS. Therefore, there are a number of

indications for NSAID administration in calves with

Ceftiofur

bacterial meningoencephalitis, although this statement

Third generation cephalosporins are widely used for

is not supported by field results. The potential benefits

the treatment of bacterial meningoencephalitis in

of NSAID therapy in more chronic CNS infections

medicine but there are no data relating to the field use

have not been investigated.

of ceftiofur in cattle. As chloramphenicol is no longer available to many veterinary practitioners,

ceftiofur would present a logical choice for bacterial

Dimethyl sulphoxide (DMSO)

meningoencephalitis.

There is no licensed DMSO product for veterinary use

in Britain, but analytical quality DMSO has been used

in the treatment of cattle with CNS dysfunction. DMSO

Trimethoprim–sulphonamide

has many properties, including reduction of cerebral

Trimethoprim–sulphonamide has been recommended

oedema and free radical scavenging (Brayton, 1986),

for the treatment of bacterial meningoencephalitis

but special handling precautions preclude its use in

and listeriosis in cattle but there are no published field

most situations encountered in general practice. In

studies.

veterinary practice, DMSO administration would most

likely be restricted to the very valuable calf suffering

Pathology

from bacterial meningoencephalitis.

In-utero BVD/MD virus infection around 90 to 130

days' gestation causes cerebellar hypoplasia and, less

Intravenous/oral fluids

commonly, hydranencephaly. The BVD/MD virus in-

vades the fetus and infects the developing germinal

Severe dehydration can be corrected by the intravenous

cells of the cerebellum and destroys the Purkinje cells

infusion of isotonic saline. Metabolic acidosis, which is

in the granular layer. Microphthalmia is uncommon.

commonly encountered in listeriosis cases caused by

saliva loss, can be corrected by regular administration

of sodium bicarbonate by oro-gastric tube.

Signs and diagnosis

Cerebellar disease is characterized by a wide-based

Summary

stance and ataxia (incoordination), particularly of the

Successful treatment of bovine CNS infections necessi-

pelvic limbs, but with preservation of normal muscle

tates a rapid and accurate diagnosis. Cerebrospinal fluid

strength. In addition to the ataxia, dysmetria may be

collection is a simple procedure and visual inspection *observed with hypermetria more commonly observed*

can reveal much useful information, particularly in

in cerebellar disease. Coarse intention head tremors

neonatal calves with bacterial meningoencephalitis,

are frequently observed, particularly during periods of

permitting a rapid diagnosis and prompt treatment.

excitement such as feeding times. Opisthotonus can

Encephalitis lesions, such as those caused by listeriosis,

occur in calves with severe lesions of the rostral cere-

result in minor changes in the CSF and laboratory

bellum. Such calves present in lateral recumbency with

examination is necessary. Ceftiofur, a third genera-

rigid extension of the neck and thoracic limbs and

tion cephalosporin antibiotic, and trimethoprim–

flexion of the pelvic limbs with clinical signs noted soon

sulphonamide are indicated for the treatment of bacte-

after birth.

rial meningoencephalitis but field data are limited. The

In addition to the cerebellar signs, calves with hydran-

usefulness of florfenicol in the treatment of bacterial

encephaly exhibit blindness and depression/somno-

meningoencephalitis has not been reported but this mol-

lence (dummies). In extensively-managed beef herds,

ecule is sufficiently similar to chloramphenicol to justify

calves with hydranencephaly may not be detected until

its use and clinical evaluation in the treatment of

the calf is several months old. Often the demeanour

bacterial meningoencephalitis in calves. Penicillin G

of such calves is attributed to another cause and such

(>44 000 iu/kg b.i.d.) is the treatment of choice for listecalves are not presented for veterinary examination.

riosis and peripheral vestibular lesions, with the first

Cerebellar dysfunction in young calves may be the

treatment administered intravenously. Insufficient data

first manifestation of active BVD/MD infection in the

are available to comment upon the efficacy of either cor-

herd and it is important that these clinical signs are

ticosteroids or NSAIDs for the treatment of central

identified so that control measures can be introduced

nervous system bacterial infections.

to prevent further losses.

Treatment and prevention

Specific diseases

There is no treatment for cerebellar hypoplasia and

affected calves should be culled because they pose

Cerebellar hypoplasia/hydranencephaly

a risk to seronegative/unvaccinated breeding cattle

The cerebellum is the most common CNS site for in-

in the herd. Biosecurity is an important aspect of

utero insult. The cerebellum is primarily concerned with herd health which is frequently overlooked on British

fine coordination of voluntary movement. In cerebellar

farms and worldwide. Increasingly, more British

dysfunction, limb movements are spastic (rigid), clumsy

dairy and beef herds will become self-contained

and jerky. Initiation of movement is delayed and may

with high health status, but in the meantime introduc-

be accompanied by intention tremors.

tion of disease by carrier animals is a major concern.

Depending upon the health status of the herd, pur-

chased cattle should either be screened for BVD/MD

Aetiology

antibody and antigen status upon arrival or vaccinated

Cerebellar hypoplasia/hydranencephaly can be the

during the quarantine period. Establishment of a

result of an autosomal recessive condition or caused by

BVD/MD-free herd is presently included in numerous

in-utero infection with bovine virus diarrhoea/mucosal health schemes packages in Britain but is not without

disease (BVD/MD; see p. 855) or Akabane virus.

risk from introduction of infection with carrier-status

cattle and from adjacent herds via direct contact, water

within two days or so, although this may be difficult to

courses, carrion, etc (Chapter 57).

visualize against the surface of the brain. Over the cere-

bral hemispheres the exudate is largely confined to

the fissures. The brain is swollen in the acute stages of

Bacterial meningoencephalitis (see p. 251)

disease and may be so severe to cause displacement of

Bacterial meningoencephalitis most commonly affects

the cerebellum into the foramen magnum and coning.

calves 3 to 8 days old and is associated with poor im-

munoglobulin status and high bacterial challenge in the

Signs and diagnosis

environment (Rings, 1987). The early clinical signs of

lethargy, depression and failure to suck rapidly progress

The early clinical signs include lack of suck reflex,

to hyperaesthesia, opisthotonus and death (Scott &

depression, failure to follow the dam (beef calves) and

Penny, 1993). Compulsive wandering and head pressing

weakness (Green & Smith, 1992; Scott & Penny, 1993).

have also been reported (Jamison & Prescott, 1987) but

Fever is not a consistent feature. Affected calves stand

are less common. The prognosis is poor despite intensive

with the neck extended and the head held lowered.

antibiotic treatment and supportive care.

Flexion of the neck is painful and may result in vocal-

ization. In the absence of appropriate treatment the calf

becomes increasingly weak over the next 6 to 12 hours

Aetiology

with an altered gait, and may be unable to stand. Dili-

Bacteraemia, with subsequent localization within the

gent stockmanship is important when checking young

meninges, results from failure of passive antibody trans-

beef calves because the early clinical signs of lethargy
fer (Jamison & Prescott, 1987) and high levels of bac-
and weakness can easily be overlooked, especially when
terial challenge in the calf's environment. The disease
the calves are lying together in a group during adverse
is more common in those calves born indoors in unhy-
weather conditions. Depression and poor appetite
gienic calving boxes than in those born of cows at
are more readily detected in individually-penned dairy
pasture. Failure of the calf to ingest colostrum equiva-
calves. As the disease progresses there is lack of menace
lent to 7 per cent of its bodyweight within the first six
response and dorsomedial strabismus. Episcleral injec-
hours of life may be caused by calf and/or dam factors.
tion is often present at this stage. Depression progresses
Dystokia, weakness, nerve damage, overcrowded
to stupor, but the calf is hyperaesthetic to auditory and
calving accommodation, udder shape, dirty teats and an
tactile stimuli which may precipitate seizure activity
overly-anxious dam may all contribute to poor/delayed
during handling for intravenous antibiotic injection.

sucking behaviour by the calf. Dystokia, nerve damage,

Opisthotonus is observed during the agonal stages of

hypocalcaemia and weakness may result in prolonged

disease approximately 24 to 36 hours after clinical

recumbency of the dam. Poor nutrition, short dry period

signs are first noted. There may be evidence of infec-

and mastitis cause reduced colostrum accumulation in

tion involving other organ systems such as hypopyon,

the udder. Heifers' colostrum contains 25 per cent less

polyarthritis, diarrhoea and omphalophlebitis. Infarcts

colostrum than cows' colostrum. Bacteraemia may

in the liver and kidney are frequently observed at

result via the oropharyngeal route, respiratory tract,

necropsy. In a study of ten calves with meningo-

gastrointestinal tract or umbilicus. Escherichia coli and encephalitis, three calves had polyarthritis, three

Streptococcus spp . were the more common isolates calves showed hypopyon and two calves had

from lumbar CSF of calves with meningoencephalitis

omphalophlebitis, but none exhibited diarrhoea (Scott

(Scott & Penny, 1993).

& Penny, 1993).

The important differential diagnosis for bacterial

meningoencephalitis is metabolic acidosis resulting

Pathology

from diarrhoea of 2 to 3 days' duration. Septicaemia

Septic foci are prone to localize within meningeal

presents with similar clinical findings to meningo-

vessels and are either rapidly walled off or may lead to

encephalitis as the meninges are a common site

diffuse suppurative meningitis. A combination of syn-

for bacterial colonization in neonatal calves.

ovial, meningeal and intraocular localizations is almost

Lumbar CSF is readily collected under local anes-

invariably of streptococcal origin; coliform infections

thesia from depressed or stuporous calves. Calves with

rarely cause endophthalmitis (Jubb & Huxtable, 1993).

bacterial meningoencephalitis frequently have a CSF

Once bacteria gain access to the leptomeninges there is

protein concentration above 1.0 g/l (deLahunta, 1983)

little resistance to spread and the inflammatory process

and greater than 2.0 g/l (Green & Smith, 1992; Scott & becomes diffuse.

Penny, 1993). The normal CSF protein concentration is

In the first day or so the meninges are opaque and

<0.3g/l with a white cell concentration less than 0.012 ¥

hyperaemic with pus accumulating in the basal cisterns

109/l. There is also a marked increase in CSF total white

cell count in the order of 100-fold and a change in the

Septicaemia

predominant white cell type from lymphocyte to neu-

Calves with septicaemia frequently present with

trophil (neutrophilic pleocytosis). These CSF changes

clinical signs similar to bacterial meningoencephalitis

cause increased turbidity of the sample which is visible

because the meninges are simply one site for localiza-

upon gross CSF inspection and affords the veterinary

tion of blood-borne pathogens. The clinical course of

surgeon an immediate diagnosis. One to two days' delay

septicaemia is generally peracute and affected calves

in detailed laboratory examination of the CSF would

may be found either dead or in extremis within 12 hours.

undoubtedly result in death of the calf if left untreated.

Other sites of infection such as eyes (hypopyon), *However, routine antibiotic therapy of all diarrhoeic*

gut (diarrhoea), joints (polyarthritis) and umbilicus

calves is not recommended because many antibiotics

(omphalophlebitis) may be identified. Foci in the lung,

slow the mitotic rate of enterocytes, which is an impor-

kidney, liver and spleen are only detected following

tant factor in recovery from viral causes of diarrhoea.

necropsy.

Bacteriological culture of lumbar CSF is often unre-

warding and is unnecessary because of the sporadic

nature of the disease and its causation by opportunist

Enteric infections causing metabolic disturbances

organisms.

Sequestration of water and electrolytes in the gut

lumen, often without overt signs of diarrhoea, caused

Treatment and prevention

by the heat stable enterotoxin produced by K99 strains

of E. coli, can result in recumbency in one to four day-A successful outcome necessitates early detection of

old calves which often rapidly progresses to coma and

abnormal calf behaviour by the client and prompt clin-

death. Older calves with severe metabolic acidosis
ical diagnosis by the veterinary practitioner supported
secondary to enteric viral infection, typically 6 to 14
by visual inspection of lumbar CSF. Any delay in vet-
days old, are weak, unable to stand and depressed with
erinary diagnosis and implementation of treatment
deterioration of mental state to stupor. It can prove
has a hopeless prognosis, but prompt treatment with
difficult to undertake a thorough neurological exami-
chloramphenicol achieved a 30 per cent recovery rate
nation, e.g. menace response and spinal reflexes, in such
(Scott & Penny, 1993). Few broad-spectrum bacterioci-
depressed or stuporous calves to differentiate such
dal antibiotics are capable of penetrating the intact
calves from early cases of bacterial meningoencephali-
blood–brain barrier, although it is commonly assumed
tis. Collection of lumbar CSF on the farm reveals a
that the disruption of the blood–brain barrier, which
normal clear sample which allows immediate differen-
occurs in bacterial CNS diseases, increases the degree
tiation from bacterial meningoencephalitis (Scott &

of antibiotic penetration. This increased membrane

Penny, 1993).

permeability may allow sufficient passage of antibiotics

Treatment of acidotic calves with intravenous

to achieve minimum bactericidal concentrations

isotonic saline solution, spiked with 400–600 mEq of

(MBC) within the CSF. A peak CSF antibiotic con-

bicarbonate, is successful with a rapid improvement in

centration 10 to 30 times the effective MBC may be

demeanour and ability of the calf to stand within 6 to

more important than the maintenance of CSF antibiotic

12 hours.

MBC (Prescott & Baggot, 1988) and emphasizes that

high dose antibiotic therapy is indicated as soon as pos-

Brain abscess

sible after the onset of clinical signs of bacterial CNS

infection.

Neurological signs of a brain abscess typically appear

It is reported that the best treatment for Gram-

in 4 to 12 week-old calves following localization of

negative bacillary meningitis in man is the third *neonatal bacteraemia. Extension of infection through*

generation cephalosporins, in particular cefotaxime

the calvarium following infection of the frontal sinus

(Cherubin & Eng, 1986; Feldstein et al. , 1987) but no as a consequence of dehorning, while reported in the

data could be found in the veterinary literature relating

literature, is uncommon in Britain.

to the use of ceftiofur in the treatment of infectious

bovine neurological diseases under field conditions.

Aetiology

Chloramphenicol is no longer permitted in food-

Arcanobacterium pyogenes is the most common isolate

producing animals in many countries; there are no field

from brain abscesses.

studies which report the clinical efficacy of its closely-

related successor florfenicol. Other antibiotics which

Pathology and pathogenesis

could be administered for bacterial meningoencephali-

tis include trimethoprim–sulphonamide combination or

Brain abscesses are usually of haematogenous

ceftiofur.

origin. Most cerebral abscesses are small and track

inward to the white matter rather than out to the

this condition from cervical spinal lesions which often

meninges.

appear at around 6 to 12 weeks old.

Signs and diagnosis

Unilateral middle ear infections/vestibular

Affected calves are usually dull and depressed with a

syndrome (see also p. 252)

sluggish gait. These calves have a poor appetite and as

a consequence appear ill thriven. Approximately 90 per

The vestibular system helps to orientate the animal in

cent of efferent nerve fibres cross at the optic chiasma;

its environment with respect to gravity, and maintains

therefore animals with a left-sided cerebral abscess

position of the eyes, trunk and limbs during movement.

are blind in the right eye but the pupillary light reflex

Unilateral middle ear infections (otitis media) are not

is normal. As the abscess continues to grow the animal

uncommon in growing calves and yearlings and usually *becomes increasingly depressed, sometimes over many*

arise from ascending infection of the eustachian tube,

months. Ipsilateral compulsive circling may lead to the

often following respiratory disease.

calf becoming stuck with its head in the corner of the

pen or fence. Once in this position, the calf may stand

Signs and diagnosis

motionless for long periods of time, sometimes hours.

The gait is often sluggish and ataxic. There is ipsilateral

The major clinical sign in unilateral peripheral vestibu-

deviation of the head towards the flank, but this altered

lar disease is an ipsilateral head tilt of 5° to 10° down

head carriage must not be confused with a head tilt.

to the affected side. There may be loss of balance,

The calf may display ipsilateral postural deficits such as

leaning and movement/circling toward the affected

knuckling of the fetlock joints. In most cattle there

side. When walking, cattle tend to drift toward the

are no cranial nerve deficits. There is frequently an

affected side. During the early stages of unilateral

increased protein concentration and elevated white cell *peripheral vestibular lesions there is spontaneous hor-*

concentration in lumbar CSF, which reflect any accom-

izontal nystagmus with the fast phase away from the

panying suppurative meningitis.

side of the lesion. There is often ipsilateral ventral devi-

ation of the eye (eye drop), which is exaggerated when

the head is raised. The facial nerve travels close to the

Treatment and prevention

middle ear and facial palsy is often seen in conjunction

Treatment with high dose penicillin (minimum 44 000

with otitis media.

iu/kg b.i.d.) for 10 days may halt progression of the

In central vestibular disease the nystagmus may be

abscess but the long term prognosis is very poor. Pre-

horizontal, vertical or rotary, and there may be ipsilat-

vention of bacteraemia in neonatal calves necessitates

eral limb weakness. Depression indicates involvement

ensuring adequate passive antibody transfer and redu-

of the reticular formation.

cing environmental bacterial challenge by maintaining

It is important to differentiate vestibular lesions from *good hygiene standards in the calving accommodation.*

listeriosis because of the different treatment regimens

and control measures.

Cerebellar abiotrophy (postnatal

degeneration)

Treatment and prevention

Cerebellar abiotrophy is an inherited condition which

The bacterial infection responds well to five to seven

has been reported in Holstein calves in the UK. The

consecutive days' treatment with 44 000 iu/kg procaine

cerebellar abiotrophies are considered to be familial

penicillin s.i.d. The condition occurs sporadically and

and degenerative but not congenital. Similar clinical

there are no specific control measures.

signs have been reported in a six month-old Limousin

cross heifer caused by selected cerebellar degeneration

(Woodman et al. , 1993; see also pp. 178, 893).

Polioencephalomalacia

(cerebrocortical necrosis, CCN)

Signs and diagnosis

(see also p. 261)

Clinical signs of pelvic limb ataxia, especially when

This is a sporadic condition that affects young growing

turning quickly, wide-base stance and hypermetria

cattle. It is characterized clinically by dullness, bilateral

appear from around six weeks of age and are slowly

lack of menace response, dorsomedial strabismus

progressive over many months, leading eventually to

and hyperaesthesia to auditory and tactile stimuli,

recumbency by one year of age. The preservation of

progressing over days to lateral recumbency and

strength and chronicity of the condition differentiates

opisthotonus.

Aetiology

of menace response and dorsomedial strabismus.

Affected animals are hyperaesthetic to tactile and audi-

Healthy ruminants obtain their requirements from thi-

tory stimuli. As the disease progresses animals often

amine synthesized by the rumen flora. Free thiamine is

head press into corners and there is frequent bruxism

readily absorbed and is actively phosphorylated to *(teeth grinding). Twitching, muscular tremors and inter-*

thiamine pyrophosphate (TPP). The brain is critically

mittent opisthotonus are evident, followed by recum-

dependent on carbohydrate for energy and TPP has

bency and clonic convulsions with intermittent periods

a coenzyme role in decarboxylation of a-ketoacids

of spasticity and terminal flaccidity. Untreated cattle die

for entry into the tricarboxylic acid cycle. Thiamine

within three to five days.

pyrophosphate is also a coenzyme in the transketolase

Diagnosis of PEM is based primarily on the history,

reaction of the hexose monophosphate shunt and the

clinical signs and response to intravenous thiamine

alternative, glycolytic, pentose phosphate pathway.

administration. Laboratory tests are of equivocal value

Outbreaks of PEM have been described in cattle, and

and response to treatment of early cases is commonly

sheep (Low et al. , 1996), when fed diets high in sulphur.

employed as a diagnostic indicator by practitioners.

Changes in lumbar CSF include a slightly increased

Pathology

protein concentration, but this result is of little diagnostic value.

The brain usually appears pale and swollen with flattened gyri, which in the frontal, dorso-medial and parietal regions often show a patchy, bilaterally

Treatment and prevention

symmetrical, yellow discoloration. There is swelling of

The response to large doses (10–15 mg/kg) of thiamine

the cingulate and parahippocampal gyri, which may

hydrochloride given intravenously early in the disease

herniate beneath the tentorium cerebelli. The posterior

is usually evident within 24 hours. The thiamine should

vermis may have herniated through the foramen

be repeated within 4 to 6 hours, then twice daily for

magnum and appear necrotic. The cut surface of the

three consecutive days. Full clinical recovery may take

cerebrum reveals that the necrotic cortical tissues have

one week. Intravenous administration of dexamethasone (1.0 mg/kg) at first presentation may aid recovery.

a laminar configuration and may have separated from

the underlying white matter. When viewed in ultravio-

Prevention of PEM involves the maintenance of
let light (wavelength 365 nm) affected regions of cortex
normal rumen fermentation with adequate dietary fibre
have a bright white autofluorescence, which has been
ensuring production of volatile fatty acids which curtail
attributed to ceroid lipofuscin (Little, 1978).
the growth of thiaminase-producing organisms. The
Histologically, there is increased prominence of cap-
efficacy of metaphylactic thiamine injections during
illary endothelium (neovascularization) and dilatation
an outbreak of dietary sulphur-induced PEM in cattle
of perivascular spaces with occasional small perivas-
remains equivocal, although this did appear to halt
cular haemorrhages. Astrocytes and neurones show
appearance of new clinical cases in housed lambs (Low
hydropic changes and nuclear pyknosis, which proceeds
et al. , 1996).
in time to a laminar necrosis. In well established cases
there is a massive influx of macrophages into the
necrotic areas and adjacent leptomeninges.

Listerial encephalitis *(see also p. 156)*

Listerial encephalitis is the result of infection of the brain substance with Listeria monocytogenes.

Signs and diagnosis

PEM occurs sporadically, affecting weaned calves and

Aetiology

young feedlot cattle. It is associated with diets low in fibre, although cases have occurred in animals grazing

Listeria monocytogenes is a microaerophilic Gram-

lush aftermath. Under these circumstances, changes

positive, flagellated coccobacillus which is present in a

occur in the rumen flora that permit multiplication of

wide range of moist environments and may cause

micro-organisms such as Bacillus thiaminolyticus and

disease in man and a variety of domestic species.

Clostridium sporogenes, both of which synthesize thi-

Listeriosis occurs sporadically in cattle, where most

aminase type 1, thereby inducing thiamine deficiency.

cases are associated with feeding poorly fermented

During the early stages of PEM there is frequently a

silage during the winter months. Cattle show a similar

brief period of diarrhoea before nervous signs appear.

age incidence to sheep with the majority of cases affect-

Affected animals are dull and may isolate themselves

ing two to three year-olds, although cattle appear much

from others in the group. There is high head carriage

less susceptible to listeriosis than sheep. Rarely are

and affected cattle may stagger. There is bilateral loss

outbreaks of listeriosis encountered in cattle.

Pathology

tation is uncommon in cattle with listeriosis. Hypoglos-

sal nerve dysfunction leading to tongue paralysis

The pathogenesis of listerial encephalitis involves

and protrusion is more commonly observed in ovine

centripetal passage of the organism along branches of

listeriosis.

the trigeminal nerve from minor breaches in the buccal

The course in untreated cattle lasts 10–14 days,

mucosa. Intracranial pathology initially consists of a

progressing to coma.

small focus of necrosis in the lateral part of the pons,

A moderate increase in CSF protein concentration *which is associated with activation of microglial cells*

in the range 0.8 to 2.0 g/l is observed in meningo-

and astrocytes followed by an influx of monocytes and

encephalitis caused by L. monocytogenes (Rebhun &

a few neutrophils. The initial focus may be unilateral

deLahunta, 1982).

but thereafter (intraneural) spread results in micro-

Listeriosis is frequently associated with the feeding

abscesses forming bilaterally in the mid brain and

of silage and may be suspected on the basis of the

lower medulla.

clinical signs and supported by findings of an elevated

CSF protein concentration and monocytic pleocyto-

Signs and diagnosis

sis. Vestibular lesions (p. 896), lead poisoning (p. 944),

The rectal temperature of affected cattle is within the

brain abscess, BSE (p. 909) and nervous acetonaemia

range 38.5 to 39.2°C. There is reduced appetite with a

(p. 795) should be considered amongst the differential

gaunt appearance, marked fall in milk production in

diagnosis.

lactating cattle and weight loss. Loss of saliva leads to

Isolation of the causal organism from the brain may

rumen impaction, causing abdominal pain manifest as

require extended periods of ‘cold enrichment’, but the

an arched-back stance and frequent bruxism.

neurohistopathology is usually sufficiently characteris-

As most of the cranial nerve nuclei are present within

tic to permit firm diagnosis.

the brainstem, ascending infection of the trigeminal

nerve by L. monocytogenes is characterized by multiple Treatment and prevention

unilateral cranial nerve deficits, depression and, in some

cases, circling to the affected side. Ipsilateral hemipare-

Penicillin or trimethoprim-sulpha remain the antibi-

sis may also be present and should be differentiated

otics of choice for listeriosis. Oxytetracycline is not con-

from ataxia observed in cattle with BSE.

sidered an appropriate antibiotic for listeriosis because

Involvement of the trigeminal nucleus results in

of its large molecular size, although good results have

paralysis of the cheek muscles and decreased facial skin *been claimed. A minimum dose rate of 44 000 iu/kg sensation. Facial palsy is evident as drooped ear, procaine penicillin injected intramuscularly b.i.d. must drooped upper eyelid (ptosis) and flaccid lip. Occa- be considered for at least 10 days in addition to 44 000 sionally, there may be paralysis and protrusion of the iu/kg penicillin G injected intravenously b.i.d. on the tongue. Exposure keratitis may result from paralysis of first day. Penicillin dose rates as high as 300 000 iu/kg the orbicularis oculi muscle. Loss of cheek and lip have been recommended for the first day of antibiotic muscle tone result in drooling of saliva from the therapy because it is essential to exceed MICs by 10 to affected side of the mouth. Depression is attributed to 30 times to achieve a successful outcome.*

a lesion in the ascending reticular activating system. A Loss of saliva may lead to dehydration and metabolic head tilt toward the affected side is an inconsistent acidosis. Care must be taken when replacing fluids by finding. Circling can be observed with involvement of orogastric tube because contraction of the rumen

the vestibulocochlear nucleus. Cattle frequently display
caused by anorexia of some days' duration may result
a 'propulsive tendency' and may be found with the head
in passive regurgitation of these fluids around the oro-
forced through a gate, under a feed trough or wedged
gastric tube. The amount of fluids administered in this
across the front of a cubicle. Indeed, dairy cows have
way should be restricted to 15 to 25 litres four to six
barged through the milking parlour under the cows
times daily. Transfaunation with rumen liquor from a
ahead of them causing chaos and often falling into the
healthy cow may promote rumen function and aid
milking area; such behaviour in previously quiet cattle
recovery.
led to misdiagnosis of BSE. Caution must be exercised
There are no published studies which have reported
when cattle are found with the head trapped under a
the efficacy of prophylactic antibiotic administration in
feed barrier, etc., because casual examination may
the face of an outbreak of listeriosis, but such epide-
attribute the facial palsy to trauma but this would not

miology is unusual in cattle.

explain the unilateral loss of jaw tone and facial skin

Listeriosis occurs sporadically in cattle and is pre-

sensation.

vented by management practices which ensure the

Loss of cranial nerves IX, X and XII function results

making and storage of high quality silage. Soil contam-

in stertorous breathing and dysphagia, but this presen-

ination is limited by rolling grass fields at the beginning

of the growing season. Good fermentation is guaran-

macrophages. In cattle with long survival periods these

teed by cutting grass at an early growth stage

cortical lesions may be extensive, and similar lesions

(digestibility value >72) when it contains a high fer-

may be present also in the thalamus and hypothalamus,

mentable sugar content, and the use of various silage

medulla and spinal cord.

additives, whether sugars, organic acids or bacterial cul-

tures. Compaction of the silage clamp is important to

Signs and diagnosis

expel all air followed by air-tight sealing to prevent
aerobic bacterial multiplication. Poor quality or spoiled
Irrespective of the rate of uptake of lead, the clinical
silage should be discarded. Prevention of listerial
signs of intoxication are sudden in onset and charac-
encephalitis by vaccination is not an established proce-
terized by behavioural changes. During the early stages
dure in ruminant species.
of lead poisoning affected cattle become isolated and
depressed. These animals are hyperaesthetic to tactile
and auditory stimuli and may show muscle twitching,

Lead poisoning *(see also p. 944)*

especially of the palpebral muscles. Affected cattle are
Cattle, through their innate curiosity, indiscriminate
blind and may head press forcibly into corners and
feeding habits and relative susceptibility to lead, are the
against walls. The disease progresses and cattle become
species most commonly poisoned by lead compounds.
frenzied, bellow, stagger and crash into obstacles. There
Lead poisoning in cattle is characterized by an acute
may be signs of abdominal pain including kicking at the

encephalopathy.

abdomen and frequent bruxism (teeth grinding). Bloat

is often seen and attempts to alleviate this problem

often precipitate frenzy. Death may occur suddenly or

Aetiology

within days.

The common sources of lead include discarded storage

The diagnosis of lead poisoning is suspected on the

batteries, flaking old lead-based paint, putty, asphalt

basis of clinical signs and the presence of a source of

roofing materials and used motor engine oil. Intoxica-

lead. Confirmation depends upon the histopathological

tion may result from a single large dose of lead or from

findings and the chemical determination of the concen-

ingestion of smaller amounts over a long period of time.

tration of lead in tissues. In kidney and liver concen-

In both forms the neurological signs are acute in onset

trations >4 ppm wet weight and blood values in excess

and similar in type.

of 0.3 ppm are considered diagnostic.

Pathology

Treatment and prevention

The severity of neuropathological change in lead poi-

Cattle with severe neurological signs of some days'

soning correlates more closely with survival time than

duration probably have extensive neuropathological

with the concentration of lead in the tissues, being most

changes and are unlikely to respond to treatment.

severe in cases that survive longest.

However, if a source can be identified, in-contact

Grossly, the brain appears pale and slightly swollen

animals at risk from a single large dose may be

with flattened gyri, but without herniation of the hip-

drenched orally with magnesium sulphate (500–1000 g)

pocampal gyrus beneath the tentorium or cerebellar

to precipitate and remove lead from the alimentary

coning (cf. PEM). Some gyri, most commonly those in

tract and injected with calcium disodium edetate at 110

the occipital region, show a yellow discoloration. The

mg/kg by slow intravenous infusion on alternate days

cut surface may show separation of these yellow zones

for three treatments. The similarity of the pathological *of cortical tissue from the underlying white matter at*

changes to those of PEM has encouraged the use of

the tips of the gyri with actual cavitation in the deeper

thiamine (10–15 mg/kg intravenously) along with

cortical laminae. In cases of longer survival these

EDTA therapy and is reportedly beneficial. Control of

changes may extend to the tips of almost all gyri and

convulsions proves very difficult because drugs such as

extend down the sides of the convolutions (Christian &

diazepam have such a short half-life in cattle. Chloral

Tryphonas, 1971).

hydrate sedation may be attempted but this drug is not

Histologically, the earliest changes in affected gyri

licensed for use in cattle in Britain. Pentobarbitone

comprise swelling and prominence of capillary

is frequently used to control seizure activity in cattle

endothelial cells, which is sometimes referred to as

with acute hypomagnesaemia and could be used in

neovascularization. Swelling of astrocytes, and fine

emergency situations for lead poisoning to control

microvacuolation of the neuropil, also occur at an early *convulsive episodes.*

stage, advancing to spongy transformation with

Prevention is a matter of good management, not

necrosis of neurones, malacia and infiltration by

allowing access by cattle to sources of lead.

Thromboembolic meningoencephalitis

tation reveals widespread wheezes. Pleural friction rubs

(TEME) *(see also p. 240)*

are described in some reports but significant pleurisy

severely restricts movement of the underlying visceral

Under conditions of stress or intercurrent disease a ful-

pleura such that no sounds are generated by this

minating Haemophilus somnus bacteraemia may occur

localized pathology. Localization of bacteria within

with disseminated intravascular coagulation. Throm-

joints causes joint effusion and swelling with associated

boemboli may lodge in meninges, brain, muscles and

severe lameness which may result in recumbency.

joints causing depression, blindness and recumbency

Retinal haemorrhages, hyphaema and hypopyon have *with muscular weakness. Retinal haemorrhages may be*

also been described in some cattle following localiza-

found.

tion of the bacteraemia.

Aetiology

Treatment and prevention

Thromboembolic meningoencephalitis (TEME) is a

Prompt detection of early neurological signs is impor-

fulminating Haemophilus somnus bacteraemia. TEME

tant to ensure early antibiotic therapy; therefore cattle

is a significant problem in feedlot cattle in North

should be regularly inspected by trained stockmen

America associated with stresses of weaning, long jour-

during the high risk period following introduction of

neys (often thousands of miles), co-mingling in auction

groups of cattle to the feedlot. H. somnus is susceptible markets and the feedlot, changes in diet, husbandry,

to a wide range of antibiotics in vitro including oxytet-altitude and nutrition, and processing on admission to

racycline, penicillin and ampicillin; however, oxytetra-

the feedlot. Processing is a collective term used to

cycline does penetrate the blood–brain barrier well.

describe a range of procedures undertaken on admis-

Penicillin offers the most cost effective treatment at

sion to the feedlot and may include castration, dehorn-

dose rates greater than 44 000 iu/kg b.i.d., which should

ing, anthelmintic treatment, ectoparasite treatment,

be administered for at least five consecutive days.

vaccination against a wide range of viral and bacterial

Vaccination is not undertaken in Britain due to the

pathogens including parainfluenza 3 virus, bovine

sporadic nature of H. somnus infections where respira-respiratory syncytial virus, infectious bovine rhino-

tory disease is the more common clinical presentation.

tracheitis, Mannheimia haemolytica and Pasteurella Prophylactic injection with long-acting oxytetracycline

multocida, implantation with hormonal growth pro-

and in-feed medication have been described in North

moters and ear tagging. These procedures and stresses

American feedlot situations, but these are of doubtful

render the weaned beef calf susceptible to a wide

use. Greater attention must be paid to the sourcing

range of respiratory tract and other infections. Infection

of feedlot cattle. Preconditioning including weaning,

with H. somnus probably occurs through the respira-
dehorning, castration, vaccination and introduction of
tory tract from asymptomatic carriers to non-infected
concentrate feedstuffs must be undertaken at least
cattle. Bacteraemia results in thrombosis in the brain-
three weeks before sale and transportation. Cattle
stem, spinal cord, synovial membranes, pleurae and
sourced directly from ranches have a much lower inci-
lungs. Outbreaks of TEME are often preceded by
dence of respiratory disease than those from auction
respiratory disease, which is all too common in large
markets or sale barns. Unfortunately, such sensible
feedlots where morbidity rates may exceed 40 per cent
husbandry practices will not be undertaken until a sig-
despite prophylactic antibiotic administration during
nificant premium is paid for such calves. The use of
processing.
prophylactic antibiotic administration on admission to
feedlots in North America requires urgent review.

Signs and diagnosis

The neurological signs of TEME are sudden in onset

Aujeszky's disease

and death may occur within 36 hours of onset. Affected

cattle are pyrexic (40 to 42°C), anorexic and depressed.

Aujeszky's disease is a herpes virus infection principally

The depression may extend to somnolence and has led

of pigs, which can be transmitted to most other mam-

to the term 'sleeper calves'. Proprioceptive deficits are

malian species including cattle.

commonly observed and affected cattle appear ataxic.

Cattle may be found recumbent in the pen with the

Aetiology

head averted against the chest and are unable to raise

themselves. Blindness, nystagmus and strabismus are

Infections in cattle are generally sporadic and result

variably present. Terminally, there is opisthotonus and

from contact with infected pigs, foodstuffs or other

coma. Lesions are also present in the lungs and auscul-

materials contaminated with virus. The disease in cattle

is extremely severe with self-mutilation necessitating

and transmitted by the bite of an infected animal. It is *immediate slaughter for welfare reasons.*

manifested by irritability, mania, hydrophobia and

paralysis. It is usually fatal, although recoveries have

Pathogenesis and pathology

been documented.

Infection in cattle is generally by the oronasal route.

Centripetal intra-axonal transport of virus causes first a

Aetiology

severe ganglioneuritis followed by meningoencephalitis

or myelitis. Lesions are most severe in the olfactory lobe,

The causal agent is a delicate rhabdovirus readily

hippocampus and cerebellum, whereas infection of a

destroyed by disinfectants and desiccation. It causes

spinal peripheral nerve results initially in a segmental

pathological changes only in nervous tissue. Rabies

myelitis. Grey matter is principally affected with degen-

occurs worldwide except in certain island territories

erative changes in nerve cells and astrocytes in which

(Australia and New Zealand) and a few countries from

multiple, small, granular, eosinophilic, intranuclear inclu-

which it has been eradicated, such as the British Isles *sion bodies may be found. The inflammatory response is*

and Scandinavia. In the western hemisphere the infec-

essentially non-suppurative and is characterized by

tion is endemic in dogs, foxes, wolves, skunks, raccoons

lymphocytic perivascular cuffing and focal microgliosis.

and bats of several species. Infection is transmitted with

the bite of a rabid animal.

Signs and diagnosis

The clinical course is short, rarely extending beyond 48

Pathology and pathogenesis

hours in adult cattle, whilst calves may die without

obvious prior signs of illness. Usually, however, there is

Cattle are very susceptible to rabies and become

a brief period of excitement with high fever, bellowing,

infected, usually on the hindquarters or limbs, from the

and aggressive behaviour accompanied by trembling,

bite of a rabid fox, dog or bat. Following local replica-

hyperpnoea, salivation and compulsive licking of the

tion, virus travels centripetally in the axoplasm of a

nostrils. Intense pruritus of the neck, trunk or hind legs

peripheral nerve to reach the spinal cord and thence to *is accompanied by frantic efforts to relieve the itch to*

the brain. En route it replicates in neurones. From the the point of self-mutilation. Affected animals may

brain, in the later stages of the incubation period, the

become bloated and there is incoordination and, termi-

virus passes centrifugally along nerves to the salivary

nally, recumbency, convulsions and coma.

and lachrimal glands and is present in their secretions.

Except in calves, the clinical signs are usually

Rabies virus is highly neurotropic and viraemia is

distinctive enough for a provisional diagnosis of

minimal or absent.

Aujeszky's disease to be reached. Confirmation is

dependent upon demonstration of the characteristic

Signs and diagnosis

neuropathology or virus isolation from nervous tissue.

The incubation period of rabies in cattle varies from

Treatment and prevention

about two to three weeks to several months. Clinical

signs classically occur in two distinct forms, the mild

There is no effective treatment and affected cattle are

paralytic or dumb form and the furious form, depend-
killed immediately for welfare reasons. Prevention is
ing upon the pathogenicity of the strain of virus. In par-
dependent upon control of disease in the pig popula-
alytic rabies there may be partial loss of sensation in the
tion. Attenuated and inactivated vaccines are available
hind legs, knuckling of the fetlocks, locomotor weakness
and are effective in preventing disease in pigs.
and paralysis of the tail. Flaccid dilatation of the anus
However, they will not protect pigs from infection with
may be accompanied by straining and passage of air in
field virus, which will replicate and be shed for some
and out of the rectum. Drooling of saliva and yawning
time after infection. Thus control in pigs must he
are common features. The entire clinical course lasts
through the establishment and maintenance of clean
about one week and is terminated by recumbency,
closed herds by serological testing and slaughter. This
generalized paralysis with death probably due to
has been undertaken as a successful national campaign
respiratory failure. In the furious form the animal is

in Britain. The disease in cattle and sheep is notifiable

hyperaesthetic and sexually excited. It bellows hoarsely

in Britain and in some other countries.

and becomes violently aggressive towards people, other

animals and inanimate objects. Purposeful attacks,

***Rabies** (see Chapter 70)*

however, are frustrated by rapidly progressive incoor-

Rabies is a neurotropic viral disease that can affect all

dination and ataxia. Death occurs quickly following

warm-blooded animals. The virus is excreted in saliva

recumbency and paralysis.

Cattle are normally 'end hosts' with respect to rabies,

Some change in exposure of cattle to infection in

although human infection may follow manual exami-

1981–82 resulted in BSE appearing in the cattle popu-

nation of the oral cavity in which virus in saliva is

lation in 1985–86. A change in rendering practices with

inoculated into scratches caused by teeth.

an end to hydrocarbon fat extraction of rendered mate-

Clinical diagnosis of rabies is difficult, especially in *rial (NB the scrapie agent is lipotrophic) has been sug-*

those countries in which it rarely occurs. The possibil-

gested as an important factor in BSE epidemiology.

ity of rabies should be borne in mind in the differential

Subsequent studies have demonstrated that operating

diagnosis of bloat, nervous acetonaemia (p. 795), lis-

procedures in many rendering plants during the early

terial encephalitis (p. 904) and bovine spongiform

1980s would have been incapable of destroying the BSE

encephalopathy (see below). Rabid cattle invariably die

agent. To date there are no experimental data which

and fluorescent antibody staining of impression smears

demonstrate that scrapie can be transmitted to cattle by

from appropriate parts of the CNS will establish the

the oral route.

diagnosis rapidly.

BSE was made a notifiable disease in the United

Kingdom on 21 June 1988. Compulsory slaughter with

destruction of carcass (incineration since 1991) with

Treatment and prevention

compensation was introduced on 8 August 1988. On 18

No treatment of clinical cases should be attempted, nor

July 1988 the 'ruminant feed ban' was introduced which

should they be euthanased prematurely as this may

prohibited the feeding of ruminant-derived protein to

prejudice the post-mortem diagnosis. Post-exposure

ruminants. Brain, spinal cord, tonsil, thymus, spleen and

vaccination is a routine procedure in man, but in cattle

intestine (specified bovine offals) of cattle over six

clinical disease and death would probably occur before

months old were no longer permitted to be sold for

an effective immunity had time to develop.

human consumption. In September 1990, specified

bovine offals were banned from all other animal feeds.

The introduction of a ban on the inclusion of

Bovine spongiform encephalopathy (BSE)

ruminant-derived protein in cattle rations in July 1988

Bovine spongiform encephalopathy (BSE) was first

has resulted in a reduction in the incidence of BSE in

reported in the United Kingdom in 1987 as a previously

younger cattle since 1991 (Wilesmith & Ryan, 1993)

unrecognized spongiform encephalopathy affecting *which continued thoughout the 1990s and into the 2000s.*

dairy cows (Wells et al. , 1987). While the first documented BSE cases were reported in 1987, retrospective

Aetiology

case record studies suggest BSE occurred as early as

1985. Some cattle practitioners suggest that clinical

All the epidemiological evidence presently available

cases occurred sporadically over the previous 25 years,

strongly suggests that the geographically widespread

but there is no supporting evidence in limited studies of

incidents of BSE are not the result of cow-to-cow trans-

archived pathology material.

mission but conform to the concept of a single source

Bovine spongiform encephalopathy is a new member

epidemic, with concentrate feedstuffs containing animal

of a group of subacute transmissible spongiform

protein as the probable source. Many farms have expe-

encephalopathies characterized by certain physical

rienced only one BSE case although many cattle were

properties, including long incubation period but

exposed to the same feed source. In some herds *relatively short clinical course which is invariably fatal,*

outbreaks have involved the majority of animals in a

progressive neurological signs with rapid deterioration

particular cohort (Winter et al., 1989). It is possible that terminally, spongiform change visible under light

the transmissible agent was very unevenly distributed

microscopy and presence of scrapie associated fibrils

in the feed because, unlike sheep, host genotype

on electron microscopy. All members are transmissible

appears to have little effect upon either susceptibility

to laboratory animals and many other species by

or the length of the incubation period.

intracerebral injection and other routes. This group

An alternative postulate to the feeding of scrapie-

includes scrapie of sheep and goats, chronic wasting

contaminated diets as the origin of BSE is that of

disease of mule deer, transmissible mink encephalo-

spontaneous prion mutation giving rise to histopatho-

pathy of ranched mink, Kuru and Creutzfeldt–Jakob

logical changes and clinical disease of a spongiform

disease(CJD) of man and new variant Creutzfeldt–

encephalopathy of cattle (Scott et al. , 1995). The origin Jakob disease (v-CJD) of man.

of the BSE epidemic could, therefore, have been the

The postulate that BSE resulted from the ingestion

inclusion of infected material from ‘spontaneous cases’

of meat and bone meal contaminated with a scrapie-

of BSE subsequent to changes in the rendering process,

like agent (Morgan, 1988) has been supported only indi-

and not contamination of cattle rations with the scrapie

rectly by epidemiological data (Wilesmith et al. , 1988).

agent. The simultaneous widespread appearance of

BSE in the UK could be explained, in part, by the sale

neurones of certain brain stem nuclei (Wells et al.,

and movement of meat and bone meal concentrate

1987). There is fine vacuolation of the ground substance

derived from cattle. In this respect it is interesting to

whilst neurones and neurites develop one or more well-

note that the origins of chronic wasting disease of mule

defined intracytoplasmic vacuoles, which may distend

deer and elk have not been determined. It is possible *the cell body and processes. The nuclei principally*

that a scrapie-like disease did occur in cattle from

involved are the dorsal nucleus of the vagus, the nucleus

another species (not sheep) and until transmission

of the solitary tract, the reticular formation, the vestibu-

studies demonstrate classical BSE in cattle after feeding

lar and spinal trigeminal nuclei and in the mid brain the

scrapie-contaminated feedstuffs this lack of conclusive

red and oculomotor nuclei.

evidence remains a serious concern.

An additional pathological characteristic of the trans-

Reports of transmissible mink encephalopathy

missible spongiform encephalopathies is the presence

(TME) in ranched mink in Wisconsin, fed from 95 per

in extracts of brain prepared for electron microscopy of

cent downer or dead dairy cattle and a few horses

fibrils 100–500 nm in length that are known as scrapie

(Marsh & Hartsough, 1985), raise the question whether

associated fibrils (SAF).

an unrecognized spongiform encephalopathy also

occurs sporadically in cattle in the USA. However,

Signs and diagnosis

experimental exposure of mink to BSE produced an

encephalopathy with minimal resemblance to TME

Bovine spongiform encephalopathy affects cattle 2 to

(Robinson et al. , 1994). BSE has recently (2003) been 13 years of age, with peak prevalence in the four to five

confirmed in Canada. The worldwide sporadic occur-

year age group. Early epidemiological investigations

rence of CJD, with no obvious reservoir of infection or

(Winter et al., 1989) revealed that affected cattle could mode of transmission except for iatrogenic cases, may

have had access to feedstuffs containing ruminant-

support the postulate that spontaneous changes of the

derived protein only during the first four months of life.

prion, eventually resulting in clinical disease, do occur.

The disease is less common in beef suckler herds

The existence of scrapie in many countries of the world

because most replacement heifers are reared naturally

with large sheep populations means that sporadic cases

with their dam and receive no concentrate feeding.

resulting from spontaneous changes in the prion would

Disease has been commonly reported in beef herds *not be differentiated from those scrapie cases originat-*

where replacement heifers were sourced from dairy

ing from horizontal or vertical transmission of the

herds, these cattle having received supplementary con-

scrapie agent. In countries that are scrapie-free, such

centrates containing ruminant-derived protein during

as New Zealand and Australia, ‘spontaneous cases’ of

calfhood. In dairy cattle the incidence within breeds

scrapie, occurring at approximately 0.1 per 100 000,

appears to be a reflection of population size, the major-

could easily be overlooked due to the extensive system

ity of cases occurring in Friesian/Holstein cattle.

of agriculture and unwillingness of sheep producers to

Early signs include chronic weight loss and decreased

employ veterinary services for single sheep. In this

milk yield over four to six weeks (Aldridge et al. , 1988; respect it is widely regarded that the majority of BSE

Scott et al. , 1988a, 1989a). Affected cattle are often cases have been overlooked in France and Germany for

isolated from other cattle in the field. Cows stand with

political as well as animal health reasons.

an arched (roached) back and a wide-based stance.

Experimental transmission of spongiform

There is frequent independent ear movement with the

encephalopathy after intracerebral injection or oral

ears often directed backwards towards the poll. The

dosing with brain homogenate derived from cattle with

abdomen appears drawn up with sunken sublumbar

BSE has been confirmed in sheep and goats (Foster

fossae consistent with reduced appetite. During the

et al. , 1993) and by a combination of intravenous and latter stages, affected cattle spend very little time rumi-intracerebral injection to cattle (Dawson et al. , 1990).

nating. There is a profound change in attitude; affected

Intracerebral injection of calves with strains of scrapie

cattle become anxious, apprehensive and hyperaes-

agent from five flocks in four states in the USA pro-

thetic to tactile, auditory and visual stimuli. When trot-

duced neurological signs, brain lesions and distribution

ting there is marked pelvic limb hypermetria and ataxia,

of prion protein distinct from BSE (Cutlip et al. , 1994), but normal muscle strength. When in a group, BSE

but these differences could be explained, in part, by

cattle frequently push other cows along with vigorous *strain variation in scrapie and route of infection.*

head butting. Cows have considerable difficulty when

encountering obstacles such as steps, ramps and narrow

gateways and will frequently attempt to jump over low

Pathology and pathogenesis

objects such as slurry scrapers and run through gate-

The pathological changes consist of bilaterally symmet-

ways, etc. As the condition progresses cattle frequently

rical degenerative changes affecting the neuropil and

slip, especially when turning on wet concrete, have great

difficulty raising themselves and excoriation of the carpi

clinical presentation is claimed to be not dissimilar to

results (Scott et al. , 1995). When confined for veterinary BSE (Jeffrey & Wilesmith, 1996). The incidence of

examination,

stimulation often provokes violent

disease appears to be more common in beef suckler

kicking (ballism) with the pelvic limbs and bellowing.

cows with a mean age of eight years old compared to

Repetitive contractions of individual muscle groups *four to five years old in BSE. The disease is more com-*

(myoclonus) are frequently observed in the shoulder

monly reported in Scotland than England, despite

region, ventral neck and proximal regions of the pelvic

approximately similar numbers of beef herds.

limbs. There is rapid progression of clinical signs and

Brainstem chromatolysis and degeneration of brain-

cattle may become weak and recumbent within two to

stem neurons are found in all cases and are generally

ten weeks of clinical signs first being detected.

associated with a florid and severe lesion (Jeffrey &

Differential diagnoses include listeriosis, hypomag-

Wilesmith, 1996). Scrapie-associated fibrils have not

nesaemia, space occupying lesions, lead poisoning,

been found in the brains of cattle with idiopathic brain-

organophosphorous poisoning, hepatoencephalopathy

stem neuronal chromatolysis nor is there evidence of

and rabies. In common with the other transmissible

disease specific PrP (prion protein).

spongiform encephalopathies, there is no immune

The cause of this disease remains unknown but a *system response to infection; therefore routine*

toxic or metabolic insult has been suggested (Jeffrey &

biochemical investigations serve only to exclude other

Wilesmith, 1996).

diseases from the differential diagnosis list. There is no

intrathecal inflammatory response (Scott et al. , 1989b),

Sporadic bovine encephalomyelitis

which assists the clinician to exclude conventional

(SBE, Buss disease)

infectious agents from the differential diagnoses (e.g.

listeriosis). Confirmation of diagnosis depends upon a

Sporadic bovine encephalomyelitis is a generalized

neuropathological examination.

inflammatory disorder of serous membranes, synoviae

and vascular endothelium. It has no specific neurotro-

pism, the neurological signs being a consequence of

Treatment and prevention

inflammation of the mesodermal elements in the CNS.

There is no effective treatment for BSE. Notification

and elimination of affected animals have been in

Aetiology

operation in the UK since 1988. The occurrence of

Sporadic bovine encephalomyelitis is a specific disease

approximately 1700 BSE cases per annum 12 years

of cattle and buffalo caused by a strain of Chlamydia

after the implementation of the ban on inclusion of

psittaci. The disease has been observed in the USA,

ruminant-derived protein in ruminant rations suggests

Eastern Europe, the Middle East, Japan, Australia and

that vertical/maternal transmission of BSE does occur.

South Africa.

A maternal effect resulting in an increased number of

BSE cases in the progeny of affected cattle compared

to controls was demonstrated (Wilesmith et al. , 1997), Pathology and pathogenesis

but the study design was flawed because the progeny

The disease is usually fatal within four to five days. The

were probably exposed to dietary BSE. While the

gross post-mortem findings include a serofibrinous

control measures adopted for BSE control, and human

peritonitis, pleurisy and pericarditis. A serofibrinous

safety, were closely modelled on data from scrapie *exudate is also found over the surface of the brain,*

research, regulatory authorities failed to take account

especially the cerebellum and medulla. Histological

of the possibility of vertical/maternal transmission and

examination of the brain reveals a predominantly histi-

cull all progeny of confirmed cases. Such short-term

ocytic and plasma cell infiltration of the meninges.

monetary expediency has proved extremely costly. Off-

spring of affected cattle are now culled in the UK.

Signs and diagnosis

Calves less than six months old develop a staggering,

Idiopathic brainstem neuronal

stiff gait with circling and stumbling. Affected calves are

chromatolysis of cattle

dull and depressed and may exhibit muscle tremors.

Idiopathic brainstem neuronal chromatolysis of cattle

About 70 per cent of infected animals recover slowly.

has numerous clinical features similar to BSE (Jeffrey

Clinical diagnosis of SBE may be confirmed by rising

& Wilesmith, 1992) and 8 to 27 cattle with this

titres of group-specific chlamydial antibody in comple-

condition have been mistakenly slaughtered annually

ment fixation or enzyme-linked immunosorbent assay

(Jeffrey & Wilesmith, 1996). The consistent clinical

(ELISA) tests in the live animal or by isolation of the

signs include tremor, weight loss and ataxia, but the

organism from brain and lymph nodes.

Treatment and prevention

the lower limb joints. Stimulation of the skin over the

thoracic wall and flank with a blunt object produces a

Successful therapy depends upon treatment early in the

normal local response of muscle contraction (pannicu-

course of the disease using high dosages of tetracycline

lus reflex). In the case of a spinal lesion the skin caudal

(50 mg/kg s.i.d.) for five to seven days.

to the affected area of the cord has a reduced (hypal-

gesic) response, with a possible increased (hyperaes-

thetic) response cranial to the spinal lesion.

Spinal cord lesions

The presence of a spinal lesion at the level of the

Spinal cord lesions, whether focal or diffuse, are less *reflex arc results in a lack of muscle contraction in*

common in cattle than sheep but present the veterinar-

response to stimulation. Denervation of the effector

ian with a diagnostic challenge as they may result

muscle results in flaccid paralysis with atony (lower

from a wide range of aetiologies including vertebral

motor neuron disease). A spinal lesion cranial to the

body abscess, extradural abscess, trauma, protozoan

reflex arc removes the normal controlling inputs from

(encephalo-) myelitis and, in those countries where

higher centres via the upper motor neurons and results

enzootic bovine leucosis virus is prevalent, neoplasia.

in exaggerated responses and spastic paralysis (upper

Bacteraemia occurring during the neonatal period

motor neuron disease).

occasionally results in vertebral body abscess and

extradural abscess formation causing clinical signs in

two to four month-old calves. The neurological signs are

Cervical spinal cord C1–C6

frequently sudden in onset despite the chronic nature

The pelvic limbs are more severely affected than the *of the compressive spinal cord lesion.*

thoracic limbs. There is a range of muscle weakness pro-

Accurate localization of a focal spinal cord lesion

gressing to complete paralysis. It is important to differ-

is important to enable further investigation such as

entiate weakness from ataxia, which can be achieved by

radiography; surgery is rarely, if ever, undertaken in

pulling sideways on the tail as the animal is walking.

ruminant species. Localization of the lesion(s) relies

Weak animals can easily be pulled to the side, may

upon the assessment of simple spinal reflex arcs which

stumble and fall over. Spinal reflexes are increased

indicate the presence of either upper or lower motor

(upper motor neuron signs to all four limbs) but this

neuron signs in the affected limbs.

aspect of the neurological examination may prove dif-

The simple spinal reflex arc comprises three neurons:

ficult in adult cattle which are not recumbent. Cervical

pain may be evident as rigidity of the neck with resent-

• *The sensory neuron (stretch receptor in tendon)*

ment to forced movement of the head. Typically, the

• The internuncial neuron

neck is extended and the head held lowered. With

• The lower motor neuron (contraction of limb

severe lesions the animal may be unable to maintain

muscle)

sternal recumbency but will make frequent attempts to

While the reflex motor response to sensory stimuli

raise itself from lateral recumbency.

can occur without the input of higher centres, the higher

motor centres exert control of voluntary movement via

the upper motor neurons which synapse on the lower

Cervico-thoracic spinal cord C6–T2

motor neuron. Flexor (withdrawal) reflexes can be

Spinal cord lesions involving the brachial intumescence

determined by pinching the interdigital skin or apply-

may result in equally severe deficits in both the thoracic

ing pressure across the coronary band with resultant

and pelvic limbs. There is ataxia and weakness of all

unconscious flexion and withdrawal of the stimulated

four limbs. Thoracic limb reflexes are reduced (lower

limb. Recognition of pain indicates integrity of the *motor neuron signs) with increased pelvic limb reflexes*

spinal cord above the reflex arc. To determine tendon

(upper motor neuron signs).

'jerk' reflexes for the thoracic limb, the triceps tendon

is tapped 2–5 cm proximal to its attachment onto the

olecranon process. The normal response is extension of

Thoraco-lumbar spinal cord T2–L3

the elbow joint. The pelvic limb is gently supported in

Animals with a spinal cord lesion caudal to T2, but

the mid femoral region and the middle patellar liga-

cranial to L3, have normal thoracic limb function but

ment lightly tapped. The normal reflex is extension of

upper motor neuron signs affecting the pelvic limbs.

the stifle joint.

Affected cattle frequently adopt a dog-sitting posture

Lesions affecting the upper motor neurons result in

with normal thoracic limb function (Holmes et al. , 1989) conscious proprioceptive deficits evident as changes in

but with the pelvic limbs extended alongside the

flight of the foot and abnormal placement of the foot

abdomen. The dog-sitting position should immediately *on the ground, resulting in stumbling and knuckling of*

alert the clinician because ruminants raise themselves

using their pelvic limbs before the thoracic limbs. The

Treatment and prevention

withdrawal and patellar reflexes are increased and

Traumatic lesions in calves following dystokia, indi-

there are conscious proprioceptive deficits and paresis

cated by xanthochromic CSF collection, may improve

of the pelvic limbs. The panniculus reflex may be useful

within two weeks with good management and dedi-

when attempting to localize a thoracolumbar spinal

cated care with frequent turning of the calf. Treatment

lesion.

of extradural and vertebral body abscesses is hopeless

(Scott et al. , 1991) and affected calves should be

euthanased for welfare reasons.

Lumbo-sacral spinal cord L4–S2

Prevention of bacteraemia in neonatal calves dictates

A lesion involving the sacral outflow results in lower

high hygiene standards in the calving accomodation and *motor neuron signs of the pelvic limbs with superficial*

ensuring timely ingestion of adequate levels of good

sensation loss,

paresis and reduced or absent

quality colostrum by the calf within the first six hours

reflexes.

of life. Repeated dipping of the umbilical remnant in

strong veterinary iodine BP during the first 12 hours

will prevent omphalophlebitis. Control of salmonellosis

Sacrococcygeal spinal cord: cauda equina syndrome

in calves from endemically-infected herds can be

The cauda equina syndrome results from lesions involv-

attempted by prior vaccination of the dam and feeding

ing the sacrococcygeal spinal cord and results in hypo-

stored colostrum during the first two weeks of life.

tonia, hypalgesia and reduced reflexes of the tail, anus

and perineal region, bladder atony and dilation of the

rectum.

Once a lesion has been localized to a specific section

References and further reading

of the spinal cord a number of ancillary tests can be per-

formed, including radiography and myelography, to

Aldridge, B.M., Scott, P.R., Clarke, M., Will, R. & McInnes, A.

define the lesion precisely. Before such examinations

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are undertaken, which are expensive and may require

and extended neurological investigation. In Proceedings of XV World Buiatrics Congress, Palma da Majorca, October general anaesthesia to perform, considerable useful

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information can be obtained relatively easily and

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lumbar CSF.

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of protein and some inflammatory cells into the CSF. If

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the lesion also causes spinal cord compression this will

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tion of CSF protein concentration within the lateral

Berry, P.H., Howell, J. McC., Cook, R.D., Richards, R.B. & ventricles. Such compression results in accumulation of

Peet, R.L. (1980) Central nervous system changes in

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Chapter 52

Ocular Diseases

P.G.C. Bedford

Introduction 917

affected as adults and failure to produce effective

Anomalies of the orbit and globe

917

vaccines means that this disease will continue to inflict

Anophthalmia 917

severe economic loss for as long as young cattle are

Microphthalmia 918

managed intensively. Disease of epidemic proportions

Multiocular defects

918

occurs all the year round and, while the aetiological

Cyclopia 918

controversy may continue, the term IBKC generally

Strabismus 918

embraces all keratoconjunctivitis of infectious nature in

Nystagmus 918

Orbital neoplasia

918

this species. Similarly, ocular squamous cell carcinoma

Anomalies of the eyelids

918

of probable heritable nature in breeds with reduced

Congenital/paranatal defects

918

palpebral pigmentation continues to account for a high

Trauma 918

carcase condemnation rate and runs second only to

Congenital porphyria

919

lymphosarcoma in terms of condemnation for neoplas-

Diseases of the conjunctiva and cornea

919

tic reasons. At the other end of the scale there are many

Epibulbar dermoid

919

congenital, inherited and acquired defects that tend to

Infectious bovine keratoconjunctivitis (IBKC)

919

escape diagnosis on the basis of there being no unto-

Infectious bovine rhinotracheitis

921

ward effect on function, no associated discomfort or

Endothelial dystrophy

922

pain and no necessity to treat. Were cattle subjected to

Neoplasia 922

the same degree of scrutiny as the dog, then it is likely

Diseases of the uveal tract

923

Congenital anomalies

923

that the literature would indicate a similar incidence of

Uveitis 923

disease. In one study of 500 cattle of all ages, almost 20

Neoplasia 923

per cent overall demonstrated ocular anomalies of one

Disease of the lens

923

sort or another, the incidence ranging from 3 per cent

Diseases of the retina and optic nerve

924

in young cattle to in excess of 70 per cent in the older

Congenital defects

924

individuals (Amman, 1968). Examples of this kind of

Inflammation 924

survey work in cattle are few and far between, but

Hypovitaminosis A

925

general interest in ophthalmology as a refined discipline

Male fern optic neuropathy

925

in today's veterinary scenario will probably stimulate

Arthrogryposis 925

further ophthalmic studies in animals that are primarily

Progressive retinal degeneration

925

produced for food purposes in our society.

Glaucoma 925

Introduction

Anomalies of the orbit and globe

Ophthalmic disorders in cattle are more common than

Congenital and acquired defects of these structures

is generally believed, but it is only those that are of con-

both occur, some congenital anomalies being inherited

siderable economic importance that generally receive

while others are probably environmental in origin (see

much attention. Infectious bovine keratoconjunctivitis *also p. 180). The acquired defects are due to trauma,*

(IBKC), variously known throughout the world as New

infection and neoplasia.

Forest disease, pinkeye, contagious ophthalmia and

blight, is undoubtedly the commonest and most impor-

Anophthalmia

tant ocular disease that occurs in this species. In the

USA alone it is estimated that IBKC is responsible for

Absence of the optic vesicle means that an eye cannot

an annual loss in excess of £25 million (Punch & Slatter,

develop. Histologically, primordial ectodermal and

1984). Approximately three times as many calves are

mesodermal tissues cannot be identified. The condition

is rare and is often confused with the type of microph-

also seen in adult cattle, with various causes including

thalmia in which there has been some early differen-

brain tumour and abscess formation. It has been noted

tiation of the optic vesicle but no subsequent maturation.

as an occasional feature early in the course of BSE.

Microphthalmia

Orbital neoplasia

Variable degrees of development can be seen, ranging

Retrobulbar and periorbital lymphosarcoma can result

from minimal differentiation of ocular tissue to the

in exophthalmos and possible squint. The lesions may

development of a small but otherwise normal eye.

be seen unilaterally or bilaterally. Squamous cell carci-

Other ocular anomalies may also be present, however,

noma of the membrana nictitans may invade the orbital

and persistent pupillary membrane (PPM), aniridia,

tissues to produce a similar clinical picture.

cataract and neuroretinal fold and rosette formation

may be seen in association with microphthalmos. Like

anophthalmia, the condition is rare in cattle, but inher-

Anomalies of the eyelids

itance has been postulated (Gilmore, 1957) and it has

been described in calves with vertebral column defor-

Congenital/paranatal defects

mation (Leipold & Huston, 1968).

Unlike other species, inherited and non-inherited con-

genital palpebral defects are few and far between in

Multiocular defects

cattle. Eyelid colombomata and agenesis are of rare

Bilateral congenital blindness due to multiocular defects

incidence. Although primary conditions in sheep, both

not involving microphthalmos has been recorded in

entropion and ectropion occur most commonly as

Jersey calves (Saunders & Fincher, 1951). The defects

secondary defects in cattle and are associated with

are mainly related to the lens, with microphalmia,

microphthalmia, blepharitis, keratoconjunctivitis and

ectopia lentis and cataract being seen in association with

trauma. Correction of the cause alleviates the lid dis-

iridaemia. A recessive mode of inheritance has been

tortion except where there is palpebral or orbicularis

suggested, but subsequent literature contains no further

oculi damage and where cicatrization has occurred.

references to this condition in this breed.

Congenital supernumerary openings of the proximal

part of the nasolacrimal duct and the canaliculi at the

medial canthus have been described in calves, heredi-

Cyclopia

tary predisposition or intra-uterine dacryocystitis being

The development of one eye in calves is extremely

the suggested possible aetiology.

rare (Plate 52.1), but the condition has been induced

teratogenically in sheep.

Trauma

Laceration of the eyelid occurs infrequently, but when

Strabismus *(see p. 181)*

the palpebral fissure is involved repair is essential. Such

Bilateral convergent squint (esotropia) has been

wounds left to granulate or inadequately sutured may

described as a recessively inherited defect in Jersey

result in distortion of the margo-intermarginalis,

cattle, and it is probably inherited in Shorthorn and

and secondary entropion, secondary ectropion and an

Friesian cattle too (Willoughby, 1968; Bedford, pers.

incomplete blink can result in conjunctival or corneal

obs.). A degree of exophthalmos may or may not be

disease. Delayed closure is complicated by the problem

additionally present. The condition is usually noticed at *of wound contraction. Repair is easily effected using*

four to eight weeks of age (Plate 52.2a) and the degree

manual restraint and the same seventh nerve block as

of convergence increases until the sixth or seventh

that used in disbudding and dehorning can be employed

month when only sclera presents within the palpebral

should blepharospasm be a problem. Such wounds may

fissure (Plate 52.2b). Impaired vision gives way to total

require debridement, but the removal of tissue should

blindness, and attempts at corrective surgery may be ill

be avoided whenever possible. The sutures are placed

perceived in the presence of possible optic nerve,

at two levels (Fig. 52.1). Tarsal plate and subconjuncti-

central visual pathway and visual cortex anomalies.

val tissue are first repaired without penetrating the

palpebral conjunctiva, and the knots are buried in the

substance of the eyelid such that no suture material

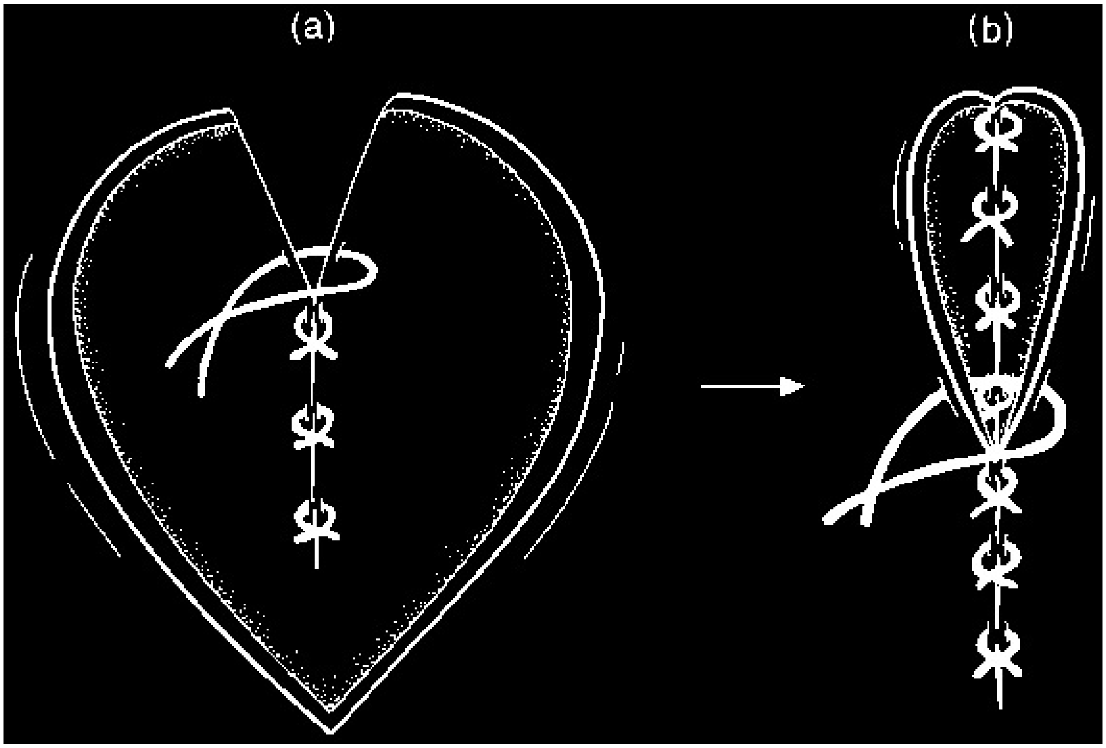
Nystagmus

can cause corneal irritation. The margo-intermarginalis

Nystagmoid movement of the globe is most commonly

must be accurately reformed, the first suture ensuring associated with congenital or paranatal blindness. It is

precise apposition at this level. The second row of



and conjunctival inflammation or they physically interfere with effective blinking and lid closure. Removal is then advocated, and topical and regional anaesthesia can be complemented by using the auriculopalpebral nerve block. The lesion must be removed in entirety to prevent recurrence. While a suprascleral lesion is easily excised, care is required with the superficial keratectomy needed to remove the corneal dermoid.

Infectious bovine keratoconjunctivitis

(IBKC, New Forest eye, pinkeye)

Fig. 52.1

Repair of an eyelid wound by two-layer closure. (a)

Aetiology

Tarsal plate and subconjunctival tissue apposed; (b) subcutis

This disease has been recognized for at least 100 years

and skin apposed.

(Billings, 1889) since when it has demonstrated both

common incidence and worldwide distribution. It is

highly contagious, and outbreaks of epidemic propor-

sutures involves the subcutis and skin, and single inter-

tions can affect grazing herds during the summer and

rupted sutures are used to ensure accurate repair and

autumn months, and housed cattle the whole year

reduce the chance of wound breakdown. Absorbable

round. Young animals are more severely affected,

material is used for the buried sutures and nylon is

dictating the development of possible local immunity

preferable for the cutaneous repair.

to the disease in those previously exposed. Over the *years IBKC has been attributed to several organisms*

Congenital porphyria

(Bedford, 1976), but currently Moraxella bovis is still regarded by most authorities to be the cause. The root

Congenital porphyria is a rare, recessively inherited

of the controversy lies in the fact that Moraxella bovis

defect of haemoglobin metabolism which results in the

can be found in the normal conjunctival sac, and

production of abnormal porphyrins. Clinical signs asso-

attempts to produce the disease using pure cultures of

ciated with photosensitization are seen in light-skinned

this bacterium have not always been successful. In addi-

cattle upon exposure to sunlight. Adenexal inflam-

tion, infectious bovine rhinotracheitis (IBR) virus,

mation is characterized by oedema, photophobia,

known to cause conjunctivitis in addition to rhinitis, and

blepharospasm and excessive lacrimation.

Mycoplasma bovirhinitis and M. laidlawii have been isolated with Moraxella bovis from IBKC patients.

Rather than representing cause, however, these organ-

Diseases of the conjunctiva

isms may act synergistically as enhancing factors.

and cornea

Undoubtedly, other enhancing factors can be at work,

and the increased incidence of IBKC during the

The occurrence of IBKC and squamous cell carcinoma

warmer months has indicated that ultraviolet light,

renders this part of the eye important in economic

flies and dust play potentially important roles in the

terms, and as the two disease conditions commonly

overall picture. Certainly flies of the Musca and

involve both structures it is convenient to discuss them

Stomoxys species have been incriminated as mechani-

both under the same section.

cal vectors, but the occurrence of epidemic disease

among winter-housed cattle suggest that flies and the

other environmental factors are not essential.

Epibulbar dermoid

Dermoid formation (choriostoma) is due to the poor

Epidemiology

differentiation of the palpebral tissue with the result

that plaques of hair-bearing skin and subcutis may be

Variation within the clinical picture of the disease may

found involving the lateral aspect of the globe (Plate
be related to the input of the several possible enhanc-
52.3). Both the cornea and episcleral tissues can be
ing factors, but may also be due to the susceptibility of
affected, the dermoid replacing the corneal epithelium
the animal to infection and the type of Moraxella bovis
and bulbar conjunctiva, respectively. Bilateral involve-
present in its conjunctival sac. Older cattle are more
ment is unusual, and dermoids are only of clinical sig-
resistant to infection, it being calves and cattle of less
nificance if they impair sight, cause trigeminal irritation
than two years of age that demonstrate the highest

morbidity and the most severe disease. Such resistance
stroma (Plate 52.4a). Throughout this stage of the
may be the result of previous exposure, but local factors
disease the eye is extremely painful, and a bilateral
as well as antibody formation may be involved (Pugh,
involvement means that the patient is either blind or
1969). It has been demonstrated that two forms of the
experiencing impaired vision. Inappetance, suppressed

bacterium exist: a smooth non-haemolytic form that is weight gain and reduced milk production are related to avirulent and can usually be isolated from recovering the severity of involvement. At this stage, and particu- and clinically normal carrier animals, and a rough larly in young animals, loss of epithelium and anterior haemolytic virulent form that causes the acute disease stroma in the central lesion may occur, and this ulcer (Pedersen, 1973). The rough form is fimbriated for may rapidly enlarge to involve deeper stromal tissue. adherence (Sandhu et al., 1974), and repeated passage Less severe forms of the disease resolve within two or has demonstrated its conversion into the smooth form. three weeks, the cornea gradually clearing from its The presence of fimbriae would appear to be necessary periphery towards the centre as the vessels cease to for disease to occur and for immunity to develop. The transmit blood to the healing ulcer site. Recovery takes difficulties experienced in the production of an effec- longer when extensive ulceration has occurred and deep tive vaccine against Moraxella bovis may be overcome *stromal scarring and keratoconus may result. In some*

as the result of further structural studies to determine

patients descemetocele formation may complicate deep

the possible immunogenic status of the fimbriae. In the

ulcers and actual rupture may lead to panophthalmitis

past, alteration of the surface components of bacterial

(Plate 52.4b). Blindness may result, and the eye may

cells in the preparation of vaccines may have been

become glaucomatous but will eventually shrink (phthi-

wholly responsible for the ineffectiveness of such vac-

sis bulbi). The occasional death has been attributed to

cines. The economic importance of IBKC demands that

meningitis following presumed ascending infection of

an effective vaccine be developed, but it could be many

the optic nerve.

years before the solution is finally produced.

Treatment

Signs

Moraxella bovis is susceptible to most antimicrobial

Epidemics occur as the result of the introduction of

agents including many antiseptics, and this, combined *incubating, chronically affected or carrier animals into with uncertainties concerning the aetiology of the con- the herd. The presenting clinical features may vary con- dition and a tendency for spontaneous resolution in siderably depending on the immunity of the exposed some patients, renders the accurate assessment of any individual and the level of enhancing factors present. treatment difficult. It is generally agreed, however, that This variation is not only seen on a herd-to-herd basis, the earlier the treatment the less severe the disease but between individual animals within the same herd. and the greater the chance of controlling the outbreak. Both unilateral and bilateral cases will be seen; in the In the absence of isolation facilities, it is suggested that latter a variation in the degree of severity may be noted treatment of the entire herd will protect the unaffected between the two eyes. Usually, inflammation of the cattle. Consideration of potential carrier status dictates bulbar and possibly the palpebral conjunctivae precedes the use of antibiotics in newly acquired stock before the keratitis, but occasionally the conjunctival involve-*

they are introduced into the herd.

ment is not seen until after corneal inflammation has

Antimicrobial drugs may be administered topically,

made its appearance. Blepharospasm, photophobia and

by subconjunctival injection and parenterally. The ideal

copious ocular discharge herald anterior segment pain,

therapy for a herd problem demands effective one-time

the discharge, primarily clear and thin, becoming puru-

dosage and, as such, topically applied preparations,

lent quite rapidly to mat the lashes and circumorbital

which require frequent administration to maintain ther-

hair. The conjunctiva is chemotic and swelling of the

apeutically effective levels in the precorneal tear film

eyelids may occur. Corneal changes usually develop

(PCTF), cannot be very effective. Their short contact

within 48 hours, a 3-mm wide, slightly raised area of

time is reduced further by the presence of ocular

cloudiness normally making its appearance centrally.

discharge and lacrimation, and blepharospasm renders

Epithelial loss can be demonstrated using fluorescein

their application difficult. Currently, increased contact *stain, and the lesion itself may take on the yellowish blue*

time as the result of specific formulation is claimed for

of pyogenic necrosis. The surrounding cornea becomes

several antibiotic preparations including cloxacillin,

oedematous and hazy, and a low-grade anterior uveitis

cephalonium and a penicillin and streptomycin combi-

with aqueous flare may be noticeable in some animals.

nation. The subconjunctival injection of antibiotics can

Corneal vascularization from the limbal blood vessels is

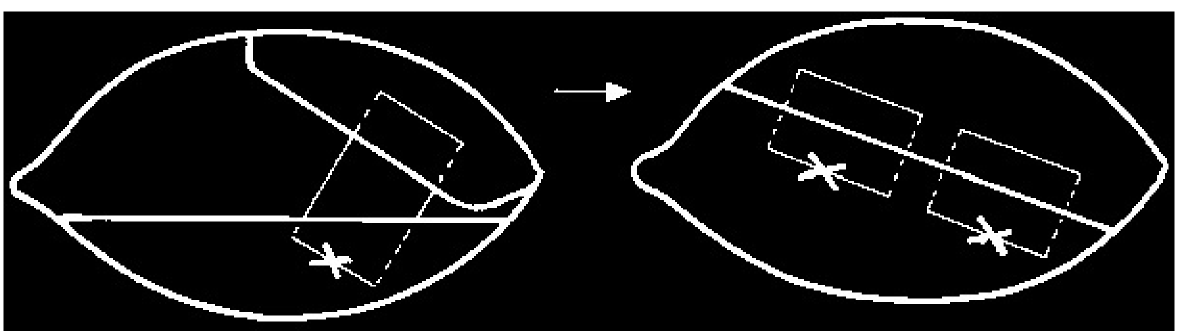
be used as an alternative to the topical route, but the

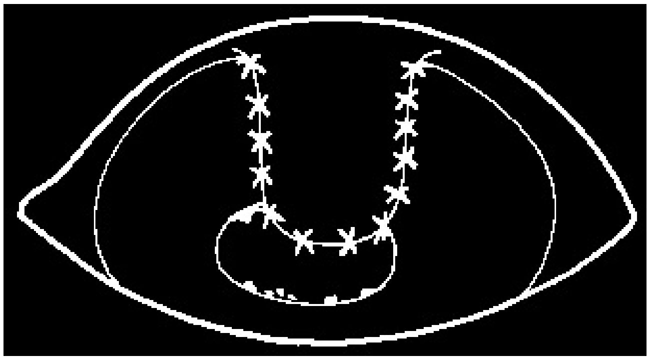
well established by the sixth day, the new vessels rapidly

antibiotic must be placed beneath the dorsal bulbar

progressing towards the central lesion in the anterior

conjunctiva. This is difficult to do for the unpractised





hand and a topical analgesic agent (proxmetacaine

hydrochloride) must be used. From this site the antibi-

otic leaks into the PCTF and thus has an effect. Intra-

palpebral injections of various antibiotics are used

commonly, but there is evidence to demonstrate that

a drug deposited in palpebral muscle gets into the

lacrimal gland or the PCTF. Long-acting ampicillin,

Fig. 52.2

The membrana flap. The membrana is sutured into

oxytetracycline and penicillin may be used parenterally

the loose dorsal bulbar conjunctiva using two or three mattress for repeated good effect. Moraxella bovis is usually

sutures.

resistant to lincomycin, tylosin and erythromycin but

has variable susceptibility to cloxacillin (George, 1990).

In an original study, Pedersen (1973) claimed that intra-

venous sulphadimidine was the treatment of choice for

IBKC. He showed that although Moraxella bovis is

present on the corneal and conjunctival surfaces, it col-

onizes the lacrimal and tarsal glands, and that any treat-

ment must effectively penetrate these tissues. A single

injection of sulphadimidine at dose rate of 100 mg/kg

Fig. 52.3

The bulbar conjunctival pedicle flap used in the repair

bodyweight will do this, and the drug will remain in the

of deep corneal ulceration.

RCTF at a therapeutically active concentration for 24

hours. It is still surprising that this method of treatment

is not utilized to any great extent for it seems to answer

both theoretical and practical aspects of therapy.

against Moraxella bovis, but some recent results are

However, some strains of Moraxella bovis have proved

quite optimistic (Lepper, 1993). The research has con-

resistant to sulpha drugs (Pugh & McDonald, 1977). In

centrated on the fimbriae or pili found in the rough

the future other delivery systems may be evaluated and

form of the organism and recombinant DNA technol-

ocular inserts that allow prolonged drug release would

ogy has been involved. Certainly pilus-antigen vaccines

appear to be of potential value in this respect.

have demonstrated acceptable levels of protection in

Surgery can have a part to play in the treatment of

several studies (Lepper, 1988; Moore & Rutter, 1989)

IBKC. The membrana nictitans can be used to support

and workable protocols are now possible. Calves are

the severely ulcerated cornea or protect a ruptured

vaccinated at approximately one month of age, with

anterior chamber, and this technique is preferred to

a second vaccination three weeks later. There is no

a temporary tarsorrhaphy in which the eyelids are

evidence that colostrum derived antibodies will negate

sutured together. Using local anaesthesia together with

this procedure. Adult cattle should have yearly

an auriculopalpebral nerve block to overcome any

boosters.

blepharospasm, the membrana nictitans and the loose

bulbar conjunctiva can be apposed to cover the cornea

Infectious bovine rhinotracheitis

(Fig. 52.2). Mattress sutures of non-absorbable material

(see also p. 286)

are used, and the cornea is left covered for two to three

weeks. The sutures should not penetrate the mem-

The role of infectious bovine rhinotracheitis virus in

brana's full thickness, otherwise corneal erosion will

anterior segment disease is not fully understood. The

occur. Should a more resilient method of repair be

virus is thought to enhance the effects of Moraxella

required then under a general anaesthetic a pedicle of

bovis in some patients with IBKC, but it is also known bulbar conjunctiva can be sutured directly into the

to cause conjunctivitis in its own right. Respiratory

corneal defect (Fig. 52.3). The pedicle is separated from

disease may or may not be present, and abortion rates

its bulbar conjunctival attachment several weeks later

may be high in IBR-affected herds.

and the residual conjunctival tissue is usually involved

The ocular involvement may be unilateral or bilat-

in the scar. This technique offers the advantages of

eral. Varying degrees of chemosis may be present, and *directly strengthening the cornea and introducing a*

a number of white plaques may be found in both the

blood supply to the ulcer site.

bulbar and palpebral conjunctivae. The discharge may

vary from serous in early disease to a mucopurulent

type later. Anterior uveitis and corneal opacity are

Vaccination (see p. 1018)

occasional findings, and this latter should not be con-

There have been considerable difficulties experienced

fused with the corneal abscess or ulcer that routinely

by those attempting to produce an effective vaccine

occurs in IBKC. Confirmation of diagnosis is not always

easy, for it requires virus isolation from swabs taken

and the marked geographic variation in incidence.

only in the early part of the disease. Seroconversion

Squamous cell carcinoma occurs in ocular tissue where

from negative to positive or a rising titre for IBR anti-

there is little or no pigment, and the bulbar conjunctiva

body will provide the final proof. There is no specific

at the lateral and medial limbi is more exposed than *treatment for the condition, but antibiotics will help*

conjunctiva elsewhere on the globe or lining the eyelids.

control any bacterial secondary infection. Normally, the

The incidence of ocular SCC is greater in those parts of

disease takes three to four weeks to complete its course.

the world with high levels of ultraviolet light, and at

high altitude. The IBR virus and its inclusion bodies

may be found in the neoplastic tissue (Taylor & Hanks,

Endothelial dystrophy

1969) and it has been postulated that the virus may play

Bilateral neonatal corneal oedema has been reported

a part in initiating tumour growth or be involved in the

in several breeds including the Friesian (Deas, 1959).

transformation of precursor lesions into carcinoma.

The oedema is uniformly present throughout the whole

Surprisingly, perhaps, the incidence of SCC is greater in

stroma, and its persistent nature ensures permanent

cattle on higher levels of nutrition, but this may be asso-

impairment of sight. Treatment is not possible, but

ciated with enhanced age changes induced by such diets

short-term clearing of the cornea can be obtained

(Anderson, 1970).

using topically applied glycerol or hypertonic saline.

Several stages of development are described in SCC

Signs of possible precursor or accompanying anterior

formation. Conjunctival plaques of hyperplastic epithe-

uveitis and other ocular abnormalities are not present,

lium (Plate 52.5a) or hyperkeratosis of palpebral skin

and defective endothelial function alone is the

represent the initial lesion. Regression may occur, but

indicated cause. The defect is considered to be inher-

the plaques are generally replaced by papilloma for-

ited as a recessive trait, and affected animals and their

mation, and this in turn is replaced by non-invasive car-

carrier parents should be avoided in any breeding

cinoma. Eventually, most of these carcinomas become

programme.

invasive, and the whole globe can be involved (Plate

52.5b). Invasion of orbital bone can occur, and with

long-standing SCC, metastasis via the lymphatics to

Neoplasia *(see p. 1126)*

involve the lungs, heart, liver and kidney is possible

Ocular squamous cell carcinoma (SCC) or 'cancer eye' (Cordy, 1978).

is the commonest bovine neoplasm, and its economic

Treatment is related to the extent of tumour involve-

importance has already been stressed. Although SCC

ment, and the possibility of metastasis may dictate a

has worldwide distribution, its incidence increases in

policy of early slaughter. Excision of the neoplasm,

countries where cattle experience long-term exposure

removal of the membrana nictitans, enucleation or

to intensive sunlight. The Hereford would appear

exenteration of the orbit represent possible early treat-

the most commonly affected breed, and tumour

ment. Alternative techniques of cryosurgery, hyper-

formation is rarely seen before five years of age. A pre-

thermia, radiation therapy and immunotherapy have all

sumed inherited predisposition is postulated, and

been tried with some success, again early in the course

genetic analysis has suggested that it is a recessive trait

of tumour development. Small neoplasms can be

(Anderson & Chambers, 1957; Vogt & Anderson,

excised irrespective of site, but recurrence and subse-
1964). However, several contributory facts seem to be
quent extension should be expected. Large lesions of
involved, perhaps one of the most important being the
the membrana nictitans may already have invaded the
role of melanin in palpebral, conjunctival and scleral
orbit. Premalignant lesions and small carcinomas can
tissues. Pigmentation is determined genetically, and
be destroyed using liquid nitrogen sprays, but adequate
undoubtedly the presence of melanin protects tissue
freezing demands the use of thermocouple assessment.
from SCC development. As such ultraviolet light is con-
Limbal-based lesions can be difficult to treat effectively.
sidered to be a significant contributory factor in the
Again neoplastic cells can be selectively destroyed by
development of SCC, its absorption by melanin being
heating tissue to 45°C, and early SCC will respond
the significant protective factor. Much SCC finds origin
to hyperthermic therapy. Various forms of ionizing
in the bulbar conjunctiva at the lateral and medial
radiation therapy have been used successfully. Beta-

limbi, but other areas where pigmentation may be

irradiation will destroy small lesions, and radioactive

reduced (the palpebral conjunctiva, the membrana nic-

caesium, cobalt or gold implants can be similarly effec-

titans and eyelid skin) can also be affected. Other pos-

tive if the dose rates can be adequately calculated.

sible contributory factors are IBR virus, dust, flies and

Immunotherapy offers potentially effective treatment,

high levels of nutrition.

with the parenteral use of modified or whole-cell

The indications that ultraviolet light may be an

tumour cell suspensions having demonstrated

important aetiological factor are the actual tumour sites

considerable promise (van Kampen et al., 1973).

Diseases of the uveal tract

panuveitis may all be seen. Anterior uveitis, choroiditis

and retinitis may all be present as a result of vascular

(see also p. 180 onwards)

necrosis and vasculitis (Plowright, 1968). A recurrent

uveitis, referred to as specific ophthalmia (Marolt et al., Both congenital and *acquired disease of the uveal tract*

1963) has been described for cattle. It is similar clini-

occur in cattle, with uveitis presenting the clinician with

cally to equine recurrent uveitis (periodic ophthalmia)

as much difficulty in treatment as it does in the other

with corneal oedema, anterior chamber and intravitreal

domestic species.

exudates, and retinal haemorrhage being seen in the

acute stage. A viral aetiology is suggested, with IBR and

Congenital anomalies

other respiratory viruses isolated from affected animals.

Listeria monocytogenes has been previously associ-

Several congenital anomalies occur in cattle, including

ated with outbreaks of keratoconjuntivitis and uveitis

aniridia, colobomata, polycoria, persistence of the

in housed cattle in the UK (Morgan, 1977), but more

pupillary membrane and anterior uveal cyst formation.

recently this organism has been isolated from housed

Aniridia is seen as part of a multiocular defect in

cattle fed on silage, presenting with anterior uveitis as

Jersey calves, in which bilateral partial absence of the

the only clinical feature (Watson, 1989). It has been iris is accompanied by microphakia or lens luxation considered that the organism in the silage gains entry (Saunders & Fincher, 1951). Vision can be affected to to the eye either directly from conjunctival sac con- the point of blindness, and the defect is inherited as a tamination or from the gingival margins by trigeminal simple recessive trait. Iris colobomata, polycoria and migration. The uveitis presents clinically in the same uveal cysts are of no clinical significance, but persistence way as any other anterior segment inflammation; it is of the pupillary membrane may be associated with lens usually unilateral with marked miosis, thickening and and corneal opacities. The vascular mesoderm in which folding of the iris, keratic precipitate (KP) and the pupil develops should be resorbed by the time of hypopyon formation and vascularization of the limbal parturition, but strands of this tissue may persist to span cornea being the presenting signs (Plate 52.6). Treat- the pupil or become adherent to the anterior lens ment includes the use of systemic antibiosis, but sub-

capsule or the corneal endothelium. Cataract or corneal

conjunctival corticosteroids and topical atropine are

endothelial and deep stromal opacities mark the areas

essential for effective resolution.

of adherence, the size of these opacities varying with the

amount of the attaching remnant tissue. Heterochromia

Neoplasia

iridis, due to a reduction or absence of melanin, is seen

in the colour dilute breeds, and it may occasionally be

Primary uveal tract tumours in cattle are rare, but

accompanied by photophobia, nystagmus and typical

secondary involvement with squamous cell carcinoma

papillary coloboma formation.

occurs not infrequently.

Disease of the lens

Uveitis

Inflammation within the uveal tract occurs in associa-

Ectopia lentis (lens luxation) occurs as part of a con-

tion with systemic disease, corneal ulceration, keratitis,

genital multi-ocular defect syndrome in Jersey and

trauma and intraocular neoplasia. Anterior uveitis can

Friesian cattle, and cataract probably enjoys higher inci-

accompany IBR infection, toxoplasmosis, tuberculosis

dence than the literature dictates. Intraocular examina-

and neonatal coliform septicaemia; panophthalmitis in

tions are not commonly practised in cattle, and cataract

which the whole uveal tract is involved may be seen in

is only diagnosed if it is large enough to be noticed

malignant catarrhal fever. Infectious bovine rhinotra-

initially with the naked eye, has an effect on sight or is

cheitis virus may be involved in IBKC and will cause

present with other noticeable ocular anomalies.

conjunctivitis; occasionally there is an associated

Congenital cataract has been recorded in several

uveitis. In calves with coliform septicaemia, acute

breeds (Odorfer, 1995) and in Jersey and Friesian cattle

anterior uveitis characterized by episcleral congestion,

its inheritance is as a simple recessive trait (p. 181).

miosis and hypopyon formation may be seen in associ-

There would appear to be a particularly significant inci-

ation with septic meningitis in which paresis, ataxia and

dence of this lesion in the Friesian and Friesian crosses

convulsions are the obvious clinical features. Occasion-
in the UK, demonstrating marked regional variation. In
ally, the choroid is involved, and haemorrhage and
congenital cataract the nuclear part of the lens is always
exudate will be seen in the vitreous. In peracute malig-
involved, but cortical extension may severely affect
nant catarrhal fever severe photophobia, marked palpe-
vision (Plate 52.7). There may also be a posterior polar
bral and corneal oedema, mucopurulent discharge and
cortical opacity with posterior lenticonus and possible

hyaloid attachment. Nystagmoid movements of the
maternal hypovitaminosis A induced papilloedema and
globe may accompany the larger opacities. In both
optic nerve atrophy are seen in the neonate. Choroidal
these breeds and in the Shorthorn other ocular anoma-
colombomata are reported to be commonplace but may
lies including buphthalmia, microphakia, lens luxation
be of no clinical significance. Typical papillary colobo-
and retinal detachment may accompany cataract.
mata in Hereford cattle with incomplete albinism are

Cataract may be secondary to uveitis, but the aetiol-

seen bilaterally but have no reported noticeable effect

ogy of other capsular and cortical lens opacity remains

on vision. However, the same bilateral defect in Charo-

obscure (Gelatt, 1971).

lais may blind the affected animal (Plate 52.9). In both

The treatment of cataract is by surgery, and two tech-

breeds the lesion is considered to be inherited, and

niques are possible. In young calves of several weeks of

genetic studies in the Charolais have indicated that it is

age lens discission can be successful if the attendant

a polygenic trait (Barnett & Ogden, 1972) (p. 181).

uveitis is minimal (P.G.C. Bedford, pers. obs.). The tech-

The hyaloid artery is part of the primary vitreous, but

nique is a simple one in which the anterior capsule of the

with the development of the ciliary vasculature it

lens is disrupted using a Bowman's needle inserted into

regresses and becomes non-functional. Large remnants

the anterior chamber at the dorsal limbus (Plate 52.8).

of this vessel can be seen commonly in cattle (Plate

Normal and cataractous lens material is released into the

52.10), but they are of no clinical importance. The vessel

anterior chamber and is usually almost completely

overlies the optic disc and extends forward from this

resorbed, leaving the posterior capsule in situ to retain structure into the posterior vitreous. Blood is often seen

the vitreous behind the pupil. Corticosteroids are used

within its lumen in young calves up to eight weeks of

to suppress the possible phacoanaphylactic inflamma-

age, and remnants of the avascular vessel will persist

tory reaction, but in young calves this is minimal. After

throughout the animal's life.

the operation cataract reformation is unusual, despite

Retinal dysplasia, in which there is typical rosette for-

the retained presence of the anterior capsule and the

mation and usually non-attachment of the neuroretina,

lens epithelium. In older animals the attendant uveitis

is seen in Shorthorn cattle with hydrocephalus and mul-

renders this technique unacceptable, and extracapsular

tiple ocular defects, and in Herefords with microph-

lens extraction or phacoemulsification offers the best

thalmia, cerebellar hypoplasia and hydrocephalus *chance of success. In the former the anterior chamber is*

(Blackwell et al., 1959; Green & Leipold, 1974). Con-opened either through a corneal or limbal section, the

genital retinal degeneration and optic nerve atrophy

anterior capsule removed and the cataractous material

have been seen in association with microphthalmia,

dislocated from the posterior capsule out through the

cataract and cerebellar hypoplasia in calves born of

section. The postoperative therapy must include corti-

dams infected with bovine viral diarrhoea/mucosal

costeroids and, just as in other species, loss of pupil as

disease. Congenital optic nerve degeneration and

the result of iris spasm and posterior synechiae forma-

papilloedema can be produced by maternal hypo-

tion is the common complication that may render the eye

vitaminosis A.

blind. However, the uveitis is usually controllable, and

the overall prognosis for sight is good. In phacoemulsi-

Inflammation

fication the cataract is removed from within the confines

of its capsular bag and then the anterior capsule is

Retinal and optic nerve lesions will accompany several

removed. This kind of surgery is less intrusive and the

systemic infections including the neonatal pyosep-

degree of associated uveitis is usually minimal.

ticaemias, bovine viral diarrhoea/mucosal disease,

thromboembolic meningoencephalitis, toxoplasmosis,

tuberculosis and rabies.

Diseases of the retina and

Septic chorioretinitis characterized by haemorrhages,

optic nerve

exudate and bullous retinal detachment can accompany

septicaemia in young calves caused by Escherichia

Both congenital anomaly and acquired disease can

coli, streptococci, Mannheimia spp. and Arcanobac-involve the bovine fundus but, as with cataract diagno-

terium pyogenes infections. Maternal infection with

sis, such lesions are not normally detected unless there

bovine viral diarrhoea/mucosal disease can cause con-

is an associated effect on sight or other more noticeable

genital optic neuritis among other ocular anomalies,

ocular defects are present.

and in thromboembolic meningoencephalitis caused

by Haemophilus somnus conjunctivitis and corneal

oedema may be accompanied by retinal vasculitis and

Congenital defects

detachment. Blindness is usually due to septic throm-

Papillary and peripapillary choroidal colobomata, per-

bosis of the visual cortex. Both anterior and posterior

sistence of the hyaloid artery, retinal dysplasia and

uveitis with possible retinal detachment can accompany

tuberculosis (p. 862). Focal retinitis has been reported

fundus and attenuation of the superficial retinal vascu-

in bovine rabies (p. 1164).

lature has been described in cattle, and compared with

canine progressive retinal atrophy (PRA). It would

appear to be a rare condition, and the comparison with

***Hypovitaminosis A** (see also p. 256)*

PRA may have been somewhat premature.

Hypovitaminosis A has been described in three situa-

tions with variability of the presenting clinical features.

Glaucoma

It occurs congenitally, and here either papilloedema or optic nerve atrophy is present. In the growing calf there is obvious papilloedema in which the disc becomes very Glaucoma is the process of ocular degeneration caused swollen, and the resultant papillary vascular congestion by an elevation of the intraocular fluid pressure (IOP) may cause focal superficicial haemorrhage (Plate beyond its physiological upper limit. The incidence is 52.11). Optic nerve atrophy will occur if the deficiency less than 1 per cent in cattle. All bovine glaucomas are is maintained. The papilloedema is due to compression due to the impairment of aqueous drainage through a of the optic nerve by bony overgrowth within the optic defective or diseased iridocorneal angle, and in the canal, and the accompanying vascular occlusion results majority of cases the glaucoma is secondary to inflam- in ischaemic necrosis of the nerve (Hayes et al., 1968). mation or neoplasia. Uveitis may result in pupillary Early papilloedema is reversible and optic nerve block due to extensive posterior synechiae formation. atrophy preventable if the diet is suitably adjusted. Nyc-

This results in the forward displacement of the periph-

talopia due to rod degeneration also occurs. Vitamin A

eral iris, the so-called pathological iris bombé, and

is essential in the formation of the visual pigment

closure of the ciliary cleft. The presence of exudation

rhodopsin, and without rhodopsin the photoreceptors

speeds the transformation of the trabecular meshwork

degenerate. This process is also reversible should

into an impervious physical barrier to aqueous outflow.

vitamin A be supplemented soon enough. It is likely

Alternatively, these peripheral anterior synechiae and

that the sight problems experienced by the calf are

ciliary synechiae may form directly to deny bulk

more likely to be caused by the optic nerve lesions

aqueous drainage. Tumour cells and the products of any

rather than the retinal degeneration. In the adult defi-

associated inflammation will block the iridocorneal

cient in vitamin A papilloedema is much less noticeable

angle to produce secondary glaucoma.

and optic nerve atrophy does not occur. Here the outer

A primary glaucoma has been recorded in the *segment degeneration is probably more significant in*

Friesian (Carter, 1960); the condition is inherited as a

terms of the effect on sight.

dominant trait and is seen in association with cataract

formation and lens luxation.

Treatment of glaucoma in cattle is determined on the

Male fern optic neuropathy

basis of whether the enlarged blind eye is of nuisance

Permanent or transient blindness will accompany weak-

value, and enucleation may be necessary in the pres-

ness, malaise and constipation in the early stages of

ence of associated corneal damage or degeneration.

male fern (Dryopteris filix mas) poisoning. The toxic

effect is on the optic nerve, and varying degrees of

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papilloedema and associated haemorrhage are seen

ophthalmoscopically. In severe cases optic nerve

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atrophy follows the papilloedema.

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(see p. 177)

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and inheritance, fetal lupin toxicosis, manganese defi-

cancer eye in cattle. Miscellaneous Publications of the

ciency and maternal viral infection have all been con-

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sidered to be involved. Joint deformities, syringomyelia

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and cleft palate may be seen, and blindness is due to

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Chapter 53

Other Conditions

A.H. Andrews

Anaphylaxis

927

Signs

Amyloidosis

928

Congestive heart failure

928

Reaction can occur about 20 minutes after the intro-

Diabetes mellitus

930

duction of the antigen. The animal exhibits pronounced

Hypothermia

930

dyspnoea with, on auscultation, bubbling and emphyse-

Lightning strike/electrocution

930

matous sounds. Muscle tremors can occur, which cause

Stray voltage

931

pyrexia to 40°C (104°F). Other reactions include bloat,

Meloidosis

932

diarrhoea, increased salivation, urticaria and rhinitis.

Mycotic diseases

932

Occasionally laminitis occurs. Death is due to anoxia.

Mucormycosis

932

Following i.v. blood transfusion, there are usually hic-

Cryptococcosis

932

coughs and then dyspnoea, muscle tremors, salivation,

Rhinosporidiasis

933

coughing, lacrimation and fever.

Candidiasis (moniliasis)

933

Aspergillosis

933

Histoplasmosis

934

Necropsy

Teat burns

934

Water availability

934

At necropsy usually only the lungs are involved in acute

Heat stress

935

cases, with marked pulmonary oedema and vascular

Acute heat stress

935

engorgement; some animals develop emphysema.

Chronic heat stress

935

Longer-standing cases show hyperaemia and oedema of

Malignant catarrhal fever

935

the abomasum and small intestines.

Anaphylaxis

Diagnosis

Diagnosis depends on the history of recent introduction

Aetiology

of an antigen to which the animal may previously have

Anaphylaxis is the result of antigen–antibody reaction

been exposed. The signs are helpful, being sudden with

and when severe it can cause anaphylactic shock.

severe dyspnoea, urticaria, etc. Haematological exami-

nation shows increased packed cell volume, leucopenia

and thrombocytopenia. Biochemical changes include a

Epidemiology

hyperkalaemia and blood histamine levels are raised in

The condition is usually very uncommon. Most cases

some cases. Finally, there is a response to therapy.

follow the parenteral injection of drugs or biological

Differential diagnoses are few because of the rapid

products such as blood. Occasionally, the problem can

onset but acute pneumonia could be confused, although

arise through exposure via the alimentary tract or lungs.

usually there is toxaemia and lesions are more pro-

Signs may be seen in the system exposed, or they may

nounced in the arterio-ventral parts of the lungs.

be generalized. Most cases follow the introduction to

the blood of an antigen to which the animal has already

Treatment and control

been sensitized, but reactions can occur where the

animal is not known to have been exposed previously.

The most effective method of treatment is an intra-

More anaphylactic reactions occur in some herds and muscular injection of adrenaline (4–5 ml of 1 in 1000

families of cattle than others. Reactions are most preva-

solution) and if necessary a fifth of the dose (0.5–1.0 ml)

lent in Channel Island breeds. Initial signs tend to be

can be given intravenously, diluted to about a 2 per cent

largely of a respiratory nature, but other areas affected

solution. Otherwise, corticosteroids can be adminis-

can be the alimentary tract and skin.

tered or they may be given immediately following

adrenaline as they potentiate the latter's activity.

uraemic, recumbent and comatosed. Death occurs two

Antihistamines give variable results, partly because

to five weeks after the onset of signs. Almost all cases

most histamine is released early in the reaction and

will eventually die unless slaughtered.

also there are other mediators of the anaphylactic

reactions. Various other compounds have been shown

Necropsy

to alter the reaction of mediators and these in-

clude sodium meclofenamate, acetylsalicylic acid and

At necropsy there are usually one or more chronic sup-

diethylcarbamazine.

purative processes present in the organs. The carcass is

Once a reaction has occurred in an animal, the

emaciated, usually with marked oedema. The affected

antigen causing the problem should not be reintro-

organs are enlarged and pale in colour. The kidney and

duced. If a blood transfusion is given, introduce up to

liver have diffuse amyloid infiltration, while in the

200 ml in a 450 kg (990 lb) animal and wait for about 10

spleen it is more localized. The amyloid can be shown

minutes before injecting the remainder.

by aqueous iodine staining.

Amyloidosis

Diagnosis

Diagnosis depends on signs, including an enlarged

Aetiology

kidney, diarrhoea and oedema. There is hypopro-

teinaemia,

proteinuria and hyperfibrinogenaemia.

The aetiology of amyloidosis is uncertain but it is the

Blood biochemical examination shows hypomagne-

result of a hyperglobulinaemia, probably causing an

saemia and a serum calcium level at the lower end of

abnormal antigen–antibody response.

the normal range. There are also a high serum urea

nitrogen and high serum creatinine. The specific gravity

Epidemiology

of the urine is low and there is a prolonged brom-

sulphthalein (BSP) clearance test.

Is a rare condition that is not fully understood. A few

Differential diagnoses are few but include

cases occur as the result of repeated antigen usage in

pyelonephritis where there is pus and haematuria, and

the production of hyperimmune sera. However, most

congestive heart failure in which there is an increased

animals are affected sporadically and spontaneously

heart rate, respiratory embarrassment and dyspnoea.

following prolonged suppurative infections. The origin

of amyloid, which is a glycoprotein, is not certain, but

is thought to be due to an abnormality of the

Treatment

antigen–antibody reaction. Renal amyloidosis is the

No successful therapy: cattle should be slaughtered.

most commonly recognized condition, but amyloid can

also be deposited in the liver and spleen. When the

main organ affected is the liver, there tends to be

Congestive heart failure

proteinuria. This leads to hypoproteinaemia and then

oedema of the organ, resulting in marked anasarca. The

Aetiology

diarrhoea produced is partly due to amyloid deposition

and oedema of the intestinal wall. Many of the animals

The condition can follow diseases of the pericardium,

affected are still growing. Foci of inflammation found

myocardium or endocardium.

can include traumatic reticulo-peritonitis, traumatic

pericarditis, salpingitis, mastitis, metritis (Johnson &

Jamison, 1984) and nephritis. Cases have occurred

Epidemiology

following repeated hormonal injections in donor cows

It is relatively uncommon and mainly affects older which are superovulated several times.

cattle. Pericarditis or hydropericardium can interfere

with the normal filling of the heart during diastole.

Pulmonary hyperaemia, which may occur in diffuse

Signs

fibrosing alveolitis, can result in right-sided congestive

Usually, the affected animal is thin and emaciated. In

heart failure. In cattle, the main cause of myocardial

most cases there is marked anasarca with an enlarged

disease is foot-and-mouth disease. Endocardial diseases

liver palpated in the right sublumbar fossa and an

are the most common and are usually due to infection

enlarged kidney with loss of its lobular structure when

or inflammation.

palpated via the rectum. There is usually polydipsia and

When extra demand is placed on the heart, or the

a profuse watery diarrhoea. The animals later become

myocardial activity is reduced, then compensation can

occur by an increased heart rate, increased filling of the

there is pulmonary congestion and oedema. In left-

ventricles and improved cardiac performance. There

sided failure there is subcutaneous oedema, hydro-

are also dilatation and hypertrophy. Venous return

thorax, ascites and hydropericardium.

increases in speed and blood distribution changes so

that there is an increase in blood volume, a decrease

in renal blood flow and sodium retention. Cardiac

Diagnosis

response is reduced and the animal is less able to cope

with unusual exercise or other emergencies (Blood et

Diagnosis is by the signs, particularly those of oedema.

al. , 1983). There is a decrease in exercise tolerance and The heart rate is elevated and there is an increased area

once the compensating mechanisms have been over-

of cardiac dullness; abnormal heart sounds may be

come then the heart cannot cope and congestive heart

present, depending on the cause. Insertion of a needle

failure develops. Many of the signs of cardiac insuffi-

into a vein shows a markedly increased venous pres-

ciency are the result of increased venous pressure. They

sure. Aspiration of fluid from oedematous areas shows *result in congestion of organs or oedema and the*

it to be a transudate containing large amounts of

decreased output produces tissue hypoxia.

protein. There is also a proteinuria.

Failure of the right-sided ventricle causes congestion

of the major circulation with reduced blood flow

through the kidney, resulting in anoxic damage to the

Differential diagnosis

glomeruli and venous congestion of the portal system

Differential diagnosis includes amyloidosis but diar-

of the liver, and eventually there is transudation into

rhoea tends to be marked and the kidneys are enlarged

the intestinal lumen giving rise to diarrhoea. Left-sided

without heart abnormality. In chronic peritonitis there

ventricular failure results in engorgement and oedema

is often some pain and the aspirated abdominal fluid

of the lungs. Both left and right-sided failure can occur

contains many leucocytes. In bladder rupture there is a

together.

normal heart and urine is present in the abdomen. In

liver fibrosis the heart is normal and there is usually

Signs

jaundice or photosensitization. Parasitic gastroenteritis

occurs in a younger animal and there is oedema, mainly

Early signs are of reduced exercise tolerance with

of the submandibular area, with a high faecal egg count.

increased respiratory effort and tachypnoea following

Fascioliosis could confuse, but again there is usually

light exercise. Pulse and respiratory rates take a long

only submandibular oedema and a faecal egg count.

time to return to normal. On percussion the heart area

Fog fever (p. 866) could cause problems in diagnosis but

may be enlarged.

usually several animals are affected quite suddenly in

In left-sided failure: lungs are mainly affected so that

the autumm. Anaphylaxis is also a sudden problem with

there is a cough, tachypnoea and hyperpnoea. The heart

no cardiac signs.

rate is increased and a murmur may be present in the

region of the aorta or left atrioventricular valve. On

auscultation there are moist noises at the ventral edges

Treatment

of the pulmonary field and on percussion increased

dullness on the lower borders of the lung. Later on

The primary cause should be treated as effectively as

there is cyanosis and dyspnoea.

possible, but with most cases the prognosis is poor.

In right-sided failure or cor pulmonale: appetite is

Where oedema is present it is partly due to sodium

poor and the animal is dull with a rapid loss of condi-

retention and so the salt intake should be kept

tion. There are marked areas of oedema often affecting

as low as possible. Diuretics such as frusemide or

the skin of the lower part of the body, the neck and

hydrochlorothiazide are useful and they can be given

the submandibular space. There is ascites, hydroperi-

by injection or orally. The heart can be treated to

cardium and hydrothorax. The liver may be enlarged

improve contractility by use of etamiphylline camsylate,

enough to be palpated in the right sublumbar fossa. The

theophylline or digitalis derivatives. The use of digitalis

heart rate tends to be increased and there is hyper-

by mouth is probably of limited value because of break-

pnoea and often slight tachypnoea. There is a marked

down in the rumen. Parenteral administration of

jugular pulse. Prognosis usually poor in all cases.

digitalis extracts is little used for several reasons: intra-

venous use could result in toxicity whereas intramus-

cular administration gives variable results. There are no

Necropsy

licensed preparations. Little can be done to control the

At post-mortem examination there are abnormalities of

congestive heart failure except to treat all infections

the pericardium, myocardium or endocardium. Usually,

quickly and adequately.

Diabetes mellitus

rhage and acute synovitis. Some cases show haemor-

rhages of the adrenal glands and oedema of the iliac

This is a very unusual condition in cattle compared with

and jejunal lymph nodes.

its relatively frequent occurrence in dogs and cats.

However, lesions can occur in the pancreas resulting in

Diagnosis

this condition. It is usually seen in old cattle and often animals will have had other problems such as fatty liver.

Diagnosis depends on the history and signs. Increased

The signs are loss of condition with polydipsia and

serum glucose and phosphorus levels occur with cooling

polyuria. There is no rise in temperature and the urine

but fall during recovery.

contains both ketones and glucose. Biochemical examination of the blood shows hyperglycaemia. Usually

Treatment

treatment is not contemplated.

Treatment is by immersion in warm water, which results in quicker rewarming than use of a heat pad or heat

Hypothermia

lamp. A hot air environment could be constructed with a straw bale shelter and a hot air heater. Control is

Aetiology

by ensuring that adequate shelter is provided or by housing cattle during the bad weather.

This is also called cold stress and is mainly seen in young calves in severe climatic conditions, particularly *where there is wind chilling as well as a cold ambient*

Lightning strike/electrocution

temperature. The problem is not encountered anything

like as commonly as in lambs.

Aetiology

This is exposure to high voltage electric currents, either

Epidemiology

natural or generated by man.

Exposure to cold conditions mainly occurs in calves of

cows calving outside in the winter months with no

Epidemiology

shelter. It is particularly prevalent in suckler calves and

occurs more frequently in countries such as Canada and

The condition is uncommon but it is often of interest as

Australia than say Britain. Mortality is usually higher in

it is one of the few problems that farmers have usually

calves born in winter and early spring. There is a delay

insured against. Problems arise from lightning, expo-

in the onset and rate of immunoglobulin absorption

sure of electrical wires or faulty wiring or earthing in

from colostrum in cold-stressed calves. Primary *farm buildings. Cases may be single or a group. In many*

hypothermia with no associated disease can be seen in

instances, damp ground or floors help to conduct the

young calves, and secondary hypothermia with no other

electricity. Low voltages of 110–220 V are sufficient to

disease has been recorded in older calves.

kill cattle. Outside, trees such as oak, poplar, elm and

conifers are all prone to lightning strike.

Signs

Signs

The rectal temperature may be low and can be defined

as a temperature less than 37°C (98.5°F) and there is

The signs in the severe form are such that animals die

shivering. Shivering appears to be more intense during

without a struggle. Burns or singeing may be seen

the initial period following exposure to cold. Most

because of the severity and often they involve the

calves have no problems in the cold but some are

muzzle and feet. Death is usually due to paralysis of the

depressed and stand or walk about stiffly. A few animals

medullary centre, accompanied in some cases by ven-

may remain in sternal recumbency. The heart rate tends

tricular fibrillation. In the less severe form the animal

to be raised but respiratory rate is low.

becomes unconscious for a varying time and there is

usually some sign of a struggle. After regaining con-

sciousness there may be dullness, blindness, paralysis of

Necropsy

one or more legs, and surface hyperaesthesia. The signs

At post mortem the most common lesions involve the

may persist or slowly disappear over a period of up to

limbs and include subcutaneous oedema and haemor-

two weeks. If burns are present, sloughing of the skin

rhage. Experimentally, more haemorrhages occur in the

in the area is seen. Minor problems may occur such as

hindlimbs. Some animals show oedema of the ventral

the animal may jump, be restless, show periodic con-

sternum. The joints may show mild to severe haemor-

vulsions or be knocked down.

In lightning strike the animal is usually close to a

Occurrence

fence, barn, trees or a pond. Often there are signs of There are a large number of different origins for this burning affecting these objects. The animal itself may problem. Stray voltage is an electrical current passing show singeing of the hair or burn marks on the muzzle between two points. Should an animal come into and feet. Half-chewed food may be present in the contact with these points the current will pass through mouth. The animal quickly becomes distended with gas the animal. Cattle are more sensitive to electrical volt- and decomposes rapidly. Blood often exudes from the ages than human beings, who often do not feel any nostrils, rectum and vulva. The pupils are dilated and shock due to wearing clothes and boots which can insu- the anus relaxed. There tend to be petechial haemor- late them from the problem. While there is individual rhages throughout the body and the viscera are variation in the susceptibility to electricity, most cases congested. The superficial lymph nodes are often will only be detected when several animals show similar haemorrhagic.

signs. The most common place for this to occur is in the

milking parlour, although feed and water troughs as

Diagnosis

well as other farm building equipment can be involved.

The history may contain the fact that there has been

Diagnosis depends on the history of a storm, position

some alteration or modification of the electrical supply

of the animal near trees, etc. and sudden death of a

or there has been some building. Otherwise most prob-

group of animals. The signs may also be helpful such as

lems result from old and exposed wiring, often with

singeing of the hair, burns on the muzzle and feet and

damage to the insulation covering or vermin damage.

evidence of sudden death.

Signs

Differential diagnosis

These will vary and are related to the area of the stray

Differential diagnosis includes anaphylaxis but there is

voltage. If the source is in the parlour, the cattle are often marked pulmonary involvement. Acute heart failure

reluctant to enter, are fidgety during milking and will *can cause problems but there is engorgement of visceral*

rush out of the parlour after milking. If the source is a

veins and macroscopic or microscopic myocardial

water trough it may be avoided by the cows or they may

lesions. Brain trauma can occur but usually there is a

lap rather than drink normally. Other signs include rest-

haemorrhagic lesion of the brain. Nitrate/nitrite poi-

lessness, muscular twitching, etc. Milk production may

soning results in sudden death but methaemoglobin is

suffer and feed intake as well if the feed area is affected.

present. Anthrax can be confused, but stained blood

smears assist in determination. Bloat is a possibility but

Diagnosis

on necropsy the front part of the animal is congested,

there is a distended rumen and sometimes froth

This is often difficult; any behavioural change will

present. Blackleg results in swelling of the part affected

usually only be seen in the area of the stray current.

with the causal organism present.

If several animals are showing similar discomfort or

behavioural changes then diagnosis is made more easy.

Confirmation will depend on a qualified electrician and

Treatment

will require a sensitive voltmeter. It may also be neces-

No treatment is usually given as often the cattle

sary to set up the conditions that cause the shock, i.e.

are either better or dead before any therapy can be

have the milking equipment working.

administered. Central nervous system stimulants can be

given. Artificial respiration may be helpful. Although

Differential diagnosis

nothing can be done about lightning strike, all

Behavioural changes will usually only affect a single

electrical installations should be properly fitted and

animal and will be less likely to be related to a par-

earthed.

ticular area of the farm. BSE can result in signs such as

reluctance to enter the parlour and difficulty in milking,

but would always involve the same animal. Other signs

Stray voltage

would also occur.

While not a very common problem, the signs are often

Control

difficult to determine and also the origin is hard to find.

These stray electrical currents result in mild electric

Ensure all electrical installations and equipment are

shocks to the animals and cause discomfort, often

properly earthed and maintained. Have wiring checked

resulting in apparent behavioural problems.

periodically.

Meloidosis

Mycotic diseases

Aetiology

Mucormycosis

The cause is Pseudomonas (Malleomyces) pseudo-Aetiology

mallei. It can survive for long periods in the soil and There are various fungi of the family Mucoracae that

water.

can cause infection, including the genera Absidia, Ento-mophthora, Mortierella, Mucor, Rhizopus.

Epidemiology

The condition is primarily a disease of rodents but occa-

Epidemiology

sionally it spreads to man and farm animals such as

The fungi occur usually in soil and water and are

sheep, goats, horses and pigs. It is very rare in cattle. The

often plant pathogens and food decomposers. They are

disease was first recognized in South East Asia but it is

opportunistic.

now seen in Australia, Malaysia, Papua New Guinea

and Nigeria. Infection is passed in the faeces of rodents

Signs

and is spread by ingestion of contaminated feed or

water, by insect bites, wounds and possibly inhalation.

Infection can cause a necrotic placentitis in cattle

Mortality is high and disease lasts about two to eight

resulting in abortion at three to seven months' gesta-

weeks.

tion. There is necrosis of maternal cotyledons and

yellow, raised, leathery lesions on the intercotyledonary

areas. Granulomatous lesions of the mesenteric and

Signs

mediastinal lymph nodes can occur. Calves can develop

The main signs are a marked pyrexia with anorexia and *alimentary tract lesions after prolonged antibiotic*

a thick yellow exudate from the eyes and nose. Nervous

therapy. Following acidosis the ruminal wall can be

signs may be exhibited. Some cattle have infection

invaded with Rhizopus spp.

without signs.

Diagnosis

Pathology

Hyphae are present on smears of cotyledons, fetal

stomach and skin. The lymph nodes need to be exam-

There are multiple abscesses in many areas of the body

ined. There may be a history of antibiotic usage and on

as well as in the subcutaneous tissues and associated

post mortem there may be abomasal ulceration. The

lymph nodes. The size of the abscesses is variable from

animal will become black tinted.

a few millimetres to over 2.5 cm in diameter.

Prevention and control

Diagnosis

As the fungi are ubiquitous it is impossible to control

This depends on demonstrating the causal organism by *properly. There are no satisfactory antibiotics.*

culture from pus, nasal discharges or blood.

Cryptococcosis

Treatment

Aetiology

There is little information available on satisfactory

The cause is Cryptococcus (Saccharomyces) neofor-treatment of meloidosis. Chloramphenicol is used in

mans (synonyms C. hominis, Torula histolytica).

man and in vitro tests suggest oxytetracycline may be of use in animals, and perhaps novobiocin, chloramphenicol and sulphadiazine. Treatment is to be discour-

Epidemiology

aged because of the possibility of spread to humans.

The incidence is worldwide and is high in areas of

warmth and moisture.

Control

Signs

Infected animals: slaughtered, disposed of by burn-

ing. In-contact animals: slaughtered, the premises

Latent: There is a mastitis in many cases with no visible disinfected.

signs in the udder or milk.

Severe: The quarter(s) swells slowly and becomes firm

Treatment

and swollen. The subcutaneous tissue also develops

Polyps are best removed surgically.

oedema, which persists for several weeks. There is

often some discomfort with the legs held apart. Pyrexia

occurs up to 40°C (104°F) with anaemia. The supra-

Candidiasis (moniliasis)

mammary lymph nodes are enlarged. Milk production

is reduced but the milk itself shows few changes except

Aetiology

a few flakes. Later, in persistent cases, there is a watery

The main causal agent is Candida albicans but C. trop-secretion.

icalis, C. krusei, C. parapsilosis and C. guillermondii can also initiate disease.

Mild: A swelling of the quarter(s) is seen with little effect on the milk. Occasionally a granulomatous

meningoencephalitis may develop or the nasal mucosa

Epidemiology

may show nodular lesions.

The organisms are worldwide and found in animal *faeces.*

Pathology

Infection is mainly confined to the udder, although

Signs

there may also be reddening and thickening of the

brain tissue and oedema, and naso- or oropharyngeal

A chronic pneumonia can occur with dyspnoea plus

nodules.

only a moderate fever. There is a profuse stringy sali-

vation and brown-streaked nasal discharge. Abortion

can occur and there can also be mastitis with mild

Diagnosis

transient signs that are self-terminating. Where there is

Diagnosis is by direct examination of the fluids.

severe mastitis it may follow the use of intramammary

tubes. The udder is swollen and spongy and the animal's

Prevention and control

temperature is 40–41.5°C (104–107°F).

Ensure proper disinfection.

Diagnosis

Rhinosporidiasis

Isolation of the organism provides the diagnosis.

Aetiology

The causative organism is Rhinosporidium seeberi.

Treatment and control

There is a limit to what can be done but amphotericin

Epidemiology

B can be successful. An iodine in liquid paraffin intra-

mammary infusion can be left in the udder for 10–15

The disease is distributed worldwide.

minutes, and then stripped out. This is repeated in seven

days, and oral iodides may be given if necessary.

Signs

There is the formation of large polyps in the posterior

Aspergillosis

nares and this interferes with respiration. The lesions

are small, about 0.5–3 cm in diameter. They are soft,

Aetiology

friable and bleed. The surface of the polyp shows many

There are many Aspergillus spp. including Aspergillus small white specks. The nasal discharge results in dys-fumigatus, A. flavus, A. niger and A. terreus.

pnoea with mucopurulent and bloody discharge.

Pathology

Epidemiology

There is a polyp of papillomatous epithelium, which is

The organisms are widespread. Placental infection of

hyperplastic and contains numerous sporangia.

cattle is thought to be via abomasal ulcers or from the

respiratory tract. It also occurs following inhalation of

spores from mouldy straw, hay and sugar beet pulp.

Diagnosis

Outbreaks of abortions can occur following the feeding

Isolation of the organism provides the diagnosis.

of mouldy silage.

Signs

may lead to side-effects. The imidazoles may be

satisfactory.

Aspergillosis is a quite common cause of abortion with

a placentitis. Abortion is in the sixth to eighth month of

pregnancy. Another form is a fatal gastroenteritis with

Teat burns

ulceration of forestomachs and oesophagus. Pulmonary *aspergillosis also occurs in animals subjected to diar-*

Epidemiology

rhoea and poor ventilation. There is fever and dyspnoea.

In parts of the world where forest and grass fires are

common, burns can result in damage necessitating the

Diagnosis

slaughter of cattle. However, in other cases the animals

Examine placental direct smears for fungi. Culture

will survive but there may be injury to the teats or

stomach contents or cotyledon.

udder. In such cases it is necessary to provide an accu-

rate prognosis. Often several teats are affected.

Treatment and control

Signs

Nystatin can be used in the treatment of diarrhoea.

The lesions can be assessed according to the severity of

There is no effective preventive but avoid feeding

the burn (Morton et al. , 1987).

mouldy silage to cows in mid to late pregnancy. Defi-

nitely mouldy straw or hay should not be used in

Mild burns: These are reddened with a loss of the *enclosed buildings, and preferably not at all.*

outer, white, paper-thin tissue, which sloughs. A teat

may have normal tissue interspersed with multiple

Histoplasmosis

small black areas over the teat surface or a uniform rel-

atively thick black or red–brown surface layer. There

Aetiology

may be areas of sloughing or crusts that develop in the

There are two species causing infection, Histoplasma

tissue and milk is apparently normal. In all cases the

capsulatum and H. duboisii.

teats are pliable on palpation.

Severe burns: The teats tend to be dull brown or black, Epidemiology

dry and often are corrugated. If sloughing has occurred

Whereas H. capsulatum is found worldwide, H. duboisii then a thick layer (over 1 mm thick) of tissue is

is only found in Africa. It is a rare condition but can

sloughed. Underneath there is red haemorrhagic tissue.

occur in man and other species. Histoplasma capsula-

On palpation the teat is leather-like and lacks pliability.

tum is found in the soil. Infection follows inhalation of In some cases the teats tend to be distorted, especially *contaminated dust and entry to the lung.*

in heifers.

Prognosis

Signs

With mild lesions prognosis is good. In severe lesions

Affected cattle may show chronic emaciation, dys-

prognosis is variable but tends to be better in cows than

pnoea, diarrhoea, swelling of the brisket and grinding

heifers. Some cows only show partial return to function

of the teeth. At post-mortem examination there is an

with reduced milk flow.

enlarged liver, ascites, oedematous thickening of the

large intestine and interstitial emphysema. Histologi-

cally, eosinophilic round bodies can be found in

Treatment

endothelial cells.

Treatment can increase recovery. Application of 0.5 per

cent cetrimide in lanolin daily is helpful. However,

Diagnosis

healing is slow, taking about 14 weeks. When the surface

skin starts to peel antibiotic ointment is helpful. Teat

Diagnosis is from the signs, and samples should be

orifice restrictions often respond to surgery.

taken for culture and histology.

Water availability

Treatment and control

Amphotericin B given intravenously at 1 mg/kg body

Water debility need not necessarily damage cattle in the

weight daily has been effective but a prolonged course

dry season in semi-arid regions. Some breeds are obvi-

ously less susceptible. They are less affected when they

air is hot and humid, then every attempt must be made

are on pastures containing a very low crude protein

to ensure good air flow by louvred windows, fans, etc.

level. If fed a high plane of nutrition without water,

The cattle should receive an adequate amount of water.

problems could arise, but in practice this is unlikely to

Feeding at night will also ensure maximum heat pro-

occur. The amount of water required varies but is obvi-

duction is during the cool period.

ously higher in a dairy cow than a beef animal. Animals *are capable of being watered only once every three days*

if necessary but they should not have to walk more than

Malignant catarrhal fever

about 2.5 km to it. If water deprivation occurs there is

a reduction in milk or meat deposition. If dehydration

Aetiology

persists there is circulatory collapse when the level of

sodium reaches 170 mEq/l.

Also known as bovine malignant catarrh and malignant

head catarrh. Caused by two different agents but clini-

cally identical. In many countries only one of the agents

Heat stress *(see Chapter 8)*

is present. The African strain, (alcelaphine herpes virus

1 and 2 or bovid herpes virus 3) is wildebeest-associated.

Acute heat stress

The European, North American and Asian strain has not

been characterized but is sheep-associated.

If the heat produced by the animal and the heat

absorbed from the atmosphere are higher than the heat

lost then the animal's temperature will rise. It thus

Epidemiology

develops hyperthermia and if the rise is great and sudden the animals will pant, salivate excessively, Malignant catarrhal fever (MCF) has a sporadic world-become restless and then prostrate. Problems often wide distribution. It mainly affects single animals, occur if cattle are made to walk long distances. Heat although outbreaks have occurred. The wildebeest stroke can occur at a normal outside temperature if strain is seen in Africa and in zoological gardens. The animals are packed tightly in poorly ventilated vehicles sheep-associated strain occurs when sheep associate travelling during the hottest parts of the day.

with cattle, which are considered 'dead-end' hosts. The If action is not quick death occurs. Affected animals African form is more easily transmitted, transferred via should be sprayed with cold water. They should be kept the placenta into the fetus. Soon after birth, the wilde-in the shade and attempts made to increase the air flow. beest calf sheds infection which can be contracted by Clipping the hair, particularly along the mane, withers other species. Transmission of the sheep form is not *and backbone, will assist but such animals are then sus-*

known, although cattle have usually been in contact

ceptible to direct sunlight and so they should be kept in

with pregnant or lambing sheep. The virus is fragile and

the shade.

does not survive more than a day outside the host.

There may be many distinct MCF virus forms.

The incubation period is shorter for the African form.

***Chronic heat stress** (see Chapter 8)*

Following infection, there is an eclipse phase of nine to

seventeen days, then viraemia continues until death.

The chronic or subacute form occurs more frequently

After a further three to fifteen days, signs develop, fol-

than acute heat stress. When exposed to high tempera-

lowed by death five to ten days after their onset. Trans-

tures cattle compensate by increasing their loss of heat

mission is probably by inhalation or possibly blood

by panting and sweating. They can also reduce heat pro-

transfusion.

duction by reducing food intake, drinking more and

reducing activity. Cattle are able to accept high midday *temperatures if the evenings and nights are cool.*

Signs

In chronic heat stress there is decreased milk pro-

duction, reduction in weight gain and sexual maturity.

Cases are sporadic. Animals are very ill with anorexia,

There is also some loss in fertility, particularly involving

pyrexia (40.5–41.5°C; 105–107°F), depression and loss

spermatogenesis in the bull. When animals are affected

of condition. An early pathognomonic sign is an intense

they should be provided with shelter or otherwise given

scleral congestion with bilateral keratitis and corneal

access to well-ventilated shady areas. Oestrus suppres-

opacity starting at the edge of the sclera, causing blind-

sion may also occur. When cattle are grazed in very hot

ness. Early lesions also involve the buccal mucosa, with

conditions grazing should be restricted to the evenings,

reddening of the lips, gingivae and muzzle. Erosions

nights and mornings. If necessary zero-grazing may

develop, including necrosis of the tips of the labial

need to be adopted. In such circumstances, where the

papillae and the mouth corners.

Other signs vary. They can include nervous signs such

diffuse mucosal erosion are indicators. At necropsy the

as muscle tremors and hyperaesthesia. The superficial

histological presence of vasculitis confirms diagnosis.

lymph nodes are grossly enlarged. There is profuse

There is leukopenia. Serological tests can be used in the

mucopurulent oculo-nasal discharge which can encrust

African form. Viral isolation or transmission can be

around the nostrils and eyes. There is often excessive

attempted.

salivation, followed by dyspnoea and stertor due to

exudate accumulation. Faeces vary between profuse

diarrhoea and soft, scanty faeces. Laminitis and der-

Differential diagnosis

matitis can occur in the sheep-associated form.

Differential diagnosis includes mucosal disease, but

At later stages, more prominent nervous signs may

ocular lesions are not severe and there is no lymph node

occur, such as incoordination, leg weakness and nystag-

enlargement. Rinderpest and foot-and-mouth disease *mus followed finally in some by head pressing, convul-*

are herd problems with no severe ocular lesions. Infec-

sions or paralysis.

tious bovine rhinotracheitis usually affects several

Uncommonly, a mild form occurs with mild, transient

animals, with mainly respiratory signs. Calf diphtheria

fever and some oral and nasal mucosal erosions. These

does not produce ocular signs.

animals can recover.

Treatment and control

Necropsy

There is no treatment or suitable vaccine. Infected

Lesions occur in many parts of the body including the

animals should be separated from others. Cattle should

respiratory, alimentary and urinary tracts. They include

not be grazed with sheep, particularly at the time of

varying degrees of haemorrhage, hyperaemia and dis-

lambing, nor near wildebeest. Bought-in sheep should

crete or extensive erosions. The eyes show scleral con-

come from disease-free farms.

gestion and keratitis. The lymph nodes show marked *enlargement. The skin around the coronets may show*

lesions. Histologically, the epidermis shows extensive

hydropic degeneration and vesicle formation with

References

rupture. The dermis shows vasculitis with proliferation

and necrosis and marked lymphoid cuffing.

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Diagnosis

cows. Journal of the American Veterinary Medical Associa-

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History helps with a record of other species contact

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and one animal affected. Nervous signs, lymph node

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enlargement, scleral congestion, corneal opacity and

*of treatment. Australian Veterinary Journal, **64**, 69–72.*

Chapter 54

Major Poisonings

C.J. Giles and A.H. Andrews

Introduction

937

in general, must rely on the vigilance and safety stan-

Diagnosis of poisoning

937

dards of industry and the monitoring authorities.

Relationship between the veterinary clinician and the

Most instances of poisoning in cattle therefore are

diagnostic laboratory

939

not the result of large-scale incidents but arise from

Principal toxicoses

940

accidental access by cattle to toxic substances at the

Organophosphate and carbamate poisoning

940

local farm level either by cattle moving from a safe to

Lead poisoning

944

a toxic environment or by the inadvertent introduction

Ragwort poisoning

945

Bracken poisoning

946

by man of a toxicant into the animals' previously safe

Yew poisoning

947

environment.

Copper poisoning

948

Poisoning in cattle can vary greatly in severity, mor-

Fluoride poisoning (fluorosis)

949

bidity and mortality. In the most severe cases, where a

Nitrate/nitrite poisoning

950

large number of cattle have consumed toxic quantities

Oak poisoning

951

of poison very high morbidity and mortality can result.

In contrast, mild episodes occur where the clinical

effects are transient and few animals suffer harmful

Introduction

effects. Some of such cases are often so insignificant

that they are missed or misdiagnosed.

The nature of many farming practices such as the wide-

spread and increasing use of agrochemicals and the wide

Diagnosis of poisoning

variety of potentially toxic plants, coupled with the

The diagnosis of poisoning in cattle is not easy, as often

innate inquisitiveness of cattle to investigate (often by

it is the last thing a clinician will consider when pre-

licking) new or unusual substances, means that many

sented with an outbreak of disease and not infrequently

cattle live in a potentially toxic environment. It is

it is a subject about which he knows little. In many cases

perhaps surprising therefore that despite this, incidents

the evidence of intoxication is merely circumstantial,

of poisoning remain comparatively uncommon in cattle.

the materials required to establish a definitive diagno-

Most toxic dangers to cattle are well understood and

sis have long disappeared and in many cases the clini-

documented. This fact, together with the usually respon-

cal signs are vague and confusing. However, poisoning

sible and diligent approach to the handling of toxic

incidents are often serious, potentially litigious and

chemicals and the correct and proper management of

hence must always be handled with care and vigilance.

pasture, considerably reduces the risk of cattle gaining

There are essentially three stages in establishing a

access to poisonous substances. Most instances of poi-

diagnosis of poisoning:

soning arise, therefore, by accident, usually as the result

of human error, ignorance, neglect or, rarely, malice.

(1)

Recognition that the incident is probably a case of

Such errors, of course, may not always be under the

intoxication.

direct control of the stockworker, for it may be the

(2)

Reaching a presumptive diagnosis of the toxicant

actions of a third party, often unconnected with live-

or class(es) of toxicant.

stock that are to blame for a poisoning incident. As an

(3)

Establishing a definitive diagnosis of the intoxication.

example, the environment and feed of cattle, like all

It is not possible in many cases for all three stages to be

livestock and indeed humans, may be subjected to the

accomplished.

effects of industrial pollution. However, incidents where

there is gross contamination of the environment or

Recognition of apparent intoxication

where an accident results in the release of highly toxic

substances are very uncommon and for the maintenance

Rarely is an outbreak of disease in cattle immediately

of such a state the livestock farmer, like the population

attributable to poisoning on clinical or pathological

grounds alone. Before the clinician comes to such an

Any recent use of agrochemicals should elicit ques-

opinion he needs to consider fully the history, epidemi-

tioning of farm staff as to their correct usage and the

ology and clinical signs presented and consider care-

disposal and storage of concentrate. Anything in the

fully the differential diagnosis in order to exclude the

environment of the cattle that would not normally be

more common non-toxic causes of the condition.

present should be investigated with suspicion; for

Poisoning incidents should be suspected in the

example, old farm machinery or rubbish left in fields,

following circumstances:

lead from old batteries and discarded sump oil may be

the sources of various toxicants. The water supply must

• *The onset of disease is clearly associated with a*

always be critically examined, especially if the supply is

change in management of the affected animals, for

provided by means other than a piped mains supply.

example a change in feed, movement to a new envi-

Could the supply have been contaminated by local

ronment or a concurrent agricultural management

dumping of toxic rubbish, or run-off from nitrogenous

practice, e.g. spraying or dipping.

fertilizers from fields? Only when there is no known

• *The epidemiology of the disease is not that* *indication of local contamination should more distant*

expected of an infectious disease, for example the

sources, e.g. industrial sites, be considered.

condition may quite obviously arise simultaneously

The clinician's best initial guide to the type of toxi-

in several animals or groups rather than appear to

cant involved is detailed appraisal of the clinical signs

be the result of spread.

and post-mortem findings, where appropriate, and to

• The clinical signs as presented are not typical of the

correlate these with the known effects of the major

more common infectious, parasitic or metabolic

types of toxicant (Table 54.1). However, few toxicants

diseases with broadly similar clinical pictures.

produce a clinical picture not shared with other poisons

• There is circumstantial evidence that animals may

or non-toxic causes and several can produce a wide

have had access to unusual materials.

array of clinical signs.

• The differential diagnosis of the disease as deter-

mined by clinical and post-mortem examination *includes poisoning as a possible cause.*

Establishing a definitive diagnosis

Having attempted to form an opinion as to the type of

toxicant involved, the veterinary clinician is now in a

Presumptive diagnosis of the toxicant

position to attempt to reach a definitive diagnosis. To

Having established the incident may be a case of

achieve this, in most cases, especially when chemical

intoxication the clinician needs to consider what agent

rather than plant toxicants are involved, he will require

or type of agent might be responsible. In some cases this

the assistance of a diagnostic laboratory. In some cases

may be straightforward as the history and circums-

a routine thorough gross and histological examination

tantial evidence of poisoning may direct the clinician

by the laboratory may provide strong supportive evi-

immediately to the probable cause. More frequently,

dence of the toxicant as may the botanical examination

however, it is far from obvious and requires a detailed

of rumen contents in cases of plant poisoning, but in the

consideration of the clinical signs, the post-mortem

majority of instances a definitive diagnosis of poisoning
findings (if appropriate) and the circumstantial evi-
is dependent on the finding, by chemical analysis, of
dence. The overall aim should be to answer the ques-
toxicant in the tissues, ruminal or intestinal contents or
tion: What possibly could the cattle have had access to
food of the poisoned animal. The results of such chem-
that could account for the signs and post-mortem
ical analyses must always be interpreted carefully and
picture as observed? This inquiry needs to be wide-
in conjunction with the history, clinical picture and post-
ranging. A full history should always be taken; the
mortem findings. The question to be answered is: Would
clinician should examine the animals in the housing or
the observed level of chemical (as determined by analy-
pasture in which they developed the condition but
sis) in the particular tissue at the time of examination
should not merely concentrate on the animals them-
account for the signs and disease picture originally
selves as it is necessary also to inspect the environment
observed? Only when this question can be answered

for possible sources of toxicants. It is vital, of course,
in the affirmative can a definitive diagnosis result. This
always to inspect the feed but this should not automati-
is not always possible, especially with the economic
cally be viewed as the prime suspect source, although
constraints usually imposed on veterinary laboratory
a recent change in feed is strong supportive circum-
examination, and the clinician must view attempts at
stantial evidence that it may be the source of intoxi-
establishing a definitive diagnosis in this light. The
cation. In grazing animals the pasture should be thor-
required evidence is often not available; for example, a
oughly inspected for the presence of known toxic
suspect batch of feed may have long since disappeared
plants.
and despite a diligent examination the analyst is unable

Table 54.1

Initial linking between clinical abnormality and type of poisoning.

System

Abnormality

Suspected class of poison

Chemical

Plant

Alimentary

Diarrhoea

Heavy metals, organophosphates,

Solanine containing, oak, GI

ionophores

irritants, ragwort

Colic abdominal pain

Heavy metals, formaldehyde, urea

Oak, GI irritants

Hypersalivation, vomiting

Organophosphates, urea

GI irritants, rhododendron

Central nervous system Depression, coma

Ionophores

Oxalate containing, solanine

containing

Hyperexcitability, hyperaesthesia,

Heavy metals, nitrofurans,

Atropine containing

convulsions

organochlorines

Eye

Mydriasis

Lead

Atropine containing, Hemlock,

Cicuta sp.

Miosis

Organophosphates

Blindness

Lead

Respiratory

Dyspnoea

Nitrate/nitrite

Cyanide containing

Skin

Photosensitization

St John’s wort, ragwort

Gangrene

Ergot

Locomotor

Lameness

Fluoride

Ergot

Urinary

Haematuria

Bracken

Haemoglobinuria

Copper

Brassica spp.

Allium spp.

All

Wasting

Pyrrolizidine containing

Sudden death

Cyanide containing, yew,

water dropwort

GI, gastrointestinal.

to determine a chemical cause of the signs observed.

Table 54.2

Specimens submitted for toxicological examination.

The veterinarian at this stage must conclude the case,

after referral if necessary, as merely one of suspected

Tissue

Amount usually required

intoxication.

Serum (separated from clot,

up to 10 ml

not haemolysed)

Relationship between the veterinary

Urine

50 ml

clinician and the diagnostic laboratory

Liver

100 g

Kidney

100 g

If a significant number of investigations are to be con-

Other tissues

100 g

cluded beyond the stage of 'suspected intoxication' by

Rumen contents

500 ml

the clinician, a working cooperation must develop

Feed

minimum 100 g

between the veterinary clinician and the diagnostic

laboratory. Once intoxication is suspected the golden

rules are to contact the laboratory earlier rather than

later and to take too much material for examination

should be packaged or sent and any special instructions.

rather than too little. When the clinician suspects intox-

Accompanying all specimens must be the clinical infor-

ication and has concluded the initial clinical and envi-

mation as above together with details of any treatments

ronmental assessments contact should be made with a

given and the time of death. As a general rule, contain-

laboratory experienced in diagnostic toxicology. The

ers should be glass or plastic and tightly sealed, differ-

clinician should inform the laboratory of the following:

ent organs should be packaged separately and no

history, clinical signs, post-mortem findings (if appro-

preservative added. As tests for different toxicants *priate) and the results of the environmental assessment,*

require different samples the need for prior discussion

indicating an opinion as to possible toxicants. The cli-

between the clinician and the laboratory is paramount.

nician must then be guided by the laboratory as to what

Detailed discussion is not warranted here. Table 54.2

samples to submit, the size of specimens, how they

serves as a guide.

Principal toxicoses

tion, respectively) at cholinergic nerve endings and

myoneural junctions. The continued presence of acetyl-

There are a vast array of potentially toxic chemical

choline at these sites produces continued nerve stimu-

compounds and toxic plants which can, theoretically at

lation and accounts for the clinical signs observed. The

least, cause poisoning in cattle due to the fact that they

time of onset of clinical signs varies with the dose and

contain known toxic agents and/or have been proven as

route of absorption from five minutes to a few hours.

toxic by experimental observation. In practice, a few

Clinical signs are similar for both organophosphate and

principal toxicoses are commonly observed in a given

carbamate toxicoses and are broadly threefold, namely

region or country and the majority are rarely, and a few

stimulation of the parasympathetic nervous system

almost never, encountered.

(muscarinic effects), stimulation of the skeletal muscles

Local, regional and geographic factors greatly influ-

(nicotinic effects) and central nervous effects. The mus-

ence the importance of the various toxicoses in differ-

carinic effects in general precede the nicotinic. The first

ent regions and countries, so much so, particularly with

effects are excessive, followed by profuse salivation.

toxic plants, that attempting to define the principal

This is accompanied by nasal discharge, cough, dys-

toxicoses is fraught with difficulty. Nevertheless,

pnoea, colic, diarrhoea, excessive lacrimation, frequent

certain types of toxicant are encountered much more

urination and miosis. These are then joined by the nico-

frequently than others. These common toxicoses, based

tinic signs, muscle fasciculations, stiffness, adoption of a *generally on the position in the UK, are accorded*

'saw-horse posture', which then progresses to muscle

detailed treatment in the text, whereas for those

paralysis. Cattle usually show marked central depres-

considered of lesser importance a summary of the

sion although rarely they may show central nervous

principal facts is given in Table 54.3.

excitation. As the condition progresses the muscarinic

signs become very pronounced with profuse salivation,

Organophosphate and

severe colic, sweating and dyspnoea progressing to

carbamate poisoning

collapse and death. Death is the result of hypoxia due

to severe bronchoconstriction with respiratory hyper-

The organophosphate compounds are widely-used

secretion and irregular slowing of the heart.

agrochemicals in agriculture, horticulture and livestock

production, and accidental overdosage or overexposure

can lead to toxicosis.

Diagnosis

The history and characteristic clinical signs of parasym-

Source of toxicant

pathetic stimulation are suggestive of poisoning. This

The principal uses of organophosphates are as insecti-

will be reinforced if there is circumstantial evidence of

cides and acaricides, and preparations are made for

exposure to organophosphates or carbamate com-

animal treatment (dusting powders, sprays, washes, dips,

pounds. Particular attention should be paid to the

pour-on, etc.), sprays for application to plants and

possibility of inadvertent therapeutic overdosage, for

granules for application to soil. Carbamates, which have

example by combinations of oral and topical exposure.

a similar mode of action, are used as molluscicides and

Chemical analysis of blood or tissue for the toxicant is

herbicides.

usually of no value due to the fast breakdown of

Cattle may become poisoned by a variety of methods,

organophosphates; the analysis of contaminated feed

principally due to human error, negligence or igno-

or rumen contents is likely to be more successful.

rance. The compounds can be absorbed orally, dermally

However, the preferred method of confirmatory diag-

or by inhalation. Cattle may gain access to stored com-

nosis is by the determination of the reduction in

pounds, they can be mistaken as feed ingredients, and

cholinesterase activity. This test is often performed, for

they may also consume treated seed. Containers may

convenience or necessity, on whole blood, but exami-

be used for feed or water without cleaning. Sprays for

nation of brain tissue is better. The test is a specialized

pest control in crops may directly contaminate animals

laboratory procedure and the testing laboratory

or pollute feed or water courses. Inadvertent over-

should preferably be consulted before the submission

dosage can occur with insecticidal sprays, dips or topical

of samples.

pour-on preparations or by a combination of topical

and oral therapy or by rapid retreatment.

Principal differential diagnoses

Signs

The respiratory signs may resemble fog fever (p. 866)

The organophosphates and carbamates block the action *in which the muscle fasciculations are not, however,*

of cholinesterases (by phosphorylation or carboxyla-

usually observed. The syndrome is similar to acute urea

Table 54.3

Summary of the less commonly observed toxicoses of cattle.

Poison

Usual source(s)

Clinical signs

Management guidelines

Aflatoxin

Feeds containing groundnut,

Reduced feed intake, poor weight

No specific treatment. Remove all

cottonseed or maize

gain (or decreased milk yield),

suspect feed, submit samples of

contaminated with the toxigenic

inappetence, rough hair coat,

feed for analysis (permitted

fungi Aspergillus flavus and A.

reduced resistance to infectious

levels of dietary aflatoxin

parasiticus. Growth of toxigenic

disease. Less commonly acute

controlled).

fungi is only possible when

severe signs may be observed

moisture content of stored grain

especially in calves less than 6

exceeds 15%, feed levels should

months, including nervous signs,

not exceed 50 ppb.

circling, blindness, convulsions,

death.

Arsenicals

Accidental contamination of feed

Often sudden death. Acute –

Rarely successful. Adsorbents

with inorganic arsenicals or

severe colic, salivation, teeth

orally, sulphur compounds, e.g.

organic (herbicides, pesticides).

grinding, weakness,

dimercaprol (4 mg/kg im) or

Formerly in dips and weedkillers,

incoordination, rapid collapse

sodium thiosulphate 15–30 g in

industrial chemicals,

and death. Subacute – similar

100–200 ml water i.v. and up to

horticultural sprays.

with ruminal stasis, diarrhoea,

60 g orally (adult).

severe thirst, dehydration,

collapse and death.

Atropine-containing

Deadly nightshade (Atropa

Those of atropinization, dilation of

Uncommon, often little can be

plants

belladonna), black or stinking

pupils, dryness of mouth

done; pilocarpine can be given by

henbane (Hyoscyamus niger),

progressing to excitement,

injection but is not widely

thorn apple (Datura stramonum).

incoordination, convulsions and

available and can itself be

death.

dangerous.

Brassica

Conversion of S-methyl cysteine

Peracute – collapse and death;

Stop feeding kale, blood

sulphoxide in the plants to

acute – haemaglobinuria,

transfusion, vitamin injections,

dimethyl disulphide. Kale

pallor, weakness, jaundice,

iron. Feed good quality hay

(Brassica deracea) fed as fodder

tachycardia, diarrhoea, low

before and as well as kale.

crop, rape (B. napus) and

haematocrit. Heinz–Ehrlich

cultivated cabbages. Usually

bodies in RBCs. Can be fatal.

need to eat kale as sole fodder for

Within a group usually a high

about three weeks.

prevalence of subclinical

anaemia.

Cyanide

Cyanide release by hydrolysis from

Dyspnoea, bright red mucosae,

Inject sodium nitrite 16 mg/kg iv

cyanogenetic glycosides in plants

recumbency, convulsions,

followed by sodium thiosulphate

including cherry laurel (Prunus

opisthotonus, rapid death. Often

(40 mg/kg iv). Repeat only

laurocerasus), linseed cake,

less acute; depression,

thiosulphate, 30 g doses of

sudan and sorghum grasses,

staggering, muscle tremor,

sodium thiosulphate orally.

couch grass, white clover.

dyspnoea, death within 2 h,

fresh blood is bright red.

Ergot

Ergots (sclerotia of Claviceps

Acute (convulsive) rare –

Remove from feed source, avoid

purpurea) are found on rye and

depression, staggering,

heavily ergotized pastures or

also on other cereal grains and

blindness, convulsions. Chronic

uninspected stored grain

rye grasses particularly in warm

(gangrenous) – lameness,

following warm wet summers.

wet seasons.

abnormal gait, extremities

swollen, reddened, gangrenous,

particularly tail, ear tips, distal

limbs.

Formaldehyde

Formalin used for agricultural

Mild – salivation, inflammation of

Do not leave cattle unattended

(formalin)

purposes, e.g. foot baths.

buccal mucosae. Severe –

near source of diluted formalin.

Usually associated with a lack of

dullness abdominal pain, weak

Symptomatic therapy.

available drinking water.

pulse, coma, death.

Furazolidone

Accidental overdosage following

Acute – hyperaesthesia,

Stop administration of

(see p. 260)

therapeutic or prophylactic use,

convulsions, death. Chronic –

furazolidone, sedatives to control

improper mixing in milk

haemorrhages, necrotic lesions in

hyperaesthesia.

substitute.

mouth, dysentery.

Hemlock; spotted

Umbelliferous plant common in

Dilation of pupils, weakness,

Avoid contact with plant and

hemlock, Conium

wasteland and neglected pasture,

staggering, muscle tremor, death

overgrazing, especially in early

maculatum

characterized by permanganate-

from respiratory failure.

part of the grazing season.

coloured spots on stems and

mousey odour when crushed.

May be eaten when grazing is

sparse; palatibility decreases as

plant gets woody in late summer.

contd.

Table 54.3

Continued

Poison

Usual source(s)

Clinical signs

Management guidelines

Hemlock; water

Plant grows in wet ditches and on

Dilated pupils, frothing at the

None, awareness of the potential

hemlock, cowbane,

edges of ponds and swamps.

mouth, abdominal pain, violent

danger.

Cicuta virosa

Contains the very toxic

convulsions, rapid death.

cicutotoxin, the roots being the

most dangerous.

Mercury

Organic mercury compounds from

May not appear for three to four

Poisoned animals can be treated

grain dressed with fungicide, no

weeks after feeding dressed

with sodium thiosulphate (20 mg/

longer common due to control of

grain; inappetence, blindness,

kg i.v. and orally) or dimercaprol

seed dressings.

staggering, weakness, nervous

(BAL) 2.5–5 mg/kg iv 4¥

signs.

daily.

Metaldehyde

Molluscicide for slug/snail control.

Incoordination, hyperaesthesia,

Sedation or anaesthesia to control

salivation, tremor, dyspnoea,

hyperaesthesia and convulsions.

fever, ataxia, convulsions,

Consider rumenotomy.

opisthotonus, cyanosis, death.

Molybdenum

High soil levels on teart pastures,

Diarrhoea, often green or black

Test group for low blood copper,

exacerbated by low copper and

with offensive odour,

careful administration of copper

high sulphate levels. Induces a

depigmentation, poor condition,

supplements or injections. A

relative copper deficiency; high

stiff gait in young, anaemia,

perennial problem on known

dietary molybdenum and low

osteoporosis, fractures, poor

pastures and prophylactic

available copper are interlinked.

milk yield.

measures should be introduced.

Ionophores (monensin,

Accidental overdosage or incorrect

Anorexia, depression, diarrhoea,

History of recent access to

salinomycin,

mixing in cattle diets.

ataxia, recumbency, dyspnoea,

changed feed useful in

lasalocid)

can be fatal. Signs develop in up

presumptive diagnosis. Feed

to two days or longer with lower

assays, remove ionophore from

toxic doses.

feed of affected group, ensure

correct levels in feed.

Onion, wild garlic,

Large quantities of unwanted

Haemolytic anaemia,

Remove from source, feed well,

Allium sp.

onions fed to stock, access to wild

haemoglobinuria, pallor,

multivitamin and iron by

garlic in woodlands.

possibly jaundice. Can be fatal.

injection.

Organochlorine

Accidental access or overexposure

Acute and chronic syndromes

Give adsorbents orally and/or

compounds

to insecticides for animal or

occur – abdominal problems and

wash skin contamination with soap

agricultural use.

typically salivation,

and water. Control excitation with

incoordination, muscle tremor,

pentobarbitone or sedatives.

clonic spasms, convulsions,

Exposure of food-producing

possibly aimless or frenzied

animals to these chemicals may

movements, clonic–tonic

result in high and persistent

convulsions, collapse, death.

tissue residues, particularly in fat.

Oxalate-containing

Unwilted leaves of sugar beet,

Rapid ingestion of soluble oxalates

Treatment of clinical cases with

plants

fodder beet, mangels, also fat

induces hypocalcaemia, paresis,

calcium borogluconate as in milk

hen (Chenopodium album),

muscle tremor, recumbency,

fever. The response is not as

docks and sorrells (Rumex sp.).

coma, death. Ill-thrift due to

certain and is often unsuccessful.

Oxalate is detoxified by ruminal

chronic renal damage.

Affected forage should be

microflora and hence previous

introduced gradually, is best fed

sublethal exposure will increase

wilted, and not as the sole feed

tolerance to oxalate. Large

source.

quantities of unwilted leaves

need to be consumed over a short

period.

Plants causing

In addition to those described

Generally salivation, teeth

Uncommon, symptomatic

gastrointestinal signs

elsewhere there are a large

grinding, abdominal pain, severe

treatment of colic and diarrhoea,

number of hedgerow and wild

diarrhoea, may be accompanied

remove from access to suspect

plants which will induce

by nervous signs. Fatal in some

plants.

salivation, colic and diarrhoea,

cases.

these include: cuckoo pint (Arum

maculatum), black bryony

(Tamus communis), autumn

crocus (Colchium autumnale),

monkshood (Aconitum napellus),

hellebores (Helleborus sp.),

buttercup (Ranunculus sp.),

spindle tree (Euonymus

europaeus), white bryony

(Bryonia dioica), dog's mercury

(Mercurialis perennis), box

Table 54.3

Continued

Poison

Usual source(s)

Clinical signs

Management guidelines

(Buxus sempervirens), greater

celandine (Chelidonium major),

charlock (Sinapis arvensis).

Plants causing

St John's wort (Hypericum

Photosensitization, erythema,

House animals out of direct

photosensitization

perforatum) is a common plant in

swelling, necrosis of skin in white

sunlight, debride raw areas,

(see p. 884)

hedgerows and rough grazing and

areas only, pruritus, oedema,

protect against infection and

is the most frequently implicated

later sloughing and self-inflicted

blowfly strike.

in primary photosensitization. It

injury.

contains the photodynamic

hypericin which is retained when

dried. Buckwheat (Fagopyrum

esculentum) is also

photodynamic. Several plants

including the ragworts (Senecio

sp.) and bog asphodel

(Narthecium ossifragium) cause

secondary photosensitization

following liver damage.

Rhododendron

Rhododendron ponticum grows as a

Salivation, staggering gait,

Symptomatic treatment,

cultivated shrub but also extensively

abdominal pain, collapse, death

purgatives, ensure adequate

in the wild on acid soils where it

in a few days. Projectile

fencing of stock.

can form large thickets. Poisoning

vomiting, green froth around

Rumenotomy?

usually occurs when hungry cattle

mouth.

break out into woodland or gardens

or from hedge clippings dumped in

fields.

Selenium

Toxic levels of selenium may

Acute (rare) – blindness,

Test forage for selenium levels

(see p. 305)

accumulate in certain plants

depression, circling, head-

and withdraw suspect feed

including certain forage plants

pressing, colic, paralysis, death.

(>5 ppm is suspect). Levels in

and grasses growing on high

Chronic – loss of condition,

blood >2 ppm indicate

selenium soils. Increased levels

lameness, emaciation, hair loss

excessive exposure.

may occur accidentally in feeds; the

from base of tail, hoof damage.

diet should contain under 5 ppm.

Solanine-containing

Plants of the genus Solanum. Green

Salivation, dyspnoea, diarrhoea,

Symptomatic treatment, green

plants

tubers and leaves of the potato

depression, prostration, coma.

potatoes should not be fed to

(S. tuberosum). The woody

Can be fatal.

livestock but boiling and feeding

nightshade (S. dulcamara) is

at less than 25% of diet reduces

common in hedgerows; this plant

risk.

together with the black

nightshade (S. nigrum) are

common in neglected pasture.

All parts of the nightshades are

toxic, the berries being the most

dangerous.

Tremorgenic

Certain fungi of the genera

‘Ryegrass staggers’, usually not

Recovery is usually uneventful

mycotoxins

Penicillium and Aspergillus

observed until animals are

when removed from suspect

which grow at the base of the

disturbed, muscular tremors,

pasture and given alternative

grass sward produce tremorgens.

stumbling, swaying; when forced

feed.

Toxicity is most likely to occur in

to run develop a high-stepping

hot, dry summers with cattle

gait, staggering, sternal

grazing at the bottom of the grass

recumbency, will then recover if

plant.

left undisturbed.

Urea

Inadequate mixing or diluting of

Begin within 1 hour, excessive

Drenching with vinegar (4–7 l

dietary urea, accidental access to

salivation, frothing at mouth,

daily) together with cold water

concentrated amounts, feeding to

bellowing, bloat, muscle

(20–40 l). Ensure adequate

unadapted animals, or with high-

fasciculations particularly of the

mixing of urea, continuous access

fibre, low-energy rations.

head, colic, dyspnoea, death.

is preferred; tolerance will build

Overconsumption of urea-

up in cattle accustomed to urea

containing blocks or licks.

feeding, but is short-lived on

withdrawal.

Water dropwort

Root tubers from the plant which

Often sudden death, salivation,

No treatment, awareness of

(Oenanthe crocata)

grows commonly in ditches and

dilated pupils, convulsions,

potential danger to grazing

marshes. Usually exposed tubers

death.

animals when ditches are cleared.

on pasture following ditching or

drainage operations.

poisoning (p. 943), and it may clinically resemble nitrate

are seen. Ingestion of large quantities, particularly by

toxicosis (p. 950) but without the cyanotic mucosae. The

calves, tends to lead to an acute syndrome with the

nicotinic effects may resemble hypomagnesaemia

neurological signs predominating. Ingestion of lesser

(pp. 253, 787).

amounts results in a subacute pattern. In very acute

cases sudden death may be the presenting sign. Acute

cases are characterized by sudden onset of muscle fas-

Treatment and prevention

ciculations, particularly of the head and neck, frothing

Atrophine sulphate is the specific antidote to organo-
at the mouth, teeth grinding, jaw champing and abnor-
phosphate or carbamate toxicosis. It acts by blocking
mal movements of the head and eyelids. There is a
the effects of acetylcholine at nerve endings and will
staggering gait and apparent blindness with pupillary
thus only counteract the muscarinic effects. The re-
dilation. Colic may be observed. This may progress to
commended dose is 0.1 mg/kg bodyweight by slow
collapse, tonic/clonic seizures, hyperaesthesia and
intravenous injection followed by 0.4 mg/kg given
death. In adults, abnormal patterns of behaviour,
subcutaneously. The effects are usually observed within
including pushing through fences, charging or mania
minutes. Treatment may need to be repeated during the
can be seen.
first 48 hours depending on clinical response. Cattle
Subacute cases are dull and anorexic and are appar-
should be removed from the suspected source and
ently blind. There may be aimless wandering, there is
washed with soap and water if exposed via the skin.

muscular tremor and a staggering gait, tooth grinding,

Intestinal adsorbents such as activated charcoal given

signs of colic and a ruminal stasis resulting in constipa-

by drench or stomach tube are also useful. Prevention

tion followed by diarrhoea. The palpebral eye reflex is

is dependent on recognition of the wide diversity of

absent. Rarely, a more chronic form may be observed

uses of organophosphates and carbamates in the envi-

with poor growth and anaemia.

ronment and the possibility of accidental exposure or

overdosage.

Necropsy

Lead poisoning

In very acute cases there may be no gross lesions but

(see also p. 906)

the lead-containing material, such as flaked paint, oil or

grease, may be found in the reticulum and rumen. In

Poisoning by lead is one of the most common intoxica-

less acute and subacute cases lesions of the gastroin-

tions of cattle, which are more susceptible to this

testinal tract are frequently observed including aboma-

toxicant than other farm species.

sitis and enteritis. The liver and kidneys may be

abnormally pale and show some degeneration. There

Sources of toxicant

are frequently epicardial and sometimes endocardial

haemorrhages. The brain may be oedematous. Histo-

There are many potential sources of lead in the envi-

logical changes may be observed in the brain depend-

ronment and accidental access by cattle to a lead-

ing on the length of exposure. The hepatic and renal

containing product is the usual predisposing cause

cells may also show degeneration.

which, combined with their natural inquisitiveness and

a tendency to lick foreign objects, means that a toxic

dose is soon ingested. Common sources of lead include

Diagnosis

old flaking paint, batteries, discarded engine sump oil,

grease, putty, plumber's materials, linoleum and mine

Often the history and circumstantial evidence (sus-

washings. Grass from verges of heavily used roads can

pected lead-containing material in the environment) *also contain significant amounts of lead from leaded*

strongly support a tentative diagnosis of lead poisoning

petrol. Lead poisoning is more frequently observed in

particularly when the neurological signs are observed

calves than adults. Poisoning can result from a single

in calves. This being the case treatment should be insti-

ingestion of a toxic amount or from a continued inges-

tuted immediately, a successful outcome of which is

tion of lead from the environment with accumulation in

highly supportive of the diagnosis. A confirmatory diag-

the body tissue.

nosis in the live animal rests on a measurement of blood

lead levels. A heparinized blood sample should be sub-

mitted, and levels in excess of 0.4 ppm are considered

Signs

diagnostic. From the dead animal, kidney, liver and

The onset of disease and, to some extent, the clinical

stomach contents should be submitted. Measurement

picture that ensues depends on the dose of lead

from the kidney is most reliable and levels in excess of

ingested. Both neurological and gastrointestinal signs

20 ppm are diagnostic.

Principal differential diagnoses

important single species the common or tansy ragwort

(S. jacobaea). In temperate regions the ragwort is wide-In the absence of compelling circumstantial evidence

spread in wasteland and neglected pastures and poses

of poisoning, lead intoxication can closely resemble

a serious potential toxic threat to livestock. Plants of

several other disorders of calves characterized by neu-

the genera Crotalaria, Heliotropium and Amsinckia rological signs. These include infections, e.g. listeriosis

also contain the toxic alkaloids.

(p. 904), Haemophilus somnus infection, brain abscess, rabies, coccidiosis (p. 282), together with hypomagnesaemia, tetanus, cerebrocortical necrosis (pp. 261, 903),

Circumstances of poisoning

vitamin A deficiency, other poisoning (e.g. mercury) (p.

Common ragwort is not attractive to grazing animals

942) and in older animals nervous acetonaemia (p. 794)

and cattle will usually avoid eating the fresh vegetative

and bovine spongiform encephalopathy (BSE) (p. 909).

plant. However, this is not always the case and should *never be relied upon. The plant is relatively late in*

Treatment and prevention

emerging through the sward in the spring and, particu-

larly following widespread seeding from the previous

Treatment is threefold: (i) supportive and symptomatic,

year, small, young plants can become finely distributed

(ii) oral salts to precipitate soluble lead and (iii) intra-

within the grasses. This is then non-selectively grazed.

venous administration of lead-chelating agents, which

In dry conditions and where grass growth is poor, cattle

can increase by up to 50 times the rate of lead

may also be attracted to ragwort. The unattractiveness

excretion.

of the plant is lost, but its toxicity largely retained, when

Convulsions and nervous signs can be controlled

it is dried in hay or ensiled and this represents the single

by the use of tranquillizers and sedatives including

most important cause of intoxication. Cattle will readily

acepromazine and xylazine. Magnesium sulphate, egg

consume hay or silage containing ragwort.

whites and strong tea will precipitate any soluble lead *remaining in the gut as insoluble salts of lead. Calcium*

disodium edetate should be given by slow intravenous

Pathogenesis

injection at a dose of 110–220 mg/kg body weight. This

The pyrrolizidine alkaloids are hepatotoxic, damaging

dose should preferably be divided between two or three

the hepatocytes. The speed at which this cell damage

separate injections per day. Treatment should be given

occurs and the consequences thereof are dependent on

for two to three days, withheld for two days and then

the dose of alkaloid and the duration of consumption.

repeated, repeating this pattern again if necessary.

The liver has a large functional reserve and thus can

Good nursing care and oral fluid replacement is

withstand the functional loss of many hepatocytes

required to combat dehydration. Clinical improvement

before gross dysfunction occurs. An animal would

may take two or three days to be apparent and blind-

therefore only rarely ever ingest sufficient quantities of

ness can persist for up to three weeks. Prevention of

alkaloids over a sufficiently short period to result in *poisoning by lead is largely a matter of education of*

acute poisoning. Much more commonly cattle will

those responsible for the care of livestock. A knowledge

ingest smaller amounts of the toxicant over a period of

of the common lead-containing commodities and the

weeks or even months resulting in a more gradual loss

need to be vigilant about accidental access should be

of hepatocyte function, it only being when the func-

stressed.

tional reserve of the organ has been exceeded that gross

hepatic dysfunction and hence clinical disease results.

Ragwort poisoning

Signs

Poisoning of cattle by the pyrrolizidine alkaloids found

The clinical picture can vary: although the principal

in certain genera of plants is a common problem in

cause is a subacute to chronic intoxication, acute clini-

many parts of the world and can result in severe losses.

cal syndromes may be observed, although more usually

a subacute pattern is seen in cattle. Affected cattle will

lose weight and usually develop a mild to moderate

Sources of toxicant

jaundice, and may show photosensitization. Diarrhoea,

The principal genus of plants containing pyrrolizidine

colic and straining characteristically occur. Subcuta-

alkaloids is Senecio of which there are in excess of

neous oedema and ascites may be present due to

1200 species. The quantity and type of alkaloid varies

hypoalbuminaemia. Affected cattle are usually dull

between species, for example the widespread groundsel

and depressed. They may show signs of hepatic

(Senecio vulgaris) is much less harmful than the most

encephalopathy, resulting from the effects of raised

blood ammonia levels on the brain due to the inability

be immediately switched to a non-contaminated food

of the damaged liver adequately to remove urea arriv-

supply. Prevention relies upon control of the plant and

ing via the portal circulation. Signs of encephalopathy

an understanding of the syndrome. Hand pulling and

include an unawareness of surroundings, staggering

burning of plants before seeding and the use of herbi-

gait, aimless wandering, circling and apparent blindness.

cide sprays is to be recommended on affected pastures.

Head pressing and aggressive syndromes are rare in

Sheep are less susceptible than cattle and can often

cattle. Death usually occurs a few days after the com-

graze affected pasture or eat hay if not too heavily con-

mencement of such clinical signs.

taminated. Hay or silage should never be prepared

from ragwort-infested grassland.

Necropsy

The carcass may be jaundiced and in poor condition,

Bracken poisoning

and ascites may be present. The liver is characteristi-

cally shrunken, fibrosed, slate-grey or mottled. The his-

The bracken fern (Pteridium) is widely distributed in

tological picture of the liver in pyrrolizidine alkaloid

the UK, the USA and in many other temperate hilly

toxicosis is characteristic and highly suggestive of the

and forested areas. It can relatively quickly become

condition but not pathognomonic. The lesions are a

dominant in a grassland pasture. Where cattle have *fine pericellular cirrhosis, bile duct proliferation and continued access to bracken-contaminated grazing, hepatocytomegaly. toxicosis can result.*

Diagnosis

Source of toxicant

The history and circumstantial evidence are extremely important. It is vital to understand the chronic nature Cattle are often reluctant to eat bracken and will of the intoxication; in most cases animals will often have usually only do so when grassland grazing is sparse. eaten the plants for several weeks or months prior to Cattle need to graze bracken as a significant constituent the development of clinical signs. Bearing this in mind, of the diet for several weeks or months before clinical examination of hay, silage and pasture for the plants is disease may become apparent. The rhizomes, exposed vital, but their absence does not necessarily eliminate after ploughing of bracken-infested pasture, are more pyrrolizidine alkaloid toxicosis unless a history of an attractive and dangerous as are newly sprouted young *unchanged, uncontaminated diet can be positively*

fronds. Some of the toxicity remains when bracken

established. Histological examination of the liver is the

becomes dried in hay. Bracken contains a thiaminase

method of choice in establishing a diagnosis and, in the

but, unlike the situation in herbivorous non-ruminants,

live animal, liver biopsy is the most useful diagnostic

cattle are largely unaffected by it. Bracken also con-

aid. Serum biochemistry will usually demonstrate an

tains a variety of other toxic chemicals including a

elevation of g-glutamyl transferase (GGT), and in some

cyanogenetic glycoside (which is only usually present in

cases an elevation in aspartate amino-transferase

harmless amounts), toxins that depress bone marrow

(AST). Chemical analysis for the alkaloids is not often

and a carcinogen (ptaquiloside). These last two can

of value.

cause disease in cattle.

Principal differential diagnoses

Signs

Particularly where hepatic encephalopathy is marked, *Acute poisoning: Acute or subacute toxicosis is the*

ragwort poisoning can resemble rabies, BSE (p. 909),

result of bone marrow depression producing leucope-

brain abscess/tumour (p. 902), encephalomyelitis (p.

nia and thrombocytopenia and occurs following con-

901) or lead poisoning (pp. 906, 944). Where wasting,

sumption of comparatively large amounts of bracken.

jaundice and diarrhoea are the dominant clinical signs,

Clinical signs may develop for up to several weeks

intestinal parasitism (p. 267), fascioliosis (p. 276), hep-

after the exposure to bracken has ended. Signs may

atitis and biliary obstruction should be considered.

be sudden in onset and include anorexia, depression

and dysentery, and there may be pyrexia; various signs

of capillary fragility and haemorrhage become

Treatment and prevention

obvious including petechiae on mucosae, bleeding from

Once the clinical picture has developed there is no

nose, vagina and conjunctiva. Trauma may produce

worthwhile treatment for pyrrolizidine alkaloid toxico-

haematomata. Heart and respiratory rates are in-

sis, but clinically normal cattle in the same group should

creased. Progressive weakness ensues and death may

occur in one to five days. In calves there is often pyrexia,

bladder wall and/or carcinomas may be found in the

dysentery, frank haemorrhage and petechiation of

upper alimentary tract.

visible mucosae. Death is often the result of heart

failure. There may be laryngeal oedema and marked

Principal differential diagnoses

dyspnoea. Due to the leucopenia, a bacteraemia or

other secondary infections are often complications.

Acute disease can resemble leptospirosis, kale anaemia,

or babesiosis. Enzootic haematuria should be differen-

Enzootic haematuria: Where cattle have consumed

tiated from babesiosis (p. 748) and postparturient

comparatively small quantities of bracken over pro-

haemoglobinuria (p. 792). The syndromes caused by

longed periods, neoplastic changes can develop in the

upper alimentary squamous cell carcinoma can resem-

transitional cell epithelium of the bladder. Various *ble Johne's disease (p. 857), copper deficiency (p. 298)*

tumour types may occur including haemangiomas,

and mucosal disease (p. 853).

transitional cell carcinomas, adenocarcinomas and hae-

mangiosarcomas. The resulting clinical picture is

Treatment and prevention

termed enzootic haematuria. The condition varies from

a mild, persistent haematuria as the only clinical sign to

In acute cases the clinical outcome is probably more

severe cases in which there is pallor of the mucosae,

influenced by the degree of bone marrow damage than

dysuria and tenesmus. The urine in severe cases has

by treatment. Broad-spectrum antibiotics should be

visible blood clots in it (see p. 154).

administered to counteract bacteraemia and secondary

infections. Blood transfusions can be considered. The

Upper alimentary squamous cell carcinoma (see also

use of bone marrow stimulants including dl-batyl

p. 828): A third less common clinical syndrome result-

alcohol has been described. There is no successful ther-

ing from prolonged exposure to bracken is upper *apeutic management of urinary bladder or alimentary alimentary squamous cell carcinoma, which may neoplasia. Despite its widespread abundance in certain accompany changes or tumour formation in the bladder areas the bracken fern should always be viewed as a wall. The disease has strong regional incidence, e.g. in potentially toxic plant to cattle. Access to bracken-western Scotland and Wales, often in suckler cows. Four infested pasture should be always limited, especially if clinical syndromes are recognized depending on the site grass growth is poor. In particular, cattle should never be of tumour formation. Oropharyngeal tumours produce allowed access to recently ploughed land with bracken loss of condition, drooling of saliva, coughing or present and where the rhizomes are exposed, especially snoring, halitosis. The nasal discharge may contain if they have started to reshoot. Limited areas of bracken ingesta, submandibular lymphadenopathy and diar-infestation can be fenced off, and burning, ploughing and rhoea. Oesophageal tumours produce diarrhoea, hali-reseeding or herbicide control are all measures that can* *tosis, coughing, drooling and palpable masses in the*

reduce the level of bracken contamination.

oesophagus. Ruminal tympany can result from tumours

in the lower oesophagus; there is initially intermittent

bloat with loss of condition, then diarrhoea and resist-

Yew poisoning

ance to the passage of a stomach tube. Tumours in the

dorsal rumen produce loss of condition, diarrhoea, dis-

Cattle that gain access to yew trees (genus Taxus) are tended abdomen and bloat. Oropharyngeal papillomas

frequently fatally poisoned.

may often accompany tumours at any site.

Sources of toxicant

Diagnosis

The various species of yew (Taxus baccata, English yew; This is based on the clinical signs and an association

T. lineata, Irish yew; T. cuspidata, Japanese yew) are with bracken feeding or of prolonged exposure to

common ornamental trees or hedgeing plants particu-

bracken. In acute or subacute cases, bone marrow

larly of old established gardens. The leaves and woody

depression results in thrombocytopenia and leucope-

twigs of the yew contain various toxic alkaloids collec-

nia, prolonged bleeding time and clot formation time.

tively termed taxines. The taxines are also present in the

seeds but not the fleshy red outer part of the fruit.

Necropsy

Circumstances of poisoning

In acute or subacute cases there are multiple internal

haemorrhages of varying size and petechiation. The

Yew is well known as a toxic plant among the agricul-

bone marrow is pale. Tumour changes are evident in the

tural and rural community, and poisoning is thus usually

the result of neglect, ignorance or (rarely) malice.

absence of uptake inhibitory factors such as molybde-

Cattle will often consume the fresh plant if they are

num, iron or sulphur. The acute form follows a single

allowed access and will also eat fresh hedge clippings

large dose of copper, but more commonly it is the result

or trimmed branches dumped into their field. The

of mineral ingestion over a long period of time. The

taxines are severe cardiac depressants.

copper is retained and accumulates within the liver. It has also been seen with improper use of copper sup-plements. Some problems have arisen from industrial

Signs

contamination, and from copper addition to the

If moderate amounts of yew have been ingested,

pasture. There are some areas in the world with copper-

sudden death is often the presenting sign. If seen alive,

rich soil. While the problem of copper poisoning is

cattle may show dyspnoea, abdominal pain, muscle

common in sheep, it is much less seen in cattle. Prob-

tremor, weakness and collapse. The pulse later becomes

lems have increased in North America, Britain and

slower before finally disappearing with the heart stop-

other countries in recent years.

ping in diastolic arrest. Recovery is rare and is depend-ent on ingesting only relatively small amounts of the

Circumstances of poisoning

plant.

Cattle are less susceptible to copper toxicity than sheep and are able to ingest higher levels than the latter

Necropsy

without any deleterious effect. Animals with intercur-

Frequently, there are no significant gross findings except

rent liver disease may be more susceptible. Chronic

the presence of yew leaves and twigs among the ruminal

intoxication occurs when there is a build-up of the

contents or sometimes still in the mouth. The charac-

element within the liver until the maximum level which

teristic leaves of the yew when separated by careful

the organ can contain is exceeded. Then the copper is

washing from the general ruminal contents are thus

released into the blood and causes an acute intravascu-

highly suggestive of poisoning.

lar haemolytic crisis. Problems of copper intoxication

were reported to be increasing in the first years of the

twenty-first century (Bidewell et al. , 2000). In their find-Diagnosis

ings grossly increased copper intakes were not always

History or circumstantial evidence of access to yew, and

found. However, points to consider include the dura-

presence of leaves and twigs in the rumen contents will

tion of feeding a copper supplement and the type of *usually establish a diagnosis.*

supplement (it is claimed that the copper in many

amino acid chelated minerals is many more times avail-

able than that in inorganic compounds). Jerseys have

Principal differential diagnoses

been said to be more susceptible, possibly because of

Yew poisoning should be distinguished from other

genetic susceptibility or perhaps related to a lower

causes of sudden death, for example lightning strike

bodyweight.

(p. 930), anthrax (p. 717), blackleg (p. 723), etc.

Signs

Treatment and prevention

The problem can be either acute, which is rare, or

There is no specific therapy. Symptomatic treatment

chronic. The latter is more common but often also

can be offered to clinically affected animals but the like-

appears as a sudden presentation.

lihood of recovery or death is principally influenced by

the amount of the plant already ingested. Rumenotomy

Acute: The animal shows pronounced depression with *is possible immediately after observing cattle consum-*

colic, rapid collapse and death. In some cases there is a

ing yew. Generally, yew is well known as a toxic plant

green diarrhoea when the animal has had access to the

but the necessity of preventing cattle from gaining

excess copper within the diet.

access to the plant should be constantly stressed.

Chronic: The average length of illness before death is ***Copper poisoning***

one to three days, although individual animals may

(see p. 300)

show signs for up to three weeks. There is an acute

haemolytic crisis following a prolonged access to excess

Sources of toxicant

copper. The signs again often rapidly develop with

The normal problem is an extensive intake of copper,

anorexia, depression, rumen stasis, cold extremities,

usually from the diet and particularly where there is an

haemolytic jaundice, anaemia with pale mucous

membranes, cyanosis of the teats, haemoglobinuria,

levels before any supplementation is given. The normal *methaemoglobinaemia and death. Some animals have*

minimum dietary copper level for adult dairy cattle is

shown abortion, ataxia, photosensitization and other

12 mg/kg dietary DM. This level often has to be raised,

signs. Recumbency is common before death.

especially where there are inhibitory factors present

such as molybdenum (see p. 298). However, in many

countries there are restrictions on the amount of copper

Necropsy

supplementation. Thus in Britain the Medicated Feed-

In acute cases there is a severe gastroenteritis with

ingstuffs Regulations allow dairy cattle to receive up to

ulceration and erosion. The abomasum is particularly

35 mg/kg dietary DM (about 800 mg copper/head per

affected. The chronic signs are those of a haemolytic

day) without restriction. However, higher supplemen-

crisis. Jaundice is present but may be variable in degree;

tation levels can be licensed up to a maximum of

there is hepatomegaly. In sheep there is usually dark

2000 mg/head per day, but with certain restrictions.

discoloration of the kidneys, but this is not so common *in cattle. Histologically there is a necrotizing hepato-*

pathy and nephropathy.

Fluoride poisoning (fluorosis)

At normal levels the ingestion of fluorides causes

Diagnosis

no harm or is even beneficial to cattle. However, at

The signs and post-mortem picture are helpful. Usually

higher levels a chronic (or rarely acute) intoxication

there will be a known source of copper which has been

results.

ingested, although this may not always be the case. The

liver will contain more than 8000 mmol/kg dry matter

Sources of toxicant

(DM) (although often levels are between 10 000 and

20 000 mmol/kg DM). Plasma copper levels are usually

Cattle normally gain access to excess fluoride from

very high (normally over 50 mmol/l). Blood biochem-

grazing contaminated pasture. Historically, this com-

istry usually shows elevated liver enzymes such as

monly arose from industrial effluent, for example from

aspartate aminotransferase, glutamate dehydrogenase *brick manufacture, aluminium smelters, steel works or*

and gamma glutamyl transferase, and this assists in

phosphate production. More recently, other sources of

diagnosis.

excess fluoride have been recognized including geo-

thermal spring water (when used either as a source of

drinking water or for pasture irrigation) and high fluo-

Principal differential diagnoses

ride-bearing soils. Inorganic rock phosphate is often

Nitrate poisoning (see p. 950) may need to be elimi-

highly toxic and requires defluorination prior to use as

nated. There are also many causes of haemolytic

a phosphorus supplement.

anaemia including babesiosis (p. 948), kale poisoning

(p. 941) and post-parturient haemoglobinuria (p. 792).

Circumstances of poisoning

In most cases the history should be helpful. However,

the use of blood copper examination should provide

Rarely will cattle consume sufficient fluoride to result

good evidence of the cause if due to copper toxicity.

in acute intoxication, but this may result following heavy pasture contamination. More commonly, the

grazing of fluoride-contaminated pasture over months

Treatment and prevention

or years results in an insidious chronic disease.

First remove the animals from the copper source, if

known. While treatment is often of limited value,

Signs

calcium versanate iv at a dose of 70 mg/kg bodyweight

(see p. 945 for details) has been used in calves. Oral

In the acute disease there is anorexia, depression, rest-

sodium thiosulphate at a dose of 1 g daily has resulted

lessness, dyspnoea, excessive salivation and muscle

in some recoveries. Oral ammonium thiomolybdate at

tremor leading to convulsions, collapse and death.

100 to 400 mg daily can also be of use. In sheep, iv injec-

tion of ammonium tetrathiomolybdate at a dose of

Chronic fluorosis: The developing teeth of young cattle 2.7 mg/kg bodyweight on three to six occasions at inter-are sensitive to excessive fluoride and dental lesions

vals of two to three days has been successfully used.

are common in animals exposed before the full adult

While not licensed, it might also be of benefit to cattle.

dentition has developed. The dental abnormalities

If cattle are suspected of having a copper deficiency,

observed are: increased attrition and liability to frac-

blood samples should be taken to estimate the copper

ture, mottling of enamel with white areas, abnormal

pigmentation, and yellow or brown discoloration. Teeth

ingestion of high or suspect levels of fluoride is unavoid-

may be poorly developed and mineralized.

able, aluminium sulphate or calcium carbonate added

Bones are also affected by excessive fluoride intake.

to the diet may be beneficial in reducing fluoride

Although the bones of young cattle are more suscepti-

deposition in teeth and bone.

ble, the bones of cattle of any age can be affected by

fluoride-induced changes. These are principally periar-

ticular calcification and the formation of exostoses

Nitrate/nitrite poisoning

resulting in an intermittent lameness and stiffness of

gait, particularly of the hind legs. Palpable exostoses

Under certain circumstances various types of grazing *appear on the metacarpals and metatarsals, ribs and*

and forage crops may accumulate toxic levels of nitrate

mandible and these are painful on pressure. In severe

within their foliage. In addition, the widespread use of

cases fractures of the third phalanx are not uncommon.

inorganic nitrate fertilizers poses a potential threat of

Affected cattle are unthrifty and have a dull staring

nitrate poisoning in grazing cattle.

coat.

Source of toxicant

Necropsy

The Brassica plants, green cereals (wheat, barley, rye Dental lesions are found, as described above. Bones

and maize) as well as the Sorghum and Sudan grasses,

have a roughened surface and are chalky white, and

docks, nightshades and sweet clover may accumulate

new bone formation is evident.

excess levels of nitrate in their tissues. Nitrate accumu-

lation may occur after excessive use of inorganic nitrate

fertilizers or following heavy rain after a period of

Diagnosis

drought, which leaches accumulated nitrate into the

The history, clinical signs and post-mortem findings,

water table. Water run-off from heavily fertilized fields

together with circumstantial evidence of access to

or excess application of nitrogenous fertilizers are the

suspect sources of fluoride, are usually suggestive of

commonest dangers in intensively managed pastures

fluorosis. Radiographic examination of lower limb

and can lead to problems on grassland pasture or even

bones may demonstrate the presence of exostoses.

hay made shortly after exposure of the sward to high

Chemical analysis of urine, blood and bone for fluorine

nitrate levels. Cattle thus become poisoned by consum-

content may be useful. The levels in bone rise with age

ing normal amounts of the fresh pasture containing the

and elevated levels are indicative of previous exposure

abnormal nitrate load.

to fluoride. Fluorides are chiefly excreted via the urine

Nitrate ions in the rumen are reduced by the ruminal

and do not accumulate in soft tissues.

microflora to nitrite ions, which are subsequently ab-

Attempts should be made to identify the source of

sorbed. The nitrite ion oxidizes the iron in haemoglo-

fluoride, and feed, water and pasture analysed for fluo-

bin (to its ferric state) producing methaemoglobin,

ride content. As a guide the diet should contain less

which is unable to bind oxygen. A single intake of

than 50 ppm fluorine on a dry matter basis, and drink-

nitrate over a short period is more toxic than accumu-

ing water less than 8 mg/l.

lating the same amount over several days or weeks. A

degree of tolerance may also build up in stock receiv-

ing sublethal amounts over a prolonged period. High

Principal differential diagnoses

grain diets tend to be somewhat protective against the

The dental and bone lesions are fairly characteristic of

effects of excess nitrate.

fluorosis but in their absence other causes of ill thrift

including mineral deficiencies, parasitism and the

Signs

common forms of lameness must be differentiated.

The condition is usually acute, less commonly subacute.

In the acute condition, signs are seen within a few hours

Treatment and prevention

of consuming high levels of nitrate. The clinical picture

There is no specific antidote and dental lesions are

is due to methaemoglobinaemia and the associated

permanent. After removal from the source of excess

anoxia. The visible mucosae become blue and cyanotic,

fluoride the bones of affected cattle will gradually be

the pulse is weak and rapid, there is drooling of saliva

remodelled, with normal bone deposition ensuing, but

and tachypnoea, exercise is resented and, if forced, may

severely affected cattle will never completely recover.

result in severe dyspnoea with mouth breathing. If

Mildly affected cattle should be removed from the

untreated the condition deteriorates, and there is

source and given a good quality balanced diet. Where

weakness, ataxia, prostration, coma and death. The

rapidity of onset of the clinical signs is dependent on

Oak poisoning

the dose consumed; death can occur in one hour or up *to a day following acute intoxication.*

Poisoning by the various oaks of the genus Quercus can be a serious seasonal problem in grazing cattle.

Necropsy

Sources of toxicant

High methaemoglobin levels impart a chocolate-brown

discoloration to the blood, which is seen particularly in

Cattle may be poisoned at any time when they gain

the fresh cadaver. This brown coloration is evident

access to quantities of oak leaves or acorns, which

throughout the mucosae, viscera and possibly in the

contain the toxic tannins. Cattle can consume small

urine.

quantities of acorns or oak leaves without ill effects.

Circumstances of poisoning

Diagnosis

In temperate countries the autumn fall of acorns is the

The history may be suggestive if a link of known

principal source. The acorn crop varies considerably

exposure to nitrates can be established.

The

from year to year and hence there is wide variation in clinical picture and particularly the post-mortem prevalence. Storms and windy conditions that cause a findings are also highly suggestive. Methaemoglobin heavy sudden drop of acorns are also predisposing can be detected in blood but is not stable and a factors. Cattle may also be poisoned from browsing on fresh sample needs to be analysed within 4 hours. new leaves and buds or oak seedlings.

Alternatively, a sample of heparanized blood can be preserved, consulting the diagnostic laboratory for the preferred method. Nitrate levels in all sources of

Signs

feed and water should be analysed but tolerance to nitrate may be apparent in some circumstances as Although sudden death may be observed, poisoning described above. Levels in feed in excess of 1 per cent is usually seen as a subacute condition. Affected nitrate on a dry matter basis are highly suggestive of cattle become depressed and anorexic. Early on in the intoxication.

disease constipation occurs, often with marked strain-

ing perhaps accompanied by groaning and abdominal

pain; small, dry faecal pellets may be observed at this

Principal differential diagnoses

stage. Later on this gives way to a dark coloured or tarry

diarrhoea often with blood; straining may be persistent

Circulatory collapse or severe respiratory conditions

and severe. As the condition progresses polyuria and

can result in tissue anoxia and acute cyanosis, but in

subcutaneous oedema may be observed. Cattle then

few other circumstances does methaemoglobinaemia

become progressively weaker and collapse with death

with its characteristic chocolate-brown blood result.

supervening in four to seven days from the onset of

Intoxication with chlorates will also result in

clinical signs.

methaemoglobinaemia.

Pathogenesis

Treatment and prevention

The tannins are nephrotoxic and damage the renal

The animal should be immediately removed from the *tubules but the precise mechanism of their action is*

suspected source of nitrate. The specific antidote is

unclear. There is a necrosis of the renal tubular cells

methylene blue, which restores the iron in haemoglobin

and the consequent renal dysfunction leads initially to

to its ferrous state thus again allowing oxygenation of

oliguria or anuria, later progressing in the subacute to

the blood and so reversing the tissue anoxia. Methy-

chronic stages of intoxication to polyuria with the pro-

lene blue should be given by intravenous injection at up

duction of a very dilute urine.

to 4 mg/kg body weight in a 2 per cent solution. It can

be repeated if necessary. Defining the nitrate source

Necropsy

and reducing exposure are the key elements in control.

Ensiling will usually reduce the nitrate content of

Gross signs include those of oedema, particularly

forage as will allowing the pasture to age and set seed,

hydrothorax, ascites and ventral subcutaneous oedema,

since nitrate is found mostly in stems rather than in

oedema fluid may contain blood, and there is often *grain.*

perirenal oedema together with swollen pale kidneys.

The contents of the rumen are frequently doughy in

Treatment and prevention

consistency and often contain large numbers of acorns

There is no specific antidote. Cattle may survive poi-

and/or oak leaves, although this is not invariable in the

soning by oak but are frequently left with chronic renal

more chronic cases. There may often be colitis, with

damage, such that they will often perform poorly. The

tarry, bloodstained faecal contents. Histologically, the

only treatment that is likely substantially to affect the

acute renal lesions include hyaline cast formation

outcome of clinical cases is expensive and specialized

and a coagulative necrosis of the tubular epithelium;

involving full-scale renal supportive therapy including

later mononuclear cell infiltration and fibrosis are

measurements and adjustment of plasma electrolytes,

observed.

oral and parenteral rehydration and the re-establish-

ment of diuresis. Rumenotomy may be indicated.

Diagnosis

Anticipation of potential outbreaks by the recognition

The history and circumstantial evidence of poisoning

of the seasonal nature of the disease in inspection of

together with the clinical signs usually strongly suggest

pastures (particularly if the meteorological conditions

a diagnosis of oak poisoning. This is usually confirmed

would produce a sudden heavy acorn drop) followed by

by finding large amounts of acorns and/or oak leaves in

removing cattle from sources of contact is the key to

the rumen at post-mortem examination together with

successful prevention.

the characteristic gross and histological changes. In live

animals there will be an elevation of serum urea and

creatinine, and glucose and protein will appear in the

Reference and further reading

urine.

Andrews, A.H. & Humphreys, D.J. (1992) Poisoning in Veteri-Principal differential diagnoses

nary Practice, pp. 1–114. National Office of Animal Health, Enfield.

The main differential diagnoses include clostridial

Bidewell, C.A., David, G.P. & Livesey, C.T. (2000) Copper

infections (Chapter 44) and other toxicoses.

toxicity in cattle. Veterinary Record, ***147****, 399–400.*

Adult Cattle

Welfare

Chapter 55

Welfare

D.M. Broom

Public perceptions of the dairy and beef industries

955

which appear well founded can be very damaging to

The concept of animal welfare

955

producers, processors and retailers.

Welfare problem areas

956

Public concern about animal welfare manifests itself

Ill treatment and neglect

956

in actual product purchasing and in pressure applied to

Housing and management

957

retailers and to legislators. Major supermarket and

General points

957

cooked food chains can be influenced rapidly by cus-

Calf welfare

958

tomer pressure and can cause changes to be brought

Beef cattle welfare

960

about in the methods used by suppliers. Retailers may

The welfare of dairy cows

960

Farm operations

962

impose codes of practice on suppliers and the execution

Handling, transport and slaughter of cattle

963

of these codes is checked because the retailers cannot

afford public criticism of what they sell (Broom, 1999a).

In several European countries, certain housing systems

Public perceptions of the dairy and

and farm practices have been changed by many farmers

beef industries

because of the standards required by the purchasing

companies. For example, the use of crates for calves,

Most members of the public who are asked about the

stalls and tethers for sows, and castration of pigs slaugh-

dairy and beef industries think of cattle grazing in fields

tered at 100 kg or less has ceased on many farms.

and cows living for some time whilst a series of calves

The effect of public pressure on legislation is usually

are born and milk is produced. Milk products and beef

slower, but legislation makes for more equal constraints

are considered by the public in relation to their effects

on producers. Legislation is becoming more and more

on human nutrition and health, their effects on the envi-

international although it is clearly important that

ronment and their effects on animal welfare. If pro-

where there is legislation on wholly moral grounds, for

duction is perceived to be bad in relation to any of these *example in order to prevent poor welfare in animals,*

aspects, sales of the products could be severely affected.

there should be restrictions on imports from countries

Bovine spongiform encephalopathy (BSE) resulted in

whose moral standards are lower and that such

a substantial but sometimes brief decline in beef con-

restrictions should be authorized by the World Trade

sumption. Some people may limit their intakes of

Organization.

milk products because of a desire to reduce cholesterol

intake whilst certain aspects of the dairy industry, such

as methane production, may be criticized in relation to

The concept of animal welfare

pollution; however, it is animal welfare rather than

these topics which is the subject of this paper. Until

Animal welfare has to be defined in such a way that it

recently, the welfare of the dairy cow was not often per-

can be scientifically assessed and the term can be used

ceived to be poor and it has been only in calf rearing

in legislation and in discussion amongst animal users

that dairy production systems have been regularly criti-

and the public. Welfare is clearly a characteristic of an

cized. However, the dairy industry has been changing.

individual animal and is concerned with the effects of

Evidence of poor welfare in cows is accumulating and

all aspects of its environment on the individual. The

has had influence on public opinion in several countries.

welfare of an animal is its state as regards its attempts

It is important to the dairy industry that welfare

to cope with its environment (Broom, 1986). This state

problems should be addressed before there is any

includes the feelings of the individual, various physio-

widespread public condemnation of breeding and man-

logical and behavioural responses and its health. The

agement practices. Similarly, beef cattle production is

extent of the difficulty which the individual has in trying

not often criticized on welfare grounds. However, a few

to cope with its environment, the extent of any failure

critical newspaper articles or television programmes

to cope and the degree of happiness are all components

Box 55.1

Indicators of animal welfare (after Broom, 2000).

Box 55.2

Possible causes of cattle welfare problems.

Physiological indicators of pleasure

Ill treatment

Behavioural indicators of pleasure

Neglect: calculated, accidental or due to lack of knowledge

Extent to which strongly preferred behaviours can be shown

Inadequacies in design of housing/furniture

Variety of normal behaviours shown or suppressed

Inadequate management system or poor husbandry on the

Extent to which normal physiological processes and

farm

anatomical development are possible

Unnecessary or poorly executed mutilations of the animals

Extent of behavioural aversion shown

Poor conditions and procedures:

Physiological attempts to cope

during transport

Immunosuppression

at market

Disease prevalence

at slaughterhouse

Behavioural attempts to cope

Behaviour pathology

Self-narcotization

food access and conditions indoors or outdoors may

Body damage prevalence

lead to risk of injury (Schlichting & Smidt, 1987).

Reduced ability to grow or breed

Reduced life expectancy

Management methods and husbandry include all

aspects of feeding, moving of animals, grouping,

milking, serving, etc. Mutilations for the benefit of

farming practice or of the animal require some special

of welfare. Hence welfare varies from very poor to

mention, both as regards the methods used and the

very good and can be scientifically assessed (Broom &

consequences for the animals. Methods of handling

Johnson, 1993; Broom, 1998a, 1999b).

and moving animals are of importance before and after

Indicators of animal welfare are listed in Box 55.1.

transport, at markets and at lairage as well as on the

These include disease prevalence and reduced ability to

farm. There are also special problems of transport

grow and breed. As explained by Broom and Johnson

vehicle construction and usage, market accommodation

(1993), the welfare of a diseased individual is poorer

and procedures, and slaughter methods. Welfare prob-

than that of an individual which is not diseased, and

lems that should be taken into account in cattle prac-

reduced ability to produce offspring given appropriate

tice have been reviewed by Broom (1988).

opportunities also indicates poor welfare. Individuals

which are finding it difficult to cope with their environ-

ment, or which are failing to cope, may be more likely

Ill treatment and neglect

to become diseased, less likely to produce embryos,

less likely to carry young to term and more likely to die

Human actions that can lead to poor cattle welfare

early.

include ill treatment, neglect and inadequate produc-

tion systems. Ill treatment occurs most frequently when animals are being moved around the farm, when they

Welfare problem areas

are being loaded into or out of vehicles, or when they are at market or lairage. Those who do ill treat animals

Whilst cattle management has been changing, our

can be advised of likely economic effects of their

knowledge of cattle physiology and behaviour has been

actions as well as being told about the laws on the

improving. It is clear that cattle have complex regula-

subject. Neglect includes failure to provide an adequate

tory processes, elaborate social structure and sophisti-

diet, failure to treat disease and the lack of normal

cated learning ability (Kilgour & Dalton, 1984; Stricklin

husbandry procedures. The diet may be inadequate in

& Kautz-Scanavy, 1984; Fraser & Broom, 1990). These

nutrient composition or in quantity. Cattle are some-

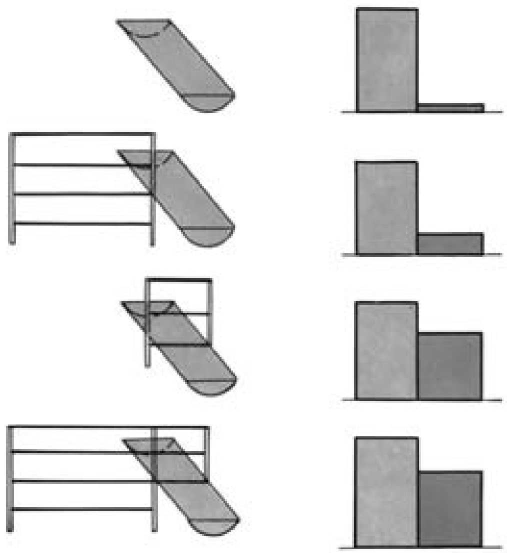
results have made many animal scientists reconsider the

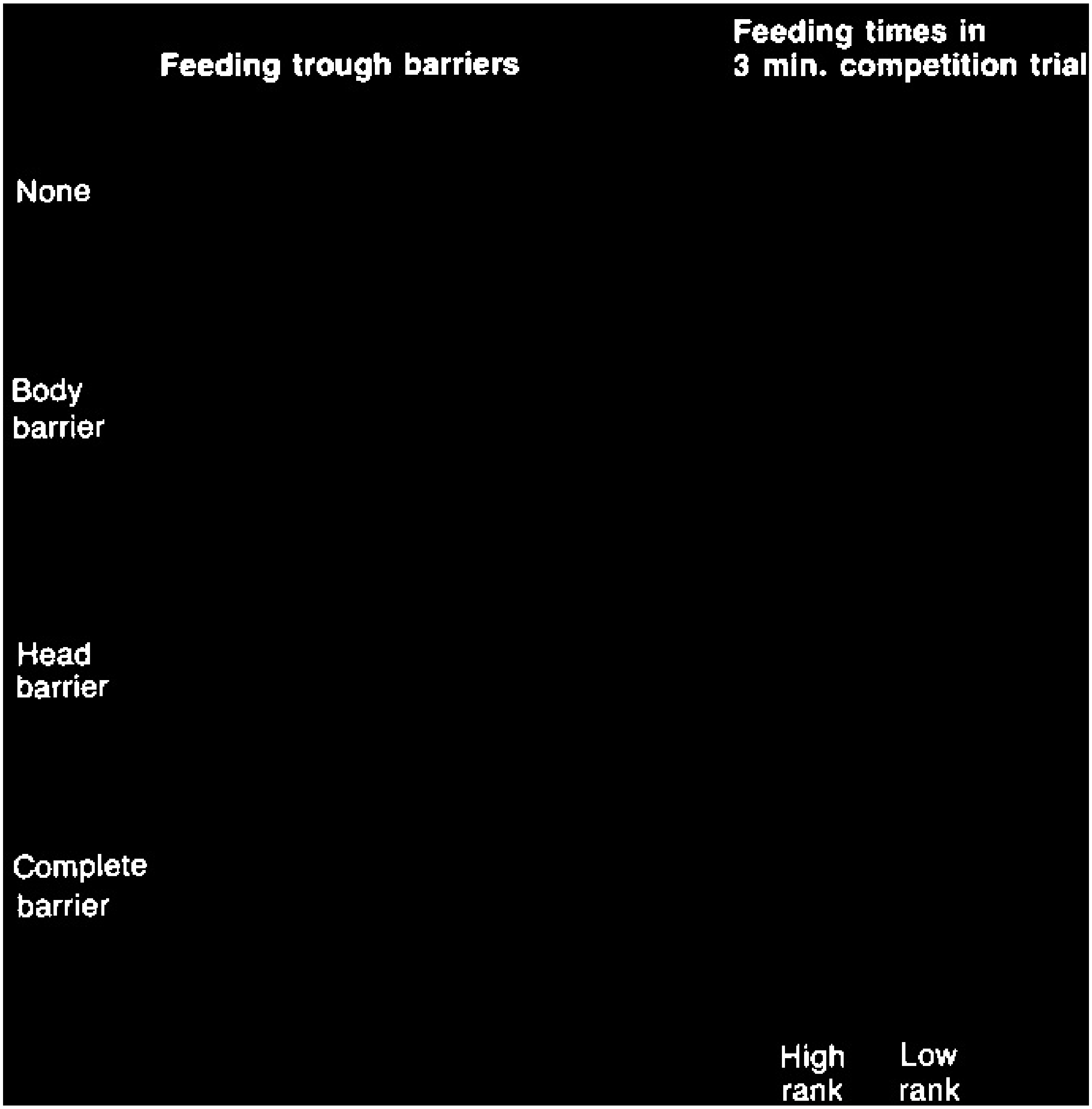
times undernourished for a period, whilst food is scarce

effects of conditions and procedures on farms, both in

or expensive, with the expectation that compensatory

terms of their efficiency as regards production and with
growth will occur when more food is provided. If
respect to the welfare of the animals.
the undernourishment amounts to starvation and this
The general range of welfare problem areas is the
is clear from the condition of the animal, then this is
same for cattle as for other farm animals (Box 55.2).
serious neglect. Lack of knowledge on the part of the
Ill treatment refers principally to physical abuse of
farmer may result in the provision of a poor diet or in
animals. Neglect includes failing to give food and water,
failure to treat disease. This is poor husbandry, a very
or to clean out, or to treat disease or to assist as neces-
important cause of welfare problems. Advice on good
sary at calving. Accommodation for animals may, for
husbandry methods can be an important veterinary
example, give insufficient space, poor flooring or poor
service. If animals are diseased and require treatment





there is a moral obligation upon the veterinarian to

remain to be determined. Competitive feeding situa-

treat them. In the UK, the veterinary oath, which is

tions where there are no individual feeding places pose *sworn on admission to Membership of the Royal*

extra problems for cattle. The subordinate individual

College of Veterinary Surgeons, includes the promise

has to attempt to obtain food despite the attacks or

that 'my constant endeavour will be to ensure the

threats of other individuals. Bouissou (1970) found that

welfare of animals committed to my care'. In certain

the greater the extent of the barrier between feeding

circumstances, treatment without any prospect of

places for cows, the fewer the attacks that occurred (Fig.

payment may be necessary. In other circumstances it

55.1). A trough that requires subordinate cows to come

may be best to call in the State Veterinary Service, the

close to dominant individuals results in those subordi-

police or the RSPCA, even if to do so might mean

nates walking greater distances and taking longer to

losing a client.

obtain a meal (Albright, 1969; Fig. 55.2). Calves of low

social rank obtain less of the favoured food if trough

space is restricted (Broom, 1982). In order to minimize

Housing and management *(see also pp.*

such welfare problems, which are often associated with

poor weight gain, farmers should provide feeding

40–44, Chapter 56)

spaces for all individuals, preferably with barriers

between the individual places. Adaptation to food

General points

access from a single source is possible for cattle

Feeding of housed cattle may lead to difficulties for the

however, for a transponder-operated feeding stall can

animals because the acquisition of food in housing

be quite successful (Albright, 1981), but some indi-

conditions is very different from that when grazing.

viduals in a herd may have difficulties in learning how

Physical difficulties may occur, as described by Cermak

to reach the feed in such systems.

(1987), but social factors are also very important. Cattle

Another general problem for housed cattle is having

synchronize their feeding to a large extent (Benham,

to stand on floors that are wet, slippery, uneven or

1982; Potter & Broom, 1987), so where group feeding is

hazardous because of sharp edges. Slippery slats can *possible enough feeding places for each animal are*

lead to difficulties in standing or lying (Andreae &

required (Metz, 1983; Wierenga, 1983). Those animals

Smidt, 1982; Fig. 55.3). These and other inadequacies of

that cannot find a feeding place may not get sufficient

flooring can result in limb injuries, foot lameness,

food and it is likely that there are adverse effects on

tail-tip necrosis and various diseases. Lameness is the

their welfare. The precise effects of the frustration that

greatest welfare problem of housed dairy cows and

occurs when food is inaccessible because of competition

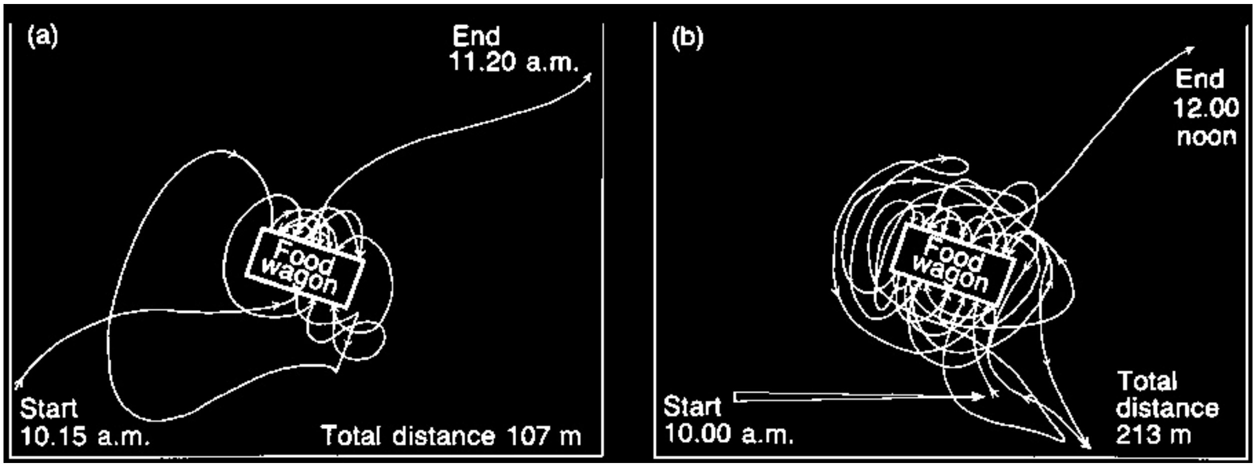
factors influencing its occurrence include floor quality

Fig. 55.1

Physical barriers affected feeding times by cows

ranking high and low in a competitive order. With no barrier (a) the low ranking cows were scarcely able to feed. A body barrier (b) improved the situation slightly for the low ranking cows but a head barrier (c) and a complete barrier (d) had a much

greater effect (redrawn after Craig, 1981; data from Bouissou, 1970).


(a)
End
11.20 a.m.
Food
wagon
Start
10.15 a.m.
Total distance 107 m
(b)
End
12.00
noon
Food
wagon
Start
10.00 a.m.
Total
distance
213 m

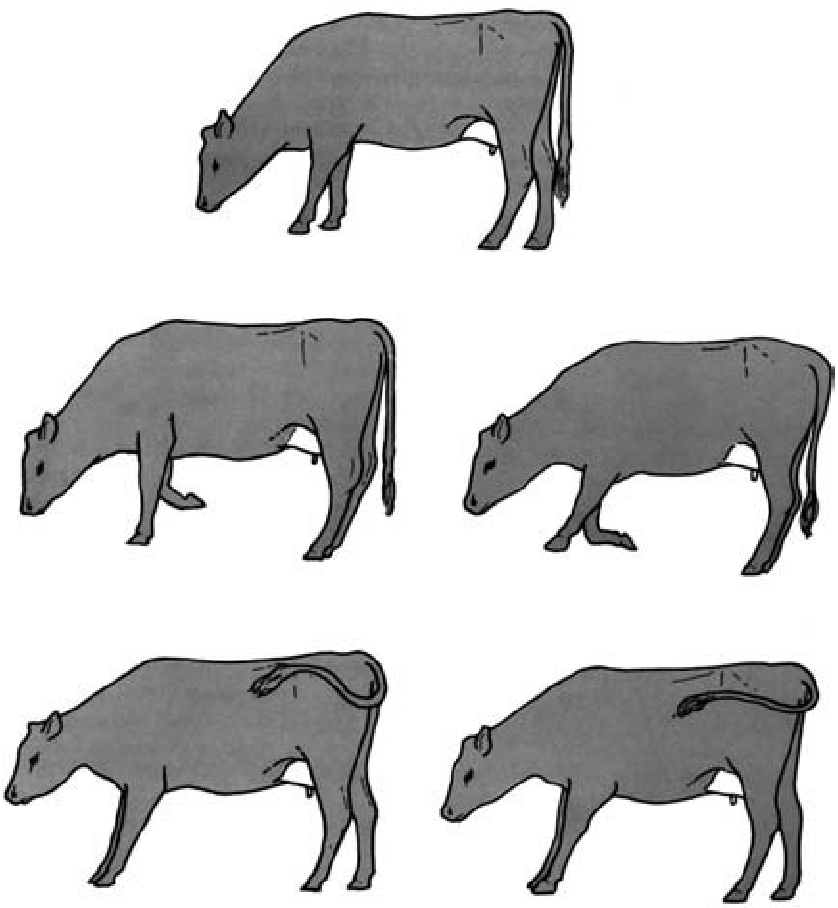


Fig. 55.2

The paths of two cows in a

herd after food is provided in a food

wagon are shown. Animal (a) was found

to be high in a competitive order

whereas animal (b), which was low in

that order, walked further because of

displacement at the food wagon and

took longer to feed (after Broom, 1981;

modified after Albright, 1969).

Fig. 55.3

Behavioural alterations in

young cattle on a slatted floor (after

Andreae & Smidt, 1982).

and poor drainage, which results in cows standing in

colostrum for a variety of reasons (Edwards, 1982;

slurry (Wierenga & Peterse, 1987).

Edwards & Broom, 1982; Broom, 1983). Management

practices that maximize the chance that colostrum will

be obtained and minimize contact with pathogens have

Calf welfare

important beneficial effects on calf welfare. If calves of

In the first few days after birth the major calf welfare *dairy cows are normally left with their mother for the*

problems are enteric and respiratory diseases. The

first 24 or 48 hours, the risk that the calf will not suckle

calves of dairy cows may fail to obtain sufficient

early enough to obtain and absorb the immunoglobulin

from colostrum can be minimized by the stockworker

Grooming behaviour is important as a means of

placing one of the mother's teats in the mouth of the

minimizing disease and parasitism and calves make

calf as early as possible after the calf stands. Group-

considerable efforts to groom themselves thoroughly

calving situations where several cows calve during a

(Fraser & Broom, 1990). Calves need to be able to

short period can lead to a cow's colostrum being drunk

groom their whole bodies effectively.

by a calf other than her own or to calves being rejected

A variety of nutrients are needed by calves. Sufficient

by their own mothers. Such occurrences can be pre-

iron is needed to allow normal activity and to minimize

vented by providing separate calving boxes, which

disease.

should ideally allow the cows some visual contact with

The needs of young calves are met most effectively

other cows. The provision of soft bedding for the calf is

by the presence and actions of their mothers. In the

also desirable and is easier where special calving

absence of their mothers, calves associate with other

accommodation is available.

calves if possible and they show much social behaviour.

Dairy calves are deprived of their mother from an

The need to show full social interaction with other

early age and many are individually housed so that they

calves is evident from calf preferences and from the *are confined in a small space and deprived of all or most*

adverse effects on calves of social isolation (Broom &

social contacts.

Leaver, 1978; Dantzer et al. , 1983; Friend et al. , 1985; Lidfors, 1994).

The needs of calves

Comparisons of veal calf housing and

A need is a requirement, which is a consequence of the

management systems

biology of the animal, to obtain a particular resource or

respond to a particular environmental or bodily stim-

The major housing systems which have been compared

ulus. The needs of calves are described in detail by

in studies of calf welfare are individual crates (Fig.

Broom (1991, 1996) and examples are given here.

55.4), group housing on slats and group housing on

The calf needs to ingest colostrum very soon after

straw. Where calves are housed individually, the size of

birth and milk thereafter. It also needs to show sucking

the crate and whether or not the sides are solid have

behaviour and if a calf is not obtaining milk from a real

been varied. All aspects of diet are important in rela-

or artificial teat, it sucks other objects (Broom, 1982,

tion to welfare. For example, if inappropriate proteins

1991; Metz, 1984; Hammell et al. , 1988).

or carbohydrates are fed, the calf may be unable to

Calves need to rest and sleep in order to recuperate

utilize them and if milk is acidified too much, calves may

and avoid danger. They need to use several postures

which include one in which they rest the head on the

legs and another in which the legs are fully stretched

out (de Wilt, 1985; Ketelaar-de Lauwere & Smits, 1989,

1991).

Exploration is important as a means of preparing for

the avoidance of danger and is a behaviour shown

by all calves (Kiley-Worthington & de la Plain, 1983;

Fraser & Broom, 1990). Calves need to explore and it

may be that higher levels of stereotypies (Dannemann

et al. , 1985) and fearfulness (Webster & Saville, 1981) in poorly lit buildings are a consequence of inability to

explore.

Exercise is needed for normal bone and muscle

development and calves choose to walk at intervals if *they can, show considerable activity when released*

from a small pen and have locomotor problems if con-

fined in a small pen for a long period (Warnick et al. , 1977; Dellmeier et al. , 1985; Trunkfield et al. , 1991).

Normal calf anatomical, physiological and behav-

ioural development occurs only if the calves have some

fibre-containing material to eat (van Putten & Elshof,

1978; Webster, 1984; Webster et al. , 1985a) so it is clear that they need fibre in their diet after the first few weeks

Fig. 55.4

Veal calf in crate with slatted floor. The front of the

of life.

crate has been removed.

find it very unpalatable. However, the two aspects of

Vries et al. , 1986). Individual housing of beef animals is diet which have been of greatest concern in relation to

more frequent when they are bulls than when they are

calf welfare have been the amount of fibre and the

steers. In Germany almost all beef animals are bulls, but

amount of iron.

in the UK most were steers before the ban on growth

The incidence of disease in young calves is too high,

promoters.

for example, 25 per cent of veal calves had to be treated

Fighting and mounting can lead to welfare problems

for respiratory disease in a study by van der Mei (1987).

when beef animals, especially bulls, are kept in groups.

The use of antibiotics to prevent disease is also a

The most important way of minimizing such problems

problem. It is important for calf welfare and for farm

is to keep the animals in stable groups, since social

economics that disease levels be lowered.

mixing leads to much fighting with consequent injuries,

One aspect of management which causes problems is

bruising and extreme physiological responses (Kenny &

the practice of mixing calves from different sources.

Tarrant, 1982). In stable groups, mounting may lead to

Webster (1984) found that calves purchased and

more injury than does fighting (Appleby & Wood-

brought into a unit were five times more likely to

Gush, 1986). Animals that are frequently mounted

require treatment for disease. A second aspect is *become bruised and may suffer severe leg injuries.*

hygienic practice by farm staff and a third is early detec-

Mounting can be greatly reduced by the use of over-

tion of disease. These variables seem to be more impor-

head bars, which physically prevent it, or an electrified

tant than the housing system in exacerbating disease.

grid, which deters animals that wish to mount. The brief

As a consequence of the evidence of poor welfare in

initial experience of an electric shock has a relatively

veal calves, the European Union passed a directive in

small adverse effect on welfare as compared with the

1997 which required group housing of calves after 8

serious effects on animals that are repeatedly mounted.

weeks of age, individual pens at least as wide as the

The stocking density of beef animals and the flooring

height of the calf at the withers, no tethering of calves

provided also have considerable effects on welfare.

except for <1 h at feeding time, sufficient iron to ensure

High stocking densities lead to more aggression, injury

an average blood haemoglobin of 4.5 mmol/l and fibre

and bruising. Beef animals increase rapidly in body-

in the diet increasing from 50 g/day at 8 weeks to

weight, but they have little exercise if they are housed

250 g/day at 20 weeks. Many EU calf producers have

in small pens and their leg growth may not be able to

found group housing of calves to be more successful

keep pace with that of the rest of the body. The final

economically than the old crate system and white veal

weights reached are much higher now than they used

can still be produced from systems which comply with

to be so the legs are scarcely adequate to support the

the new law.

body. The consequence is cartilage damage, clear indi-

cations of limb pain and obvious difficulties in standing

and lying (Dämmrich, 1987). Graf (1984) found that

Beef cattle welfare

these problems were absent if fattening bulls were

reared on deep straw and that such conditions also

The housing conditions for calves destined for beef

led to fewer behavioural problems. Beef cattle have a

production are sometimes similar to those kept for

strong preference for straw or other bedding.

veal production so they have similar welfare problems.

All of these issues are reviewed in the EU Scientific

Older beef animals are kept in small individual pens or

Committee on Animal Health and Animal Welfare

are tethered in some countries and they then show

Report on the Welfare of Cattle Kept for Beef Produc-

much stereotyped behaviour. Riese et al. (1977)

tion, 2001.

reported that stereotyped behaviour included tongue

rolling, weaving movements and self-licking. Wierenga

(1987) reported that one-third of young, individually

The welfare of dairy cows

housed bulls spent several minutes in every hour

showing tongue rolling. Physiological responses to

The major welfare problems of dairy cows are lameness,

confinement also occur. Ladewig (1984) reported that

mastitis and any conditions which lead to impaired

tethered bulls showed more frequent episodes of high

reproduction, inability to show normal behaviour, emer-

blood cortisol levels than did bulls able to interact

gency physiological responses or injury (Broom, 1999c).

socially in groups. Such abnormal behaviour and phys-

iology are probably exacerbated by both social depri-

Leg and foot problems (see Chapters 31, 32)

vation and inability to perform behaviours because of

spatial restriction. Tethered animals lack exercise and

For a review of lameness, including the extent to which

have different patterns of muscle fibres from those free

it is a welfare problem, see Greenough and Weaver

to walk (Jury et al. , 1998) and more osteochondrosis (de (1996). Almost all animals which walk with a limp, or

reduce walking to a low level or avoid walking when-

have some lameness problems which are exacerbated

ever possible suffer from some leg or foot pain. Their

by social factors (Bickert et al. , 1997). Since the best ability to carry out various preferred behaviours is gen-straw yards, with an abrasive area on which normal hoof

erally impaired and there may be adverse consequences

wear occurs, have little lameness, these may be the best

for various other aspects of their normal biological

solution for housed cows. Mastitis incidence is affected

functioning. Lameness always means some degree of

by hygiene at milking and various other conditions of poor welfare and sometimes means that welfare is very management. Poorly designed housing systems can poor indeed.
result in a variety of welfare problems and these can be Measurements of the extent to which some degree of exacerbated by high stocking density. Most of these lameness occurs in dairy cows include 35–56 cases per problems, such as those resulting from cubicles being 100 cows per annum in the USA, 59.5 cases per 100 too short for the length of the cows now occupying cows per annum in the UK and more than 83 per cent them or of poor design of cubicles which do not allow of examined cows in The Netherlands. The actual adequate movements in the cow, are well known so are figures depend upon the method of assessment and mentioned briefly here. In general it seems that many most of these cases were not treated by veterinary dairy cow housing systems, and cubicles in particular, surgeons, but there is no doubt that lameness is often do not provide an environment to which cows can adapt

a severe welfare problem (Broom, 1999c).

easily. The best straw yards seem to be the most

successful as they give the cows more opportunity to

Mastitis (see Chapter 23)

control their interactions with their environment.

Mastitis in mammals is a very painful condition. The

sensitivity to touch of affected tissues is clearly evident

Milk yield and welfare in dairy cows

and there is obvious damaging of normal function.

The dairy cow of 1998 could produce 18 000 l or more

Mastitis prevalence should have declined greatly with

of milk per annum with a peak milk yield of 75 l per day.

improved methods of prevention and treatment, but it

This compares with UK figures of 6000 l and 30 l per day

has not declined as much as it should have done.

10 years ago (Webster, 1993) and a beef cattle average

Webster (1993) reports 40 cases of mastitis per 100 cows

of 1000–2000 l and 10 l per day. The dairy animal is pro-

per year as an average for the UK.

ducing considerably more than its ancestor would have.

This raises the questions of whether it is at or beyond

Reproductive problems (see Chapters 34, 35 and 36)

its maximum production level and the extent of any

Reproductive problems in dairy cows have become

welfare problems.

very common in recent years with large numbers of

The peak daily energy output of the dairy cow per

cows being culled because of failure to get in calf. In a

unit bodyweight is not very high in comparison with

study of 50 dairy herds in England, Esslemont and

some other species such as seals or dogs, but the product

Kossaibati (1997) found that farmers reported failure to

of daily energy output and duration of lactation is very

conceive as the predominant reason for culling, with 44

high indeed. Hence long term problems are the most

per cent of first lactation, 42 per cent of second lacta-

likely to occur (Nielsen, 1998). This is what we see

tion and 36.5 per cent of cows in total being culled for

because, although some cows seem to be able to

this reason. However, mastitis, feet and leg problems,

produce at high levels without welfare problems, the

ketosis and other disease conditions can lead to repro-

risk of poor welfare indicated by lameness, mastitis or

ductive problems and it is difficult to discover their

fertility problems is greater as milk yield increases.

initial cause from farmers' records. A report by Plaizier

The steady increase in reproductive problems as milk

et al. (1998) concerning Canadian herds indicated that yields have increased is well known. As Studer (1998)

reproductive culling risk varied between 0 and 30 per

states, 'despite programmes developed by veterinarians

cent, with a mean of 7.5 per cent.

to improve reproductive herd health, conception rates

have in general declined from 55–66% 20 years ago to

45–50% recently (Spalding et al. , 1975; Foote, 1978;

Housing systems and welfare (see pp. 40–44,

Ferguson, 1988; Butler & Smith, 1989). During the

Chapter 56)

same periods, milk production has greatly increased.'

The incidence of lameness is much worse in housed

Studies showing that milk yield is positively corre-

cows than in cows at pasture. Cows at pasture may have

lated with the extent of fertility problems have come *stone damage to hooves if they do not have a suitable*

from a range of different countries (van Arendonk et

place to walk, but wet cubicle houses or poorly main-

al. , 1989; Oltenacu et al. , 1991; Nebel & McGilliard, tained straw yards can result in very high levels of lame-1993; Hoekstra et al. , 1994; Pösö & Mäntysaari, 1996; ness. Even the best cubicle housing systems seem to

Pryce et al. , 1997, 1998). Studer (1998) explains that high

Table 55.1

Positive correlations between milk production level

welfare of cows. Current trends towards ever greater

and indicators of poor welfare (from Pryce et al., 1997 with per-milk production and feed conversion efficiency should

mission of the American Society of Animal Science).

not be continued unless it can be ensured that welfare

is good (Broom, 1994; Phillips, 1997). Bovine soma-

Milk yield from 33 732 lactation records:

totropin (BST) (see p. 1073) results in high milk yields

calving interval

0.50 ± 0.06

and higher levels of mastitis, lameness, reproductive

days to first service

0.43 ± 0.08

disorders and other problems such as those at the injec-

mastitis

0.21 ± 0.06

tion site (Broom, 1993; Willeberg, 1993; Kronfeld, 1997;

foot problems

0.29 ± 0.11

milk fever

0.19 ± 0.06

Willeberg, 1997; Broom, 1998a). Whether or not much

of the effect of the genetically engineered hormone is

a consequence of the milk yield, the poorer welfare

Table 55.2

Positive correlations between milk production level

caused by the BST is unacceptable.

and indicators of poor welfare (from Pryce et al., 1998 with perThe Report of the EU Scientific Committee on

mission of the American Society of Animal Science).

Animal Health and Animal Welfare (1999) on animal

welfare aspects of the use of bovine somatotrophin

Milk yield from 10 569 lactation records:

concluded as follows:

calving interval

0.28 ± 0.06

days to first service

0.41 ± 0.06

‘BST is used to increase milk yield, often in already high-

mastitis

0.29 ± 0.05

producing cows. BST administration causes substantially

somatic cell count

0.16 ± 0.04

and very significantly poorer welfare because of

foot problems

0.13 ± 0.06

increased foot disorders, mastitis, reproductive disorders

and other production related diseases. These are prob-

lems which would not occur if BST were not used and

producing cows which are thin and whose body condi-

often results in unnecessary pain, suffering and distress.

tion score declines by 0.5–1.0 during lactation often

If milk yields were achieved by other means which *experience anoestrus. A loss of condition score of about*

resulted in the health disorders and other welfare prob-

1.0 during lactation was normal in the review presented

lems described above, these means would not be accept-

by Broster and Broster (1998). Data on the relation-

able. The injection of BST and its repetition every 14

ships between milk yield and reproduction measures

days also causes localized swellings which are likely to

from two large scale studies are presented in Tables 55.1

result in discomfort and hence some poor welfare.'

and 55.2.

In some studies, effects of health problems on repro-

The Committee also made the following

duction are evident, for example, Peeler et al. (1994) recommendation:

showed how cows which were lame in the period before

'BST use causes a substantial increase in levels of foot

service were less likely to be observed as being in

problems and mastitis and leads to injection site reac-

oestrus. The lameness could be more likely in high

tions in dairy cows. These conditions, especially the first

producing cows. Direct links between level of milk *two, are painful and debilitating, leading to significantly*

production and extent of disease conditions are also

poorer welfare in the treated animals. Therefore from

evident from a range of studies, positive correlations

the point of view of animal welfare, including health,

being reported by Lyons et al. (1991), Uribe et al. (1995) the Scientific Committee on Animal Health and Animal

and Pryce et al. (1997, 1998; see Tables 55.1, 55.2). In Welfare is of the opinion that BST should not be used

addition to mastitis and leg and foot problems, which

in dairy cows.'

are often measured in such studies, the occurrence of

other clinical conditions can also be affected by pro-

duction level. Modern, high producing cows with good

body condition have a high incidence of milk fever,

Farm operations

retained placenta, metritis, fatty liver and ketosis

(Studer, 1998).

Certain mutilations of cattle are performed on farms by

The high yields of modern dairy cows are a conse-

staff with no veterinary qualification. In most cases, no

quence of genetic selection and feeding. Cows are *anaesthetic is used. The most widespread of these*

adapted to high fibre, low density diets. The ways in

operations are disbudding or dehorning, castration and

which they have been modified genetically do not

various sorts of individual marking. Some of the proce-

change these basic characteristics much. Cows do not

dures used must also cause pain to the animals, but

adapt easily to high grain diets or to manufactured diets

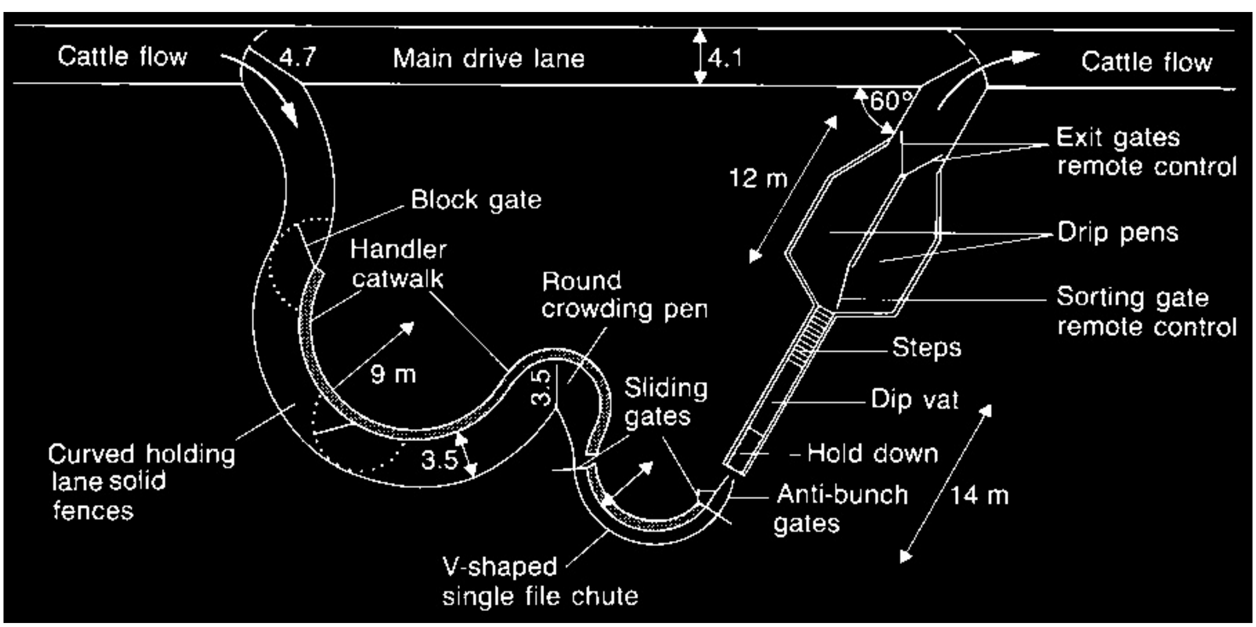
there is little precise information about this. The use of

with high protein and low fibre. Genetic selection has

caustic materials that remain in contact with living

not taken adequate account of the adaptability and

tissue for any length of time is likely to cause severe



pain and should be avoided. Any use of hot irons on

adverse effect on some cows so that their milk let-down

living tissue must also cause pain and hot iron branding

may be prevented and they may become extremely

is a painful and unnecessary form of marking. Castra-

unwilling to move towards the parlour.

tion is often carried out by applying a rubber ring

The problems associated with the design of races for

around the testicles until the tissue in them dies and it

moving cows to the milking parlour are very similar to

seems likely that this is also very painful for a long

those of designing races used for other purposes, such

period. Even the ubiquitous ear notching and punching

as movement towards vehicles prior to transport. The

must be painful for a few days and it would be better if

most extensive study of how to design good races is that

alternative marking methods such as freeze branding or

of Grandin (1983, 2000). She reported that cattle often

tattooing could be used.

balk if they encounter dark areas or areas of extreme

More extensive mutilations should only be carried

lighting contrast. Races with sharp angular turns in

out under anaesthetic by qualified veterinarians and

them may also pose problems for cattle that are being

should be permitted only if the animal will benefit. Any

driven and long straight races may result in animals

practices that necessitate the use of operations should

being either reluctant to move or moving too fast. As a

be avoided. An example of a problem area is the breed-

consequence of these observations, Grandin recom-

ing of cows such that their calf cannot be born normally.

mends that races should be evenly lit, have solid walls

No animal should be made pregnant if there is a likeli-

if animals unfamiliar with them have to use them and

hood that caesarean section or a difficult birth will

should be gently curved rather than having sharp

occur.

corners or long straights (Fig. 55.5). Other studies also

suggest that if animals are being loaded into vehicles,

the ramp should be long and sloping not more than 1

Handling, transport and slaughter

in 7, should allow a good grip for the feet of the cattle

of cattle

and should have solid sides, and the interior of the

vehicle should be well lit.

Every dairy farmer has to be able to move dairy cows

Vehicles are often not well designed as regards floor-

in milk to and from the milking parlour. If the races and

ing, ventilation and ease of subdivision. Just as impor-

collecting yards that are used or the methods of moving

tant as vehicle design, as regards the welfare of animals

the animals are inadequate and disturbing to some or

during transport, is the behaviour of the transport staff.

all of the cows, there will be welfare problems. Such

Problems arise because of rough treatment during

welfare problems will often be associated with reduced

loading, over- or understocking of compartments on the

milk yield. Cows may be reluctant to enter a milking

vehicle, inconsiderate driving or leaving the animals in

parlour because of the behaviour of the stockworker or

conditions that are too hot or too cold and windy for

because of design faults in the parlour that result in *them. The other major transport problems are the effect*

uncomfortable milking stalls or stray voltages. Such

of very long journeys, especially where there are no

problems can lead to the use of excessive force by

stops for food and water, and contact between trans-

stockworkers in the collecting yard or to forcing

ported animals or their products which results in

animals towards the parlour entrance using gates or

disease transmission and poor animal welfare. This area

an 'electric dog'. The 'electric dog', which is a row of

has been reviewed in a Commission of the European

electrically live wires hanging downwards and moved

Communities (CEC) Report (1984) (also see Broom

towards the cow in the rear of the yard, has a marked

et al., 2002).

Fig. 55.5

Races for cattle should have

no long straights or sharp corners so

Grandin (1980) designed this race for

movement to vehicles. (Measurements

are in metres.)

When cattle arrive at an abattoir they are often

production in dairy cows. Livestock Production Science, **21**, injured or bruised during unloading because of

1–12.

too much haste on the part of animal handlers or

Benham, P.F.J. (1982) Synchronisation of behaviour in grazing

inadequate ramps. Grandin (1979, 1980) reported that

cattle. Applied Animal Ethology, **8**, 403–404.

66 per cent of bruises of the loin area occurred during

Bickert, W.G., Shaver, R.D., Galindo, F.A., Broom, D.M. &

Cermak, J. (1997) Laminitis and factors predisposing to

loading or unloading of trucks. At lairage, animals are

lameness: nutrition, behavior, and housing. In Lameness in often mixed with individuals that are strange to them.

Cattle, 3rd edn (ed. by P.R. Greenough & A.D. Weaver), pp.

This causes much fighting amongst bulls and consider-

293–307. W.B. Saunders, Philadelphia.

able emotional disturbance in other cattle. Studies of

Bouissou, M.F. (1970) Role du contact physique dans la

bulls by Kenny and Tarrant (1982) show that mixing at

manifestation des relations hierarchiques chez les bovins:

lairage causes much fighting, high levels of bruising and

consequences pratiques. Annales de Zootechnie, ***19****, 279–85.*

other injury and a great increase in the incidence of

Broom, D.M. (1981) Biology of Behaviour. Cambridge Uni-dark firm dry (DFD) meat. Both bruising and DFD

versity Press, Cambridge.

meat are of economic importance as well as indicating

Broom, D.M. (1982) Husbandry methods leading to inade-

severe welfare problems prior to slaughter.

quate social and maternal behaviour in cattle. In Dis-

turbed Behaviour in Farm Animals (ed. by W. Bessei).

In an efficient slaughterhouse the period during

Hohenheimer Arbeiten, Vol. 12b. Eugen Illmer, Stuttgart.

which animals are moved from pens to the point of

Broom, D.M. (1983) Cow–calf and sow–piglet behaviour in

slaughter can be very brief and the stunning and slaugh-

relation to colostrum ingestion. Annales de Recherches

ter procedure itself can result in no pain for the animal.

Vétérinaires, ***14****, 342–8.*

Welfare is worse if the animals are kept in a confined

Broom, D.M. (1986) Indicators of poor welfare. British *race for a period of more than one or two minutes*

*Veterinary Journal, **142**, 524–6.*

before stunning, if stunning is carried out inadequately

Broom, D.M. (1988) Welfare considerations in cattle practice.

or if there is inversion before slaughter or no stunning.

In Proceedings of the British Cattle Veterinary Association Poor equipment or lack of care by slaughter staff can

1986–87 (ed. by M. Vaughan), pp. 153–64. British Cattle result in extreme pain and discomfort for the animals.

Veterinary Association, London.

Extreme pain and discomfort are also inevitable if

Broom, D.M. (1991) Needs and welfare of housed calves. In

New Trends in Veal Calf Production. Proceedings of the

animals are not stunned, for example in the Jewish sche-

International Symposium on Veal Calf Production (ed. by chita or the Muslim halal ritual slaughter procedures.

J.H.M. Metz & C.M. Groenestein), EAAP Publication No.

There is a period during which evoked potentials in the

52. Pudoc, Wageningen.

brain can still be produced after the throat is cut that

Broom, D.M. (1993) Assessing the welfare of modified or

may last for from a few seconds to two minutes, during *treated animals. Livestock Production Science, **36**, 39–54.*

which the animal must be in great pain and distress. As

Broom, D.M. (1994) The effects of production efficiency on

the heart still beats after stunning and blood drains from

animal welfare. In Biological Basis of Sustainable Animal

the animal just as effectively whether or not the animal

Production. Proceedings of the 4th Zodiac Symposium (ed.

is stunned there is no logical reason why stunning should

by E.A. Huisman, J.W.M. Osse, D. van der Heide, S. Tam-

not be carried out before the throat is cut.

minga, B.L. Tolkamp, W.G.P. Schouten, C.E. Hollingsworth

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Adult Cattle

Therapy and Disease Prevention

Chapter 56

Health, Housing and Hygiene

D.W.B. Sainsbury

Introduction

971

This chapter is concerned with those underlying princi-

The essentials for good health

971

ples of the management, hygiene and housing of cattle

The size of livestock farms

971

that are essential to assist in the prevention and control

Depopulation

971

of disease.

Group size

972

Isolation facilities

972

Housing types and systems

972

The essentials of good health

Climatic housing

973

Controlled environment house

973

The size of livestock farms

'Kennel' accommodation

973

The environmental requirements of cattle

974

From the point of view of animal health, the smaller the

Environmental factors affecting susceptibility to disease

975

livestock unit the better; nevertheless, the current trend,

Intensification and immunity

977

which appears likely to continue, has been towards

Disinfection

977

increasing the size of units to achieve economies of scale

Natural disinfectant agents

977

– in manpower, buildings and services. However, in

Chemical disinfectants

977

dealing with biological material, in this case cattle, there

Disinfectants

979

Recommended procedure in disinfection and

is clear evidence to show that if the farm becomes too

disinfestation of animal buildings and equipment

980

large, efficiency generally decreases and health and pro-

Ventilation

982

ductivity are adversely affected. Economic surveys have

Underlying principles and calculations

982

shown that very small farms as a group are generally less

Natural ventilation

983

efficient but once the three-man unit has been reached,

Mechanical ventilation

984

further improvements in performance are small or non-

Open-fronted yards and kennels

existent (Britton & Berkeley Hill, 1975). This knowl-

985

edge often goes unheeded and overlarge livestock

enterprises are a cause of great health and management

problems and enormous economic loss. It is, however,

Introduction

pertinent to emphasize that it is the young immature

animal which finds itself at greater risk from disease and

Good health is the birthright of every animal. Con-

mismanagement. Therefore, whilst there should be a

siderable progress has been made towards achieving

limit on unit size at a reasonably low level for the young

improved health in cattle but the disease pattern has

animal, it may be much higher for the adult. The main

changed radically in recent years. The most acute, spe-

reason for this, apart from the extra vulnerability of the

cific, diagnosable and preventable or treatable diseases,

young animal to stress caused by bad management, is

using vaccines, sera and medicines for their control, *the varying immunity to infectious disease among the*

have been largely controlled. In their place have

stock that is unavoidable on a large unit with a mixture

emerged more chronic, insidious and complex diseases

of animals of different ages and possibly of various

not infrequently caused by organisms that are the

sources of origin. The adult presents a more stable

normal inhabitants of the animal body but which cir-

picture in both respects, being rather more resistant to

cumstances allow to become pathogenic. These disease

management changes or errors and very much more

conditions may be difficult to diagnose, have a large and

uniform in its disease resistance or susceptibility.

confusing number of causal agents, create a massive

morbidity and economic loss and require for their

Depopulation

control great expertise in the exercise of husbandry,

hygiene, housing and management skills rather than

So far as possible the principle of periodic depopula-

recourse to the use of medicines or biological products.

tion of a building or, if possible, even a site should be *followed. The benefits of eliminating the animal hosts*

ingly no end to it unless some measures are taken to

to disease-causing agents are well understood and the

ensure a better distribution of the stock.

virtue of being able to clean, disinfect and fumigate a

When animals are kept together in large numbers the

building is also accepted. Nevertheless, in practice the

effects of a fright caused by an unusual disturbance can

whole concept of the 'all-in, all-out' policy is more

be extremely serious. It is almost impossible to guard

complex than the preceding sentences would indicate.

against all the extraneous sounds and sights that may

For example, it is in the young animal that it is particu-

adversely affect the stock. The best safeguard, there-

larly important to consider this and far less so in the

fore, is once again to have the animals in small groups

older beast, which has achieved an immunity to many

so that the effect of a panic movement will be more

of the local diseases. Much also depends on whether the *limited and will never build up into highly dangerous*

herd or flock is a 'closed' one with few or no incoming

proportions.

animals, or an 'open' one with a constant renewal of the

animal population. If the latter is the case, then the

Isolation facilities

depopulation principle is of much greater importance

as there is little or no opportunity for natural immunity

There is a critical need for farmers to give better con-

to develop, and there is a constantly running risk, and

sideration to the isolation of sick and incoming animals.

usually a near certainty, of introducing animals that are

There are numerous reasons why this should be done.

either clinically infected or carriers of disease. Basic

First and foremost, isolation removes some of the

design specifications for 'open' herds should be quite

dangers of contagion to the normal animals; it also

different from those of the closed herd.

makes it much more likely that the sick animal will

recover without the unwelcome attentions of the other

animals who will always tend to act as bullies. In nature, *the sick animal usually separates itself from the rest of*

Group size

the herd, but it is often impossible for the housed

One of the principal ways of putting the housing on a

animal to do this. Also, under the more intensive

firm footing is to keep the animals in groups of minimal

systems of management, more animals are likely to

size. At first sight this sounds an old-fashioned and even

suffer from the aggression of their pen-mates and it is

reactionary concept that may eliminate all those advan-

essential that such animals are removed to prevent

tages from automation that large units can give us, but

them from suffering or being killed. It is also easier,

this certainly need not be the case. If groups are small

with an isolated animal, to give it such therapy as it

it is easier to match the animals in them for size, weight

needs and to give it any special environmental condi-

and age. Under these circumstances it is well estab-

tions, such as extra warmth or adjustments to comfort

lished that fighting and bullying are kept to a minimum,

requirements. For new entrants to the farm it will also *if not completely prevented.*

enable such tests to be carried out to ensure the animals

There is yet another very important advantage in

are free from infection before they can be safely intro-

keeping animals in small groups. It is obviously good

duced into the herd.

practice for a farmer to keep his livestock somewhere

Many modern livestock units completely ignore the

near the level that has been shown to be the densest

provision of facilities to isolate animals and much

possible for optimal productivity yet still satisfying the

greater attention should be given to this need. It is also

welfare essentials. If livestock are kept in a house at a

an essential part of helping the attendant to do a satis-

high density it is essential that they spread across the

fying job.

house uniformly, so they do in actual practice occupy

and use the whole area. Regrettably, this is very rarely

the case in practical experience and especially so when

Housing types and systems

large numbers are housed together without any subdi-

(see pp. 40–44)

vision at all. If the animals crowd in certain parts of the

building there may be grossly overstocked floor areas.

There are three essentially contrasting types of housing:

This is bad enough in itself but it has further unfortu-

‘climatic’, giving only a cover and protection to the

nate side-effects. If they crowd excessively in a part of

animals; ‘controlled environment’, which regulates the

the house, this part may become polluted with dung and

microclimate as completely as is required for the partic-

exhalations to an abnormal and harmful degree;

ular stock being housed; and the ‘kennel’, which is in a

the humidity becomes high, proper air movement is

sense a half-way house between the other two forms and

impeded and the animals may soon become ill. Sick

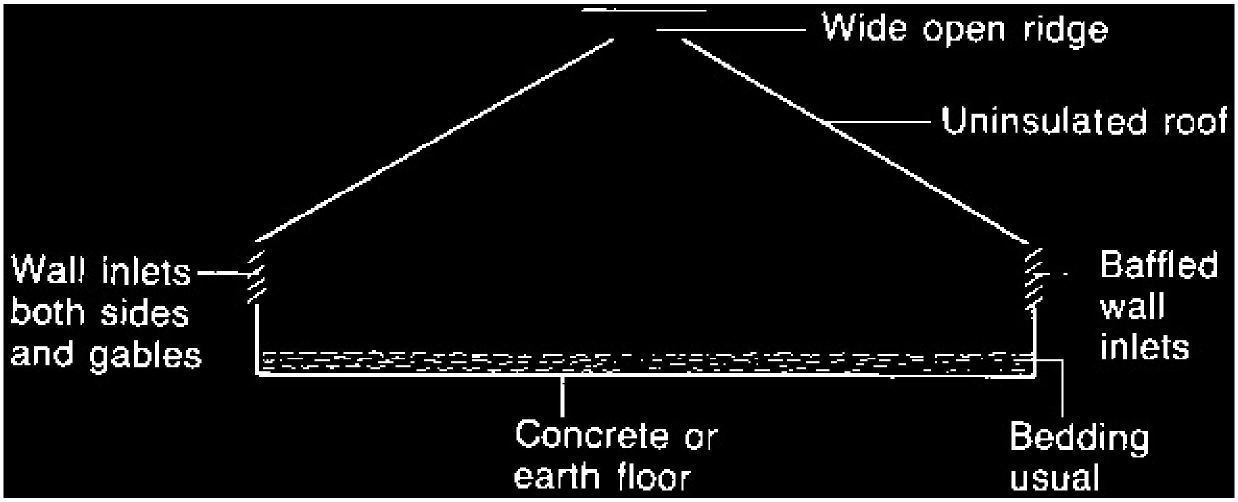
gives two environments in the one building allowing

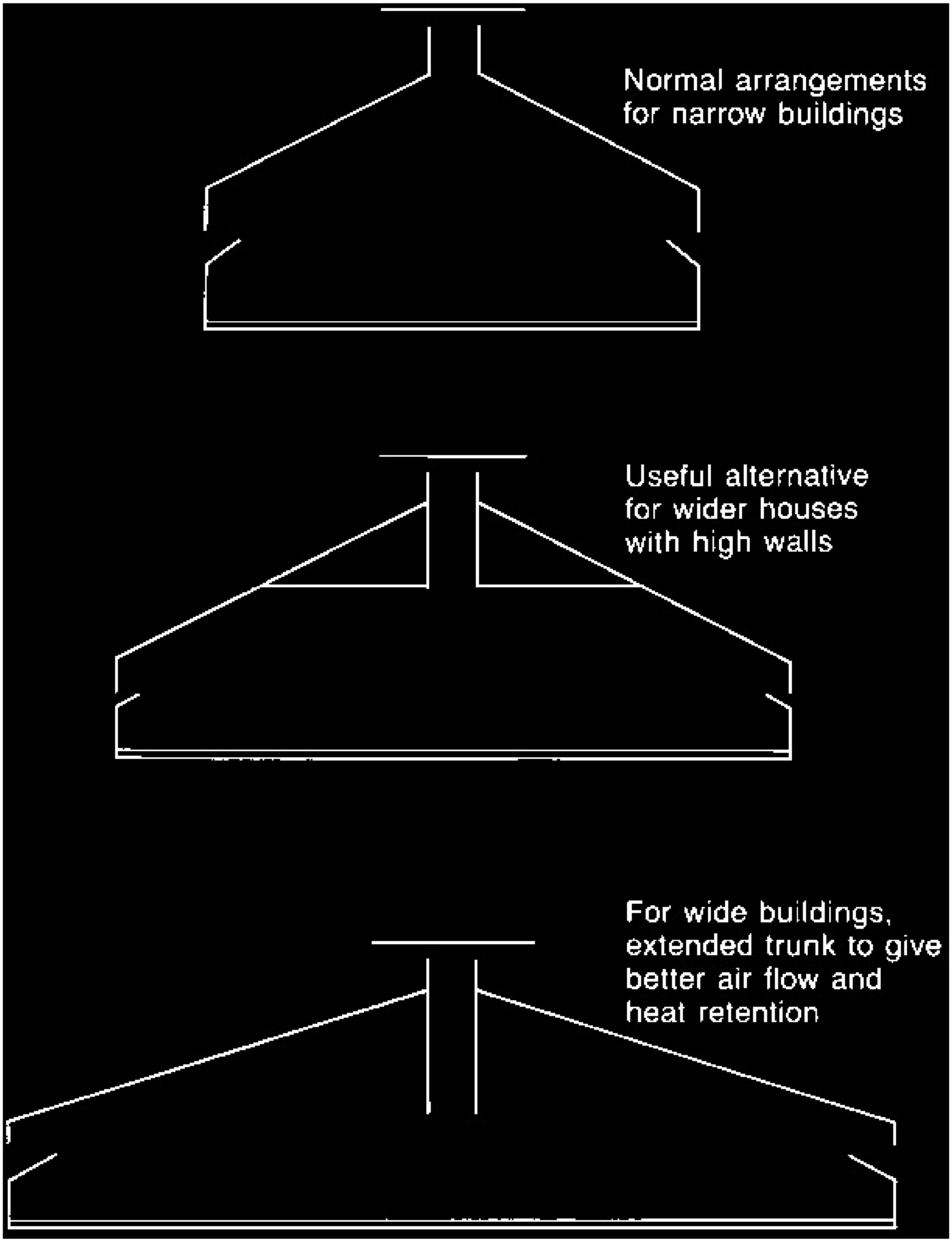
animals feeling cold tend to huddle together even more,

some free and appropriate choice for the animals. The

so the vicious circle is perpetuated and there is seem-

methods of use of each of the types and their suitability


Wide open ridge
Uninsulated roof
Wall inlets both sides and gables
Baffled wall inlets
Concrete or earth floor
Bedding usual


Normal arrangements for narrow buildings
Useful alternative for wider houses with high walls
For wide buildings, extended trunk to give better air flow and heat retention

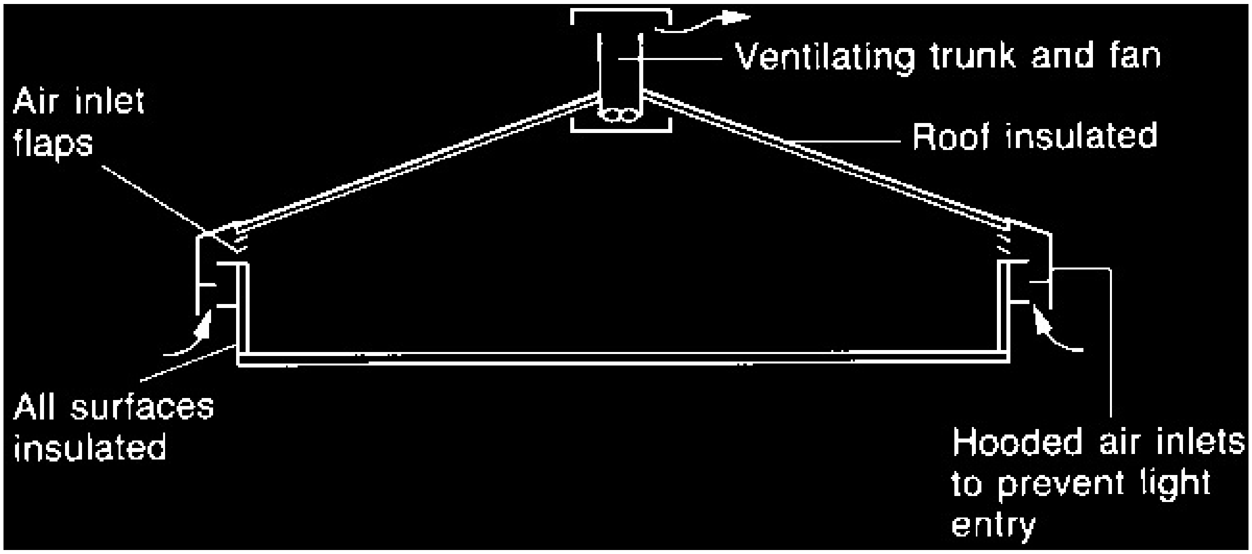


Fig. 56.1

Cross-section of 'climatic' livestock house with open ridge and baffled wall ventilators.

Fig. 56.3

Cross-section of a typical conventionally ventilated controlled environment house with roof fan extraction and hooded wall inlets.

In general, stocking densities tend to be half or less those in the controlled environment house. A major problem is created by agriculturists when they attempt to apply the high stocking rates that are suitable for the controlled environment house to the climatic house, as the building is unable to cope with the demands of the *stock and poor productivity and high disease incidence can result. Climatic housing is usually the correct choice for cattle over about six months of age. Such housing usually requires deep bedding for its success, particularly in cooler climatic areas.*

Controlled environment house *(Fig. 56.3)*

The controlled environment house is in great contrast. It has a limited use for cattle, being sometimes used for young calves and to a lesser extent for cattle kept on any bare surfaces, solid or slotted, without bedding. It is most economically viable with livestock that are fed largely concentrate food rather than substantial quantities of roughage, since the former is too expensive to be utilized as a form of energy. The housing is expensive and because of the cost it is usually necessary to

Fig. 56.2

Alternative arrangements suitable for natural ventila-

stock the buildings as densely as possible to make them

tion of various widths of buildings and using outlet ('chimney') viable economically, and this can place a great strain on

trunks.

health control. To cope with the special requirements,

management needs to be of the highest standards and

unless these criteria can be observed it is the wrong type

for different countries, climatic regions and forms of live-

of housing to have. The rewards can be great but the

stock vary enormously and must be carefully defined.

dangers are greater.

***Climatic housing** (Figs 56.1 and 56.2)*

***'Kennel' accommodation** (Fig. 56.4)*

The climatic house is ideal for the adult beast that has

This is an increasingly popular system of accommoda-

developed a large measure of adaptability to climatic

tion that is in a sense half-way between the climatic

stress. The house can be cheap because it is basically a

and controlled environment housing. It attempts to

cover alone but because of the lack of control of the

combine the virtues of both, but at low cost, and often

climate the space given to the animals must be much

succeeds. The essence of the system is that the animals

greater, especially since there usually is no powered

are kept in pens or groups that are sufficiently small to *ventilation.*

allow them to be closely confined, at least while resting,

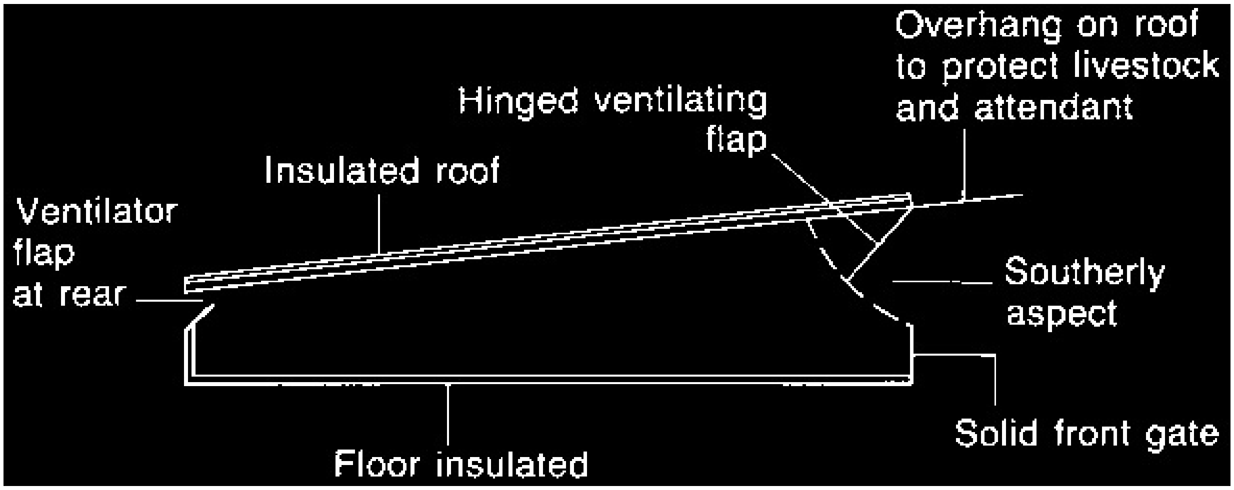


Table 56.1

A guide to the minimal space allowance for cattle

at different stages of growth in strawed yards.

Age

Area/animal (m2)

Up to 14 days

0.9–1.4

14 days to 3 months

1.4–1.8

3–6 months

1.8–2.4

6–9 months

2.4–2.7

Fig. 56.4

Cross-section of a mono-pitch ('kennel') naturally

9–18 months

2.7–3.8

ventilated stock building.

Adults

small

5

large

7

without too great a danger from respiratory or other

disease. The close confinement makes it possible to

keep the groups warm and draught-free by utilizing

there is no possible justification for this control to

their own body heat and by good insulation of the

embrace the effluent from the animals, which is not only

kennel and a limited cubic air space. This part of the

a considerable expense but is also likely to intensify the

accommodation is a simple form of controlled environ-

disease risk.

ment house: the rest is the climatic house and can be

Whatever the system, the principal practical faults in

justified as this is an area where the animals will be

livestock housing systems are as follows:

moving about freely and will not normally be inactive

• *Having too close a confinement of the animals.*

or lying down. It is likely to contain the dung and often

• *Placing too many animals in one common air space.*

the feeding and watering arrangements and so must be

• *Reducing both cubic area and floor space.*

very adequately ventilated, usually by non-mechanical

• *Failing to remove muck from close proximity to the*

means. In harsh climatic areas it is covered; in milder

animals.

regions there is no need for this and the 'yard' can, with

• *Transferring muck through pens, aiding the transfer*

benefit to health and productivity, be left uncovered.

of disease.

It is instructive to examine the logic of the 'kennel'

• *Failing to separate age groups.*

system.

• Neglecting clean feeding and water arrangements.

• The cost of the housing can be as low as any system,

• Having poor or sometimes no drainage.

especially with uncovered yarding, and such build-

• Neglecting the comfort of the stock.

ings are also the easiest type of building for the

• Inefficient ventilation systems.

farmer himself to erect.

Table 56.1 shows the space allowances for cattle in

• Good health is promoted by separation of the

strawed yards.

animals into small groups. The separation of the

kennels one from another should be as absolute as

possible as this will limit the build-up and spread of

The environmental requirements

respiratory disease. It will also be a great assistance

of cattle

to the health of the animals if the muck is not

allowed to accumulate in the warmth or the closely

In most cool, temperate environments, ruminants main-

confined resting area. It is often possible as well, by *tain a stable body temperature by regulating evapora-*

good design, to keep the dunging areas separate so

tive loss, at little metabolic cost. Ruminants have a very

that the muck from different pens does not come

marked ability to alter their zone of thermal neutrality

together until after it is out of reach of the animals.

in response to previous thermal history. Thus there are

• The cheapness of the housing is largely due to the

no absolute criteria for the thermal requirements of any

fact that the environment is controlled only where

class of ruminant livestock, except perhaps the new-

it is absolutely necessary.

born animal; they depend to a large extent on what the

It is certainly a distinct virtue if the dung can be in

animal has grown accustomed to.

an area where the air is moving more freely and the

Some examples of the lower critical temperatures for

temperature and the humidity possibly much lower,

cattle under conditions of varying air movements are

at least in temperate climates. Feeding in an outside

shown in Table 56.2. This table illustrates a situation *yard achieves this objective. Controlled environment*

where the beasts are standing up, in a dry enclosure,

housing is becoming more and more expensive and

under two variations in air movement (Webster, 1981).

Table 56.2

Lower critical temperature of ruminants housed in

depends as much on the thermal properties of the floor

a building with very low air movement (0.2 m/s) and in a draught as on the temperature.

(2 m/s). Source: Webster (1981).

It is worth stressing that European cattle tend to be

tolerant to cold but intolerant to heat. Their 'comfort

Type of animal

Liveweight

Lower critical

zone' is between about 0 and 20°C. The critical tem-

(kg)

temperature (°C)

perature leading to a decline in milk yield at the higher

level is approximately 21–25°C for most European

Low air speed

Draught

cattle, including Friesians and Jerseys, but as high as

Calf

30–32°C with Brown Swiss (see Chapter 8).

Newborn

35

+9

+17

The effect of high temperatures may be ameliorated

1 month old

50

0

+9

in practice in a number of ways. The provision of shade

Veal

100

-14

-1

makes a great difference, also of wallows and artificial

Store cattle

250

-32

-20

showers. For example, great benefit has been found in

(maintenance)

tropical climates with cattle kept under a so-called

Beef cow

450

-17

-9

desert-cooler consisting of a three-sided shelter open to

(maintenance)

the north, with an upper roof of aluminium, which

Dairy cow

500

-26

-13

reflects the heat rays, a ceiling underneath of three

layers of old hay and an evaporative cooler under the

roof at the south end of the shelter. There are a number

In an unheated building at low air movement the only

of highly effective methods of reducing heat stress by
cattle likely to experience cold sufficient to elevate the
the use of water atomizers. In some cases atomizing
heat production are newborn calves or young calves
units are suspended under the roof of the buildings
whose metabolic rate is low by virtue of starvation, sick-
whilst more sophisticated arrangements utilize a series
ness or emaciation. Such animals can undoubtedly be
of mist propagators above the stock connected by a
stressed by cold and may require special attention.
pipe-line carrying the water. Provided the humidity of
Increasing air movement to 2.0 m/s, which is not uncom-
the ambient air is not too high, significant cooling
mon in draughty buildings, increases the critical tem-
effects can be achieved at a modest running cost (see
perature in the newborn calf from +9 to +17°C. This
Chapter 8). True refrigeration plants are very occasion-
emphasizes the necessity of ensuring that adequate ven-
ally used but are rarely economic. At high temperatures
tilation for calf houses is achieved without allowing
farm stock also attempt to reduce their heat production

excess air movement (or 'draught') to impinge on the

by reduced feed intake. This leads to less production

calves.

and often also to metabolic and fertility problems.

By one month of age the healthy calf with a good

Under hot sunny conditions the temperate breeds, par-

appetite and access to an adequate feed source has a

ticularly, spend less time in grazing and, in fact, under

critical temperature close to 0°C and is not likely to be

these conditions most of the grazing will be done at

stressed by cold while indoors. Well-grown veal calves,

night. There are very marked breed differences, as

by virtue of their very high energy intake and heat pro-

might be expected, the tropical breeds being least

duction, are particularly tolerant to cold and by the

affected.

same criteria sensitive to heat. The traditional belief

In loose housing systems with open fronted barns,

that veal calves should be kept in a warm environment

protection from solar radiation and maximum provision

because they are not ruminants and are therefore *of air movement represents the limit of environmental*

somehow more sensitive to cold is unscientific and

improvement. With closed buildings, such as the cow-

untrue.

house, mechanical air cooling may be used and, in parts

No other class of cattle is likely to experience a sys-

of the world where climatic temperatures warrant it, has

temic stress of cold when standing up in a dry enclosure

been found worthwhile. For a comprehensive consider-

unless air movement is exceptionally high. However,

ation of the effects of the environment on cattle the

problems do arise in damp conditions. For the dairy

reader is referred to Clark (1981).

cow, however, cold stress should not be considered as a

systemic but as a local problem. Heat production in the

high-yielding cow is again very high and so the critical

Environmental factors affecting

temperature is low. Milk synthesis, however, depends

susceptibility to disease

on blood flow to the mammary gland, which is reduced

by local cooling. The production of dairy cows has

Many of the organisms that cause ill-health in intensive

been shown to fall at temperatures below about 0°C,

livestock units are normally present in the animals and

although it is obvious that direct chilling of the udder

their surroundings and it is environmental stress that

acts as a trigger, inducing their multiplication to such an

humidity. Rhinoviruses appear to survive better at high

extent that clinically obvious disease breaks out. There

humidities but infectious bovine rhinotracheitis (IBR)

are numerous examples, such as respiratory diseases,

and parainfluenza 3 (PI3) viruses at low humidities. In

diarrhoea and mastitis. Whilst these diseases may

these last examples the differences in survival time

always become clinically obvious in the long term, there

reflect the association between seasonal patterns of

may be a lengthy period beforehand when their effects

relative humidity and disease incidence. There is the

are limited to poor growth or productivity and an inef-

further possibility that at high relative humidity there

ficient conversion of feed by the animal. It is an essen-

is accelerated sedimentation of airborne pathogens in

tial feature of a farmer's recording system that records

large aerosols. Mycoplasma, on the other hand, tends to of productivity are kept which should allow the detec-be stable at very low and at high relative humidities but

tion of results that are beginning to deteriorate, and this

sensitive to mid range relative humidity.

can well be a warning that urgent action is needed to

So far as bacteria are concerned, a rise in tempera-

stop a slide in results leading eventually to disease.

ture produces an increasing destruction of bacteria but

Most of the conditions of this nature are insidious,

airborne spores are highly resistant. Escherichia coli

chronic and difficult to diagnose by any of the popular

survives and multiplies best at about 15°C, as also does

methods that are so effective with the well-described

Mycoplasma. Bacteria tend to be resistant to low and

diseases. Very limited use can be made of vaccinations

high relative humidity but sensitive to mid range rela-

or antisera, nor are antibiotics or drugs more than a

tive humidity; bacterial spores, however, are resistant

short-term answer. The only effective way is to attend *almost totally to relative humidity effects.*

to the whole environment of the animal by such

It is important to be aware that in airborne infections

methods that are known to reduce the risk of disease.

the size of the infecting dose will determine whether or

It is extremely difficult to reproduce clinical disease

not disease will result. Also, its severity and the likeli-

by experimental infections even when huge doses of

hood of infection making headway will depend on the

mixed organisms are used. Whether or not an animal

animal's overall resistance; for example, chilling can

becomes clinically affected depends on non-specific

markedly lower an animal's resistance to inhaled

factors of climate, housing and husbandry, which

pathogens by depressing lung clearance mechanisms

together form the total environment that is considered

(Whittlestone, 1976).

in this chapter. Above all it should be made clear that

Systems in which the air is recirculated are being

the state of health of the animals can transcend all other

favoured as a means of reducing heating costs, but in

factors in determining the economic viability of a live-
such systems some form of air cleansing, e.g. filtration,
stock enterprise. Disease at its worst kills the animal,
may be necessary to avoid a build-up of pathogens.
but even in sublethal infections seriously affects
It is known from the work of Honey and McQuitty
productivity.
(1976) that animal buildings are often very dusty, but
The factors influencing the dispersal, survival and
the factors affecting dust production are ill defined.
deposition of airborne pathogens in farm animals have
Small changes in relative humidity have been found to
been reviewed comprehensively by Donaldson (1978).
have significant effects on settled dust; lower humidities
Droplet nuclei are the primary mode of spread of a
result in more settled dust. There is, however, mounting
variety of contagious diseases and many pathogens
concern about the deleterious effect of dust on live-
have been shown to have been spread in this way via
stock health, and good systems of ventilation should be
the animals' breath and also from secretions and excre-

able to remove it from the building in the same way and

tions of the infected animals (see p. 242).

as efficiently as other environmental pollutants.

Referring specifically to virus particles, the ambient

The disposal of large accumulations of animal excre-

temperature has little effect on their survival in an

ment, bedding and litter is a further problem and can,

animal house but a general trend is that high tempera-

in some instances, be the limiting factor in determining

tures are more harmful to their survival than low ones

the size of unit. It is common practice to dilute the efflu-

(Sanger, 1969). In fact it has been suggested that the

ent from farm buildings into a slurry and then spray it

inactivation of viruses immediately after exhalation and

over farmland as a fertilizer. The hazard from the dis-

aerosol formation is dependent on the relative humid-

semination of slurry-associated pathogens over a wide

ity and any temperature effect occurs secondarily

area in this way can be considerable, particularly in

(Donaldson & Ferris, 1976). The effect of relative

windy weather (Wray, 1975). A dairy herd of 50 cows *humidity on viruses in general is that viruses with a*

causes a potential pollution load as large as that of a

lipoprotein envelope survive best at a low relative

village of over 500 people, yet frequently the manure is

humidity, whereas non-enveloped viruses are unstable

carelessly disposed of without thought of its potential

in dry conditions but survive best at a high relative

dangers to man or animal.

Intensification and immunity

Natural disinfectant agents

There are some underlying truths in connection with

Most pathogenic micro-organisms do not survive long

disease and immunity that need to be explained as they

outside the animal body, but unfortunately sufficient

have a close bearing on the incidence of disease and its

may always remain to cause renewed infection. Some

relationship to the environment.

vegetative bacteria and viruses can live several months

An animal at birth has a degree of passive immunity

if protected with organic matter and the spores of bac-

to local disease that is passed from the dam to the off-

teria can live almost indefinitely in the soil or protected

spring, partly in utero and partly from the colostrum or in cracks and crevices of the building. For example,

first milk. Such immunity is, however, only practically

Clostridium tetani and Bacillus anthracis can live for effective to local infections to which the dam has been

many years. Even coccidial oocysts may survive for

challenged. If the birth takes place in a 'foreign' envi-

years in infected quarters.

ronment, then the young may have little or no passive

The factors contributing towards natural destruction

immunity to the infective organisms in their new local

of microbes are nevertheless important as they do

environment. In many cases the young are housed

reduce the numbers and this in itself is a worthwhile aid

during the early stages of life in such a 'foreign' envi-

to the artificial processes. Sunlight, heat, cold, desicca-

ronment and it is therefore most important that the

tion and agitation all contribute. Sunlight is the most

challenge of disease-causing organism is reduced to a

potent and its powers of destruction are enormous; its

minimum.
efficiency is entirely due to the ultraviolet range of
Perhaps the first and foremost methods for reducing
wavelengths. Unfortunately, these ultraviolet rays have
this challenge are by the processes of depopulation,
little penetrating power and cannot pass through glass
cleansing and disinfection. This can obviously be under-
or translucent roofing sheets or through clouds of
stood to be most important in the case of the younger
industrial haze; the value of sunlight in animal buildings
animal, which has a poor or uncertain resistance to
is therefore wholly unreliable. Desiccation, from fresh
disease. Whilst it can never be said to be other than
air and wind, will also contribute to the destruction, par-
advantageous, it is most important on sites that have a
ticularly when the micro-organisms are exposed to this
large population of animals in an area where there are
by prior cleansing of the building.
substantial numbers of animals since many diseases,
Another process is antibiosis; many bacteria and
especially viral ones, can pass a great distance by the

fungi produce substances that are antagonistic to other airborne route. Whilst small infective particles can be organisms. Penicillin and streptomycin are agents of carried directly by dust particles moved by the wind, this nature whose antibacterial action is well known. In other pathogens are carried indirectly by vectors, espe- the soil, in floors and buildings generally, pathogenic cially birds.

organisms will be acted upon by antibiotics produced by non-pathogenic organisms that are normal inhabi- tants of the soil. Warm moist conditions will assist the action of such saprophytic agents.

Disinfection

The action of heat

The disinfection of a building implies the elimination from the house of all micro-organisms that are capable For many years heat has been used for disinfection, dry of causing disease, thus converting the place from a heat being used with the 'flame-gun' and moist heat in potentially infective state into one that is largely free the form of the 'steam-jenny', but both tend to be *from infection. A disinfectant is the agent that is*

inexact and uncontrolled methods of applying the

capable of achieving this and in livestock farming it is

agents.

usually a chemical agent.

Many bacterial spores can easily survive the transi-

The processes of disinfection of a building can take

tory attention of the heat source and pathogenic organ-

place by the action of nature (natural disinfection) and

isms may readily be protected from the heat in cracks

by artificial means (artificial disinfection). Before dis-

and crevices of the building.

cussing these processes in some detail, it should be

emphasized at the outset that 'cleansing' is an essential

Chemical disinfectants

preliminary to disinfection. Organic matter has the

ability considerably to reduce the effectiveness of

Disinfection on the farm is generally carried out by

disinfectants, so without good cleansing the action of

using chemical agents. The lethal action of disinfectants

disinfectants is often readily diluted.

is due in the main to their ability to react with the

protein and, in particular, the essential enzymes of

greater than 120°C over long periods are needed to

micro-organisms. Therefore, any agents that will coag-

inactivate the finely divided material. Resistance

ulate, precipitate or otherwise denature proteins will

to common sterilants and other chemical agents is

act as general disinfectants. Among these agents are

very high, as is resistance to extremes of pH and to

phenols, alcohols, acids, alkalis, aldehydes, halogens,

ultraviolet or ionizing irradiation. The only chemical

chloramines and quaternary ammonium compounds,

treatment so far found to be effective against all

as well as heat and certain radiations.

transmissible spongiform encephalopathies is sodium

hypochlorite at 20 000 parts per million of available

chlorine, for about one hour (see p. 909).

Selective action

Many disinfectants have a selective action on different

Dynamics of disinfection

*types of microbes. For example, Gram-positive and
Gram-negative bacteria differ in the structure of their
Disinfection is not an instantaneous process; it takes
membranes, the latter being of a more complex nature.
place gradually. However, many more microbes are
Micro-organisms also respond to changes in pH and
killed at the beginning of disinfection than at the end,
as every protein has its own characteristic isoelectric
although there is an initial lag period before activity
point, each responds individually and will be influenced
commences. The lag phase is normally only a few
by the acidity or alkalinity of the disinfectant; for
seconds, but may be seriously prolonged if the envi-
example, fungi are extremely acid-resistant, whereas
ronment is unfavourable, for example extreme cold,
viruses tend to be more susceptible to acid disinfectants,
high humidity or excessive organic matter. An exami-
such as the iodophors. Another factor affecting the
nation of the number of organisms surviving at differ-
behaviour of a disinfectant is the lipoid content of the
ent stages during disinfection shows that the number of*

cells; in some the content is high, as in acid-fast organ-

bacteria killed in unit time bears a constant relationship

isms, and it will thus attract a lipophilic moiety in a dis-

to the number of surviving organisms. Thus, after the

infectant substance and dissolve it more readily, thereby

lag phase, destruction of the bacteria is very rapid at

increasing the germicidal activity. Some disinfectants,

first but tends to slow up so that eventually destruction

which are called broad spectrum, are almost equally

of all the organisms takes a considerably longer time.

active against most species of micro-organisms, while

The usual time–survivor curve is of the sigmoid type.

others show specificity and are only active against a

The concentration of disinfectant and temperature of

restricted number of species.

disinfection influence the rate of death and also alter

the shape of the time–survivor curves. As the death rate

is increased by using higher concentrations of disinfec-

Disinfection of viruses

tant, the initial lag phase is eliminated or, in fact, is

For disinfection purposes viruses can be classified into *so quick that it goes undetected. The action of most*

two groups, lipophilic and hydrophilic. Lipophilic

disinfectants is increased, often quite markedly as the

viruses have lipid envelopes, which make them sensitive

temperature rises.

to the majority of disinfectants. Most of the animal

pathogenic viruses are in this group. Hydrophilic

The effect of organic matter

viruses are enveloped and are less sensitive to disinfec-

Almost invariably when disinfection is carried out on

tants in general. Some very important viruses are in this

the farm, organic matter will be present. It can be said

group and these have a tendency to become danger-

that organic matter always interferes with the action of

ously persistent on farms and in animal buildings; exam-

the disinfectant and may do so in the following ways:

ples are the enteroviruses and reoviruses. Against this

latter group quarternary ammonium compounds have

(1)

The organic matter may protect the cell by

a poor effect, but are very good if associated with *forming a coating on it and preventing the ready*

formaldehyde, gluteraldehyde, chloramines and certain

access of the disinfectant.

organic acids.

(2)

The disinfectant may form an insoluble compound

with the organic matter to remove it from poten-

tial activity.

Disinfection of prions

(3)

The disinfectant may react chemically with the

The various infective prions, such as those causing

organic matter giving rise to a non-germicidal

bovine spongiform encephalopathy or scrapie, have a

reaction product.

number of common characteristics. They are extremely

(4)

Particulate and colloidal matter in suspension may

resistant to heat and, whilst some loss of infectivity

absorb the antibacterial agent, so that it is sub-

occurs at temperatures above 100°C, temperatures *stantially removed from solution.*

(5)

Fats, etc. in serum and milk may deactivate the

Formaldehyde and glutaraldehyde

disinfectant.

Formaldehyde is a widely used disinfectant in both the

gaseous and the aqueous forms, being bactericidal,

Approval of disinfectants

virucidal and fungicidal. In aqueous solutions, formalin,

which is a solution of formaldehyde gas containing 40 g

There is no completely satisfactory method of assessing

of formaldehyde in 100 ml of the solution, is widely used

or standardizing disinfectants and an enormous number

at 5 per cent strength as a general disinfectant, but it

of different techniques have been used in the past.

does need to be in contact with the surface for some

There is also no universally effective disinfectant, so

time to be effective. Its action is greatly affected by tem-

that different disinfectants are required for different

perature (i.e. it has a high temperature coefficient) and *purposes.*

the warmer it is the better, blood heat being most sat-

In the UK, approvals for disinfectants are under five

isfactory. It also acts more efficiently when the surface

headings, as follows:

is wet. In agricultural use formalin is largely used as a

Group 1A are active against foot-and-mouth disease;

gas or an aerosol spray.

Group 1B are active against swine vesicular disease;

A very active complex disinfectant, which is useful

Group II are active against fowl pest;

against the most persistent viruses, is one containing

Group III are active against tuberculosis;

formaldehyde, glutaraldehyde and a quarternary

Group IV are for general farm use, the test organism

ammonium compound. This is active at much lower

being Salmonella cholerae suis.

temperatures than formaldehyde.

The official test lays down a rigid procedure for spe-

cified reduction of the organisms in the presence of

Quarternary ammonium compounds

organic matter. The most recent lists of approved dis-

infectants list over 300 of them for livestock use.

These are cationic neutral detergents available as

aqueous solutions, powders or pastes. They are effective

against a wide range of bacteria and moulds and have

Disinfectants

a high surface activity. Generally, when dissolved in

water, they have a high wetting power and the ions

Phenols, cresols and related compounds

adhere to the surfaces, giving a long-lasting residual

The phenols, cresols and related compounds are an

effect. They also have low toxicity and lack odour or

important group of disinfectants that were once the

taste. Combined with other disinfectants they can give

most popular of all such agents.

a wide spectrum of activity.

All phenols can act bactericidally or fungicidally but

generally are neither sporicidal nor particularly viruci-

Oxidizing disinfectants

dal. They have high dilution coefficients, i.e. small con-

centration changes give rise to large differences in their

Hydrogen peroxide and other oxidizing agents includ-

killing rates. They are always more active as acid solu-

ing peracetic acid and propionic acid are emerging as

tions. Organic matters can severely interfere with their

increasingly popular disinfectants. At quite low con-

efficiency and even small quantities of faeces can

centrations they are active against bacteria, their spores,

reduce their effectiveness to 10 per cent. There are

viruses and fungi. Several new proprietary forms are

many proprietary 'coal tar disinfectants', phenolic in

marketed for use in livestock buildings.

nature, and in view of their inevitable low solubility

in water they are either solubilized or emulsified. The

The halogens

solubilized types, known as 'black fluids', are those in

which the phenol fraction is dissolved in a soap base

In agriculture, chlorine is widely used for disinfecting

and the emulsified types, known as 'white fluids', are

water and in the cleansing of dairy and other farm

those in which the phenol is emulsified into a perma-

equipment. Chlorine-releasing compounds containing *nent suspension with the aid of gelatin or dextrin.*

up to 90 per cent available chlorine are available and

In more recent years a number of synthetic phenols

have an important use in the formulation of bacterici-

have been marketed. These may be a chloroxylenol,

dal detergent powders of the alkaline variety. Products

o-phenylphenol or one of the other diphenyl deriva-

of this type are suitable for use in the washing down of

tives. Such preparations, in contrast to the cresols or

an animal house. The inorganic chloramines, being a

coal tar disinfectants, are non-toxic, non-irritant and

concentration of chlorine and ammonia, are used in

have a more pleasant odour, arising chiefly from their

water and sewage treatment; organic chloramines, such

purer contents.

as halazone, are excellent water sanitizers.

The normal use of chlorine in cleaning milking and

dimethyl- O-2,3,5-trichlorphenyl phosphorathroate

other utensils is to use a detergent wash with a solution

(fenchlorphos 12 per cent) (see Chapter 60).

containing 250–300 ppm of available chlorine followed

by a rinse with a weaker chlorine solution. Failure of

Health and safety

the chlorine disinfectant is more likely due to the pres-

ence of organic matter, which does seriously interfere

There are certain dangers to people and mammals in

with its action, so that it is not normally used where

the use and disposal of disinfectants and ectoparasiti-

much dirt is present. In favourable circumstances it is

cides and the residues of their applications. For this

best used warm and will act quickly. Chloramines are

reason alone it is advised that only officially approved

much more active in the presence of organic matter and

products should be used and the health and safety

have found a secure place as general disinfectants.

regulations attached to them are followed rigidly. An

awareness of the possible harm to those using the sub-

stances and their effect on polluting the environment

Iodine and iodophors

has increased immensely lately so that the manufac-

Iodine is an effective germicide, although like chlorine *turers have been forced to update the health and safety*

its action is much depressed by organic matter. It is

data regularly. There are particular dangers with some

effective against vegetative organisms and spores. The

ectoparasiticides as well as certain disinfectants and it

most widely used iodine preparations are the

is vital that protective clothing is worn.

iodophores in which iodine is mixed with surface-active

agents, which act as carriers or solubilizers for the

Rotation of hygiene products

iodine. They lack any real odour and are not irritant.

Iodophors have been used at dilutions of around

There are no products that are ideal. All of the dis-

25 ppm available iodine for utensils. They have built-in

infectants and ectoparasiticides have their strengths

indicators that reveal quickly the approximate concen-

and weaknesses. To minimize the adverse effects of this

tration of the use dilution; a yellow tinge or pale amber

fact, it is recommended that a rotational programme is

colour is imparted by an iodophor even when only a few

instituted so that regular programmed changes are *parts per million of free iodine are present in the solu-*

made in the type of product used, thereby reducing the

tion. High concentrations give deeper shades of amber

chance of certain pathogens escaping destruction.

or brown to the solution. The use dilution of 25 ppm is

equivalent to available chlorine concentrations up to

Recommended procedure in disinfection

200 ppm. Iodophors are an ideal germicide to use in

and disinfestation of animal buildings

water utensils.

and equipment

Basically, two procedures should be adopted. The first

Ammonia

is used between batches of livestock within a building

A 10 per cent aqueous solution of ammonia is an effec-

in the absence of overt disease, and the second after an

tive agent for the destruction of coccidial oocysts. This

outbreak of a contagious and infectious disease.

is the only use for ammonia as a disinfectant.

Procedure of disinfection with no disease present

Ectoparasites

(1)

All equipment and fittings that are removable

It is of great importance to control ectoparasites in and

should be demounted and taken out of the build-

around the farm buildings. They are a nuisance both to

ing. It is advisable for them to be soaked in a bath

the attendants and the animals, may be the cause of

of disinfectant where the materials are able to

direct irritation and disease and may indirectly spread

stand up to this treatment. Alternatively, they

disease; indeed any infectious agent can be carried by

may be power-sprayed or steam sterilized. They

ectoparasitic vectors. These ectoparasites include flies

should be left outside exposed to the elements and

(the ordinary housefly, the lesser housefly and the

away from animals and their products for as long

stable fly), mites, ticks, lice, fleas, bugs, beetles and

as possible.

cockroaches.

(2)

All litter should be removed (Fig. 56.5).

For the control of external parasites of animals a

(3)

The roof and structural elements of the house

variety of compounds are available, such as gamma-

should be dusted and cleaned, preferably with a

benzene hexachloride (lindane), piperoxyl-butoxide

vacuum cleaner.

pyrethrum (pybuthrin) or O, O-dimethyldithiophosphate (4)

The lower part of the walls and all the floors

of diethylmercaptosuccinate (malathion) and O, O-

should be thoroughly cleaned, preferably using a

Fig. 56.5

Cleaning out the litter after

removal of the animals.

Fig. 56.6

Washing down with a pressure

hose using a detergent disinfectant.

pressure washer, with a heavy duty, wide-spectrum

Procedure after contagious and infectious disease

detergent/disinfectant mixture (Fig. 56.6).

(5)

The surfaces must then have a disinfectant applied

(1)

The building should be closed and isolated from

(Fig. 56.7) with a wide spectrum of activity,

all visitors.

capable of killing all the pathogens that are likely

(2)

The bedding, litter and all areas in intimate

to be present.

contact with the stock should be sprayed with a

(6)

In some cases, if there is a heavy insect infestation,

strong disinfectant.

it will be necessary to apply a special insecticide

(3)

The litter should subsequently be removed from

spray.

the building and may be burnt or buried so there

(7)

As a final measure a disinfectant is often sprayed

is no possible contact with livestock.

over all the surfaces to give a residual effect.

(4)

Portable equipment and fittings should be given

Thermal 'fogging' machines are widely used.

the same treatment as previously suggested and

Fig. 56.7

Spraying with a disinfectant.

preferably in the house, later to be taken out and aerated.

(5)

The floors and lower part of the walls should be cleaned with detergent disinfectant.

(6)

The house should then be treated in the same way as suggested in the previous section.

(7)

It may sometimes be advisable to skim off the top few inches of the soil around a heavily infected area.

(8)

The approaches to the building should be treated with disinfectant and foot-dips provided (Fig. 56.8).

Ventilation

There are few topics in animal husbandry where there have been more totally erroneous statements made *than on the reasons why housed livestock require ventilation or 'air-change'. For example, for many years it was accepted that the main deleterious effect of having too little ventilation was due to the build-up of harmful concentrations of the gaseous products of respiration, and in particular carbon dioxide, combined with a depletion in the oxygen content of the air. It is now known that this is far too simple and usually quite an incorrect hypothesis.*

Underlying principles and calculations

In any badly underventilated building the stagnant air gradually becomes both warmer and more humid and

Fig. 56.8

Using protective clothing and dipping boots in dis-

there is a rising concentration of dust, other particulate

infectant to reduce the risk of introducing infection.

matter, ammonia and other gases and any pathogenic

tective cap may be sufficient. But in other controlled-

microorganisms the livestock may be carrying. The end

climate accommodations far more control is needed *result is that the animals suffer from ‘heat stagnation’, and down-draughts, which can be common with the involving a susceptibility to chilling. Along with this will fixed open ridge, must be avoided. Experience has go poor productivity and a likelihood of disease, par- shown that for the latter, good results are obtained by ticularly respiratory, which modern experience shows to the use of a limited area of controlled outlet ventilation be of the greatest danger in intensive forms of housing. and for this purpose a simple chimney type or insulated In addition, in a badly ventilated building, condensa- ‘flue’ is satisfactory. It is good practice to have one or a tion on the surface is often likely and bedding and floors few outlets, but a much larger number of smaller air may become wet and the animals uncomfortable. This inlets, as the fresh air should come in slowly all round will tend to exacerbate the effect of disease conditions, the building, diffusely and carefully baffled. The basis respiratory or enteric in nature, or infections such as of a useful inlet system consists of hopper-type mastitis.*

windows, fitted with gussets to prevent direct draughts,

In recent years a new hazard to livestock and their

serving as principal inlets, and small baffled openings

attendants has been the risk of gaseous intoxication of

between the windows which alone are left open during

livestock due to the gases arising from slurry pits or

cold or windy weather. Since cold air coming into the

channels under the animals. The risk is very great and

building falls naturally towards the floor, there is no

has caused the death of many animals and several

necessity to site inlets at floor level, where the danger

stockworkers.

of chilling draught is considerable.

The object of ventilation, therefore, is to remove the

stale air in a building and replace it with fresh air and

The totally covered yard

remove any danger of toxic gases. But while too little

ventilation is obviously serious, so also is too much. In

In practice the following major faults are commonly

cold weather much valuable animal heat will be wasted.

found in the construction of covered yards:

Further, overventilation may be synonymous with

• Either there is no ridge outlet for stale air or it is

draught. Draughts are themselves responsible for

inadequate.

causing many deaths by direct chilling and they may

• Eaves openings are either absent or, where present,

also act indirectly by lowering the animals' resistance

uncontrollable and at the mercy of the weather,

to disease-producing organisms.

causing chilling draughts in cold weather.

In planning a ventilation system allowance has to be

• The extreme width of many yards (20m upwards)

made for all the factors that can influence the ventila-

prevents natural ventilation functioning properly.

tion required, i.e. type, age and number of livestock,

This problem is often combined with multispan

their management, the construction and locality of the

construction and low eaves and roofs, so that the

house and finally the weather conditions.

flow is generally impaired.

• The gable ends are closed and sealed.

Natural ventilation *(see p. 40)*

• There is no insulation of the roof. While insulation

is not usually necessary it may be a desirable 'extra'

If natural ventilation is to be effective, it must function

under a few circumstances, particularly where

well in all weathers. To try to avoid too great a depend-

younger stock are housed or where the roof is low

ence on external wind and weather, it is best to make

and natural air flow is difficult.

use of the so-called 'stack effect' as its foundation. The

• Poor drainage under or around the yard leads to

warm stale air around the body of the animal, being

excessive straw usage and contributes to the humid-

lighter than cold fresh air, will rise to the top of the

ity of the atmosphere.

building. Outlet ventilation is therefore provided at a

• Bad construction of the walls leads to excessive

suitable point or points in the ceiling or roof. The

moisture penetration at all points.

greater the difference between inside and outside tem-

peratures, and the greater the distance between inlets

Natural ventilation works most satisfactorily on open

and outlets, the greater the stack effect. Therefore, if an

sites; it is always useful to have it controllable, but this

area of outlet ventilation is provided to cope with diffi-

is not usually done. An open ridge 300 mm wide, with a

cult conditions (i.e. a small difference between inside

flat continuous top at least 150 mm above, is a simple

and outside temperatures) it can easily be restricted

answer to extraction in narrow yards, and a 600 mm

when temperature differences are greater or appre-

wide ridge in yards above 14 m width.

ciable winds help in the ventilation. As mentioned, in

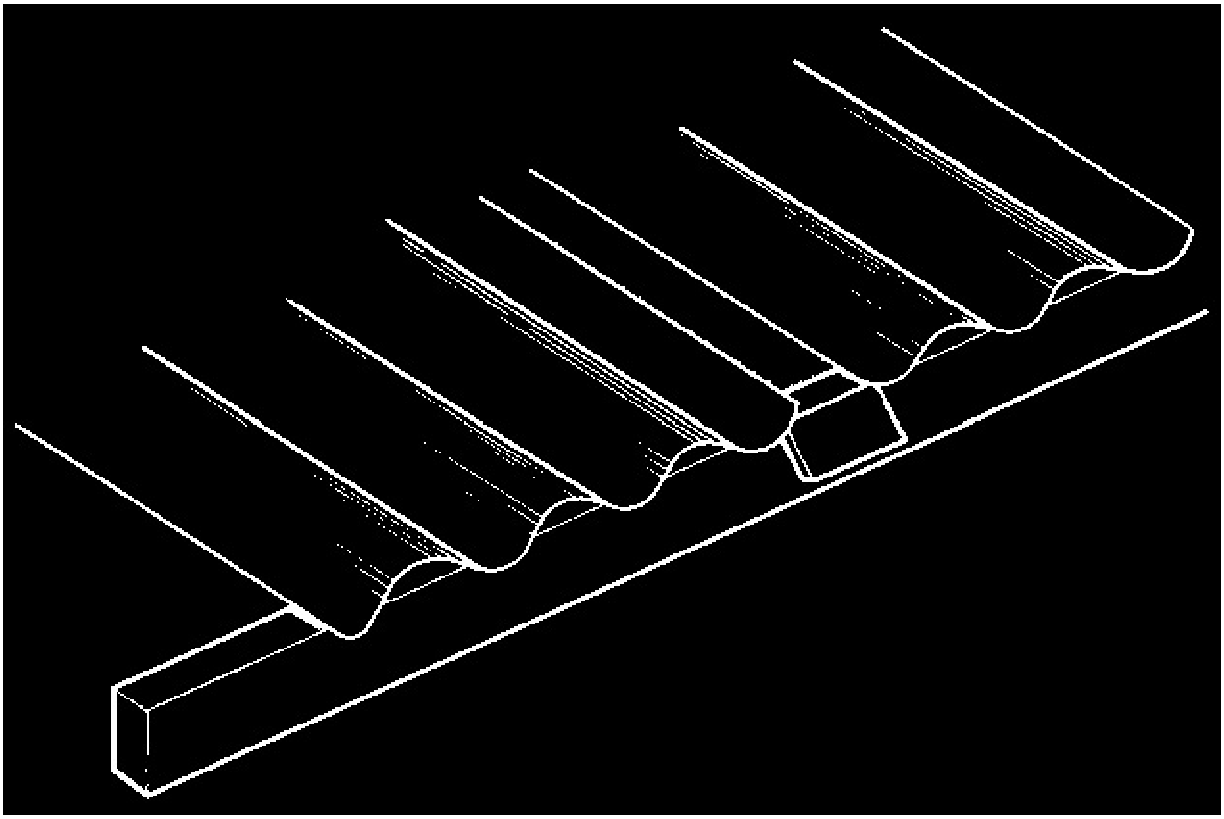
An even more satisfactory arrangement is to have a

houses where no great control is necessary, such as cli-

series of chimney-type ventilators along the ridge,

matic housing for cattle, a fixed open ridge with a pro-

allowing 0.09 m2/animal. A useful size of chimney is



of variable fan speed on a motorized thermostat or electronic control will give full automation on all fans.

Fan ventilation halves the number of roof outlets that need to be installed. The total capital cost of a fan-operated system will hardly be more than £30 per animal-place, an economical cost for automatic environmental control. Running costs may be a rather more daunting charge.

The main use of fan ventilation in cattle yards is in those cases where extremely high stocking rates are *used, as with slatted floor units, or where the topogra-*

phy of the site or restriction of wind around the build-

ing makes natural flow all but impossible.

Fig. 56.9

The 'breathing' roof: ventilation achieved by leaving

The inlet of fresh air is no less important, and it has

a gap between the roof sheets.

been found satisfactory to provide inward-opening

hopper flaps along both side walls, bottom-hung and

700–900 mm deep, with gussets and variable control

1 m2; this is sufficient for 11 animals. The throat can be

through casement stays or remote control from the

controlled by a butterfly valve or hinged flap.

feeding passage. Alternatively, the hoppers may be con-

Alternative ways of achieving good 'top' ventilation

trolled from the ends with horticultural glasshouse type

are as follows:

fittings. It is preferable if the inlets are not closer than

600 mm to the eaves, to prevent incoming air 'bouncing'

(1)

Raised sheets, consisting of conventional steel *off exposed purlins and causing an irritating down-*

sheets fitted with a batten or washers raising the

draught on the animals. The flaps should be made so

overlapping, allowing air to pass between the

that they can be removed or hinged down flat in the

sheets. A spacer batten of treated timber measur-

summer; they should extend along at least one-half and

ing 50 mm ¥ 25 mm is suitable.

preferably two-thirds of the wall length.

(2)

Upturned corrugated sheeting. Conventional gal-

With wide-span yards over 21 m, slatted boarding

vanized corrugated steel sheeting is fixed upside

(100 mm boards and 12 mm gaps or 150 mm boards and

down with a gap between each sheet, forming a

25 mm gaps) should be fitted at the gable ends and part

Venturi flow between each sheet. Typically, a

of this area made as hinged doors that can be opened

25 mm gap may be used, which would give 3.75

in the summer. This is normally not necessary, however,

per cent opening of the roof. (Fig 56.9).

in narrow-span yards. In addition, there are a number

Systems (1) and (2) are often described as 'breathing

of other excellent techniques for achieving good inlet

roofs'.

ventilation for cattle and other yards.

'Spaced boarding' is excellent all around a yard – at

the gable ends and along the walls above 'animal height'

Mechanical ventilation

(Fig. 56.10). It gives an opening area of about 20 per

This has a place in some cattle yards as it has for other

cent of the total but is uncontrollable; an alternative is

forms of intensively housed stock. With a system of

to have an adjustable system with fixed outer slats and

chimney trunks, fans can be added as a complementary

inner sliding slats. There are also various other arrange-

arrangement, since an extractor fan may be fitted at the

ments, such as the Ventair steel sheet with patented

base. If a 600 mm fan running at a maximum of

louvres (13 per cent open); slatted hardboard with slats

900 rev/min is fitted, 10 194 m3 hour will be extracted. A

5 mm ¥ 25 mm giving 30 per cent opening; Netlon *maximum allowance of 510 m3/hour per beast (or*

polypropylene mesh (45 per cent open); Ventrex steel

approximately 0.42 m3/hour per kg bodyweight) is

sheet with louvres (0.7 per cent open) and a common

found satisfactory, so that one fan will serve approxi-

device of a space left between the outer sheet and the

mately 30 beef animals to slaughter.

wall, giving a baffled protected inlet.

Automatic or semi-automatic control can be

It is in no way suggested that the systems outlined are

achieved if a proportion (one-half to two-thirds) of the

the only satisfactory methods of ventilating intensive

fans are put on a thermostatic control, with a thermo-

cattle yards. For example, other mechanical means have

stat that is easily seen and adjusted. Fans thus operated

been used, often with equal success. These do, however,

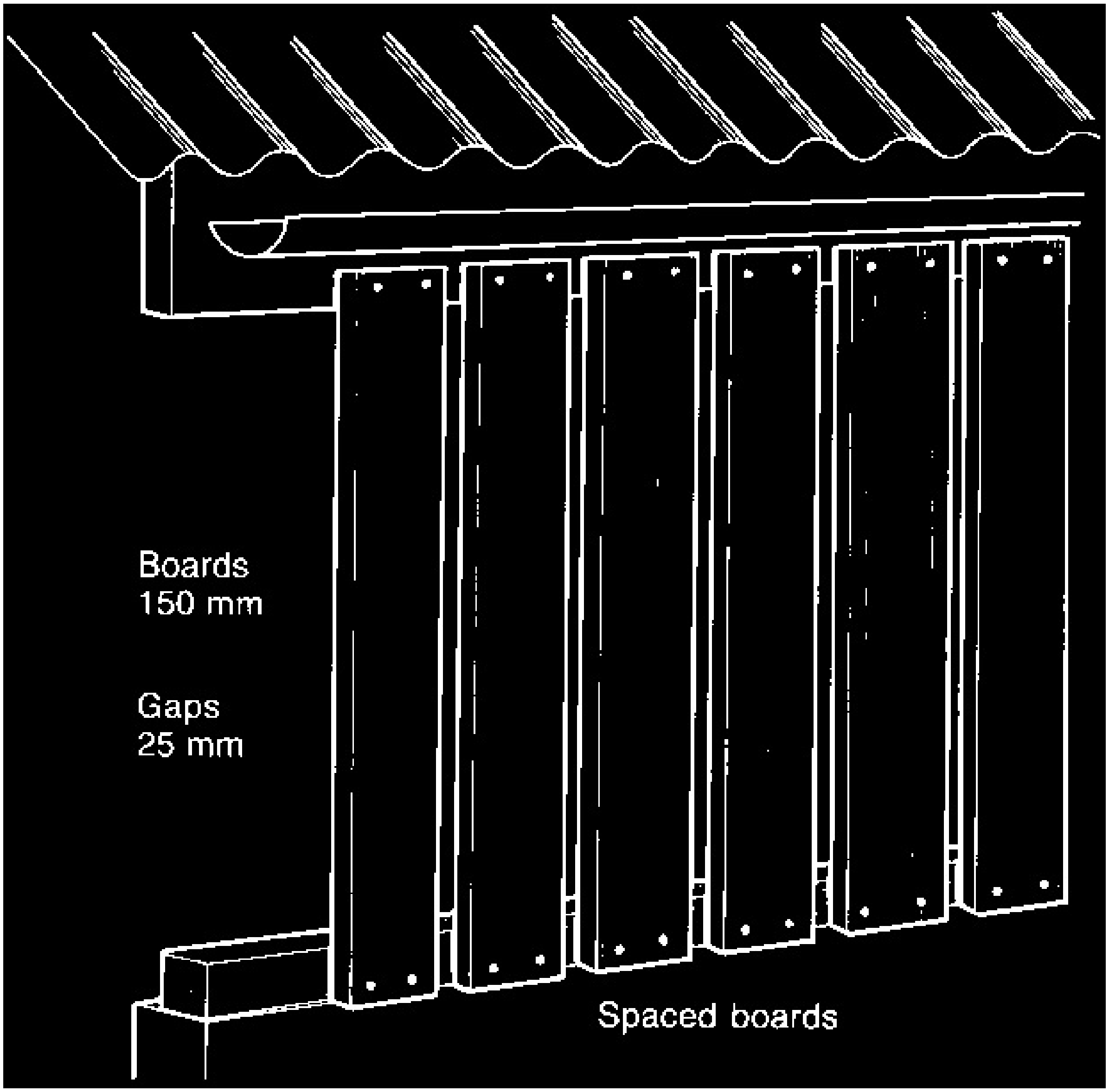
should have automatic antiback-draught flaps fitted to

often need more careful designing and management to

prevent down-draughts when they are switched off. All

prevent draughts and to give adequate control. The

fans should be speed controlled. Alternatively, a system *systems suggested are logical and generally understood*



air comes in than to open up the ventilation space in a sheltered site. Sometimes the proximity of other buildings makes it impossible to increase the airflow at all. Livestock yards are now often made very wide, of the *order of 40–50 m. These are invariably the most difficult units to ventilate. From the point of view of ventilation it is desirable to limit the span to some 30 m. Indeed, if the trend towards the use of thermal insulation continues, views on what constitutes an adequate cubic area may change. In an uninsulated yard a large cubic area helps to buffer the outside weather extremes. But in an insulated construction, the roofing area must be reduced to a minimum to cut costs and more economical dimensions would be a height of 3.6 m to eaves with a maximum yard span of 21 m. These recommendations widely used and required for cattle buildings apply, with only minor modifications, to climatic yard accommodation generally, including that for pigs, sheep and turkeys.*

Fig. 56.10

Wall ventilation with spaced boarding.

Open-fronted yards and kennels

A fundamentally different approach to climatic housing and easily controlled by the stockworker. Mechanical is the 'lean-to' or open-fronted yard, often called the assistance with the designs shown is complementary to *mono-pitch building. This is attractive in several natural flow and indeed may be used as an additional respects and continues to gain in popularity as an alter- stage in the development and improvement of a design. native to the span roof yard. For a start it is usually Draughts are least likely where there is the fullest con- cheaper. Also, by its very nature, it is impossible to trol of the system. Ventilation continues to function at make it very wide – a depth of 10 m being about the a reduced rate in the event of power failure with the limit – so the enormous problems of ventilation created system advocated, since natural stack-effect ventilation by wide spans are avoided and stock concentrations in takes over from the fans to tide the stock over this one air space are limited. Best of all, such a system gives period.*

a cheap isolation of groups by carrying vertical parti- If the trend towards high stocking rates continues it tions to the roof and if necessary supporting it every is inevitable that the farmer will turn increasingly to 3–6 m. With an open-fronted design animals have a *thermal insulation of the surfaces, especially the roof. choice of environment, as they can go towards the lower Farmers who have used insulation of the roof have back part in colder conditions to keep warm, or come recorded considerable benefits in terms of liveweight to the front for sunlight and more fresh air in warmer gain and feed conversion efficiency, but above all weather. Control of airflow can be by simple hinged because it helps also to solve environmental problems. flaps on the front and kennels can be incorporated if A popular way of arranging the insulation is by using desired. It is most desirable that open-fronted yards in two skins of metal or fibre-cement sheeting for the roof the northern hemisphere face in a southerly direction separated by a vapour-sealed layer of mineral wool or only; it is preferable not to face two rows together, since glass wool. For the latter, a 50 mm thickness is minimal there is a risk of the passage-way between becoming a but 100 mm is very much better. A cheap treatment for wind tunnel and in this situation one side at least will an existing uninsulated building is to build a false* *face north or east and so may get little sun and indeed*

ceiling of wire mesh supporting vapour-sealed insula-

may suffer from distinctly cooler conditions.

tion. It is an economical way of insulating the building,

though somewhat temporary. It must be emphasized

Dangers from gases in farm buildings

that individual attention does need to be given to each

yard according to the site and locality. It is one of the

Problems associated with gases in and around the live-

advantages of fan ventilation that with mechanical ven-

stock farm have been highlighted recently, particularly

tilation this statement is much less true. The use of fans

in association with gas effusion from slurry channels

partially rules out the dependence on site and weather.

under perforated floors, but it would be wrong to regard

It is generally better to have yards in exposed positions

these as the only dangers. While there have been

because it is easier to restrict the open area if too much

numerous fatalities of livestock recorded, and indeed of

man, due to gas intoxication, there is also mounting

References

evidence that there may be concentrations of gases in

many livestock buildings that may affect production

Britton, D.K. & Berkeley Hill (1975) Size and Efficiency in adversely by reducing feed consumption, lowering

Farming, pp. 132–47. Saxon House Studies, Farnborough.

growth rates and increasing the animals' susceptibility

Clark, J.A. (ed.) (1981) Environmental Aspects of Housing for to invasion by pathogenic micro-organisms.

Animal Production. Butterworth, London.

The most serious incidence of gas intoxication arises

Donaldson, A.I. (1978) Factors influencing the dispersal, sur-

from areas of manure storage in slurry pits or channels

vival and deposition of airborne pathogens of farm animals.

under the stock, usually but not always associated with

Veterinary Bulletin, ***48****, 83–94.*

Donaldson, A.I. & Ferris, N.P. (1976) The survival of some forms of perforated floors. The greatest risk arises when

airborne animal viruses in relation to relative humidity.

the manure is agitated for any reason, usually when it

Veterinary Microbiology, 413–20.

is removed. There is also an ever-present danger if a

Honey, H.F. & McQuitty, J.B. (1976) Dust in the Animal mechanical system of ventilation fails and this is the

Environment. Departement of Agricultural Engineering,

only method of moving air in the house. Several cases

University of Alberta, Canada.

of poisoning have been reported when sluice-gates are

Sanger, J.R. (1969) Influence of relative humidity on the sur-

opened at the end of slurry channels and the movement

vival of some airborne viruses. Applied Microbiology, ***15***, *of the liquid manure has forced gas up at one end of*

35–42.

the building.

Webster, A.J.F. (1981) Optimal housing criteria for ruminants.

High concentrations of gases, chiefly ammonia, may

In Environmental Aspects of Housing for Animal Produc-

also arise from built-up litter in animal housing. The

tion (ed. by J.A. Clark), pp. 217–32. Butterworth, London.

Whittlestone, P. (1976) Effect of climatic conditions on

danger has undoubtedly been exacerbated within more

enzootic pneumonia in pigs. International Journal of Bio-

recent years owing to the mistaken insistence of main-

meterology, ***20****, 42–8.*

taining relatively high house temperatures in order to

Wray, C. (1975) Survivial and spread of pathogenic bacteria

reduce food costs. The farmer has often attempted to

of veterinary importance within the environment. Veteri-

achieve such temperatures by restricting ventilation

nary Bulletin, ***45****, 543–57.*

and in the absence of good thermal insulation of the

house surface, so that the result may often be generally

harmful if not actually dangerous.

Chapter 57

Biosecurity

D.C. Barrett and A.J. Taylor

Introduction

987

While the public health aspect of biosecurity is

Benefits of improved biosecurity

988

obviously extremely important, the prime role of the

Routes of infection

988

veterinary surgeon is to safeguard the health of

Infectious diseases that can be introduced into cattle herds

989

food-producing animals, because disease will reduce

General principles of biosecurity

989

productivity and/or be detrimental to animal welfare

The 'closed' herd

990

(Barrett, 2001a). It is this animal health aspect of biose-

Introduction of purchased stock

990

curity which will be dealt with in most detail in this

Risk of disease in the herd affecting an incoming animal

991

Principles of biosecurity planning

991

chapter.

Producing a biosecurity plan

991

From the point of view of cattle health, biosecurity

Herd biosecurity: where is the final frontier?

994

can be defined as 'the efforts put forth to prevent the

Conclusions

994

introduction of pathogens or toxins that have the

potential to damage the health of a herd of cattle or

the safety and quality of a food product' (Sanderson

Introduction

et al. , 2000). An interrelated concept is that of

biocontainment, which is the 'effort to contain the

Biosecurity means a multitude of things to different

spread of disease or intoxication within a herd'

people. In its broadest interpretation in relation to

(Sanderson et al. , 2000). For the purposes of this

human health it is defined as 'those cumulative steps

chapter, we will concentrate on the infectious disease

taken to prevent transmission of pathogens and other

components of both biosecurity and biocontainment,

harmful agents to individuals or populations of human

and use the term biosecurity in a generic sense to cover

beings' (Gillespie, 2000). Gillespie (2000) further states *both concepts.*

that the harmful effects of these agents may be direct

In the past, efforts to use biosecurity principles to

(e.g. smallpox virus causing disease) or indirect, by

control diseases of cattle in the UK have been largely

disrupting the food supply (e.g. animal or plant

confined to the statutory control and eradication, or

pathogens), and that any substance that disrupts bio-

attempted eradication, of notifiable diseases such as

logical systems necessary for human health and well-

foot-and-mouth disease (FMD), bovine tuberculosis

being is a threat to biosecurity. In addition to

(TB) and brucellosis, or specific diseases such as bovine

pathogens, it is also suggested that naturally produced

herpes virus-1 (BHV-1), the cause of infectious bovine

poisons, such as aflatoxin, toxic chemicals and pesti-

rhinotracheitis (IBR) (p. 286), and leptospirosis (L.

cides, all have the potential to disrupt beneficial and

borgpetersenii serovar hardjo and L. interrogans necessary biological systems and can therefore also be

serovar hardjo) (p. 735) within non-statutory cattle *considered to threaten biosecurity.*

health schemes. This has resulted in an attitude amongst

From the point of view of human health, the ultimate

many cattle producers that infectious disease control is

aim of biosecurity is therefore to safeguard the human

either something that government should take charge

food chain. While major epidemic diseases of cattle

of, and pay for, on their behalf, or is something that is

such as foot-and-mouth disease and rinderpest may

only relevant to a small number of herds who may

threaten food supplies, they do not have direct public

benefit from having an 'elite' health status. The major-

health implications. However, most foodborne illnesses

ity of commercial herd owners have considered that

are the result of inadvertent contamination of foods

endemic infectious diseases are always going to be

by pathogens, including viruses, bacteria, protozoa and

present within their herds. This has resulted in many of

perhaps also prions. These organisms may be zoonotic,

them tolerating the infections and acting in a reactive

causing disease in cattle and humans e.g. Salmonella way to treat disease when it occurs while living with the

spp., or foodborne pathogens that are non-pathogenic

associated depression in productivity, rather than taking

in cattle, e.g. Escherichia coli O157.

a proactive disease control and/or eradication stance.

This is in contrast to the attitude in the UK pig and

Box 57.1

The benefits of improved biosecurity to an

poultry industries where there are pyramidal structures,

individual farmer.

designed amongst other things to help control infec-

Increases in production, productivity and profit

tious disease. Pig and poultry producers, whether they

Improved animal welfare

are breeding companies or commercial units, would not

More efficient utilization of resources

entertain the idea of introducing new stock without

Reduced use of medication, such as antibiotics and

taking specific precautions to protect both the new-

anthelmintics, with an associated reduction in the risk of

comers and the indigenous herd or flock from infectious

resistant pathogens emerging

diseases. Although the cattle industry is structured very

Enhanced value of the individual herd, with livestock, and

differently from the pig industry, cattle producers could

livestock products, of known health status commanding

learn a lot from the biosecurity principles that have

premium prices

been developed for pigs over many years (Moore,

1992). Even so, the outbreak of classical swine fever in

Eastern England in 2000 (Sharp et al. , 2001) and the

Box 57.2

The benefits of improved biosecurity to the wider

spread of new diseases such as post weaning multisys-

farming community.

temic wasting syndrome with the movement of pigs

Maximizing export markets by the prevention of disease-

between farms (Done et al. , 2001) has shown that

orientated barriers being put in place by importing countries

disease transmission between pig units remains a

Possible limitation of imports by creating disease-orientated

problem.

barriers to the importation of livestock, and livestock

Even before the devastating outbreak of FMD in the

products, from countries of lower health status

UK in 2001, the challenge to enhance biosecurity on

cattle units was already very real. Biosecurity had

become an increasingly topical issue in relation to cattle

selected infectious diseases, there will be potential

production, prompted by suggestions that TB control

benefits related to international trade (Box 57.2).

measures would be enhanced if biosecurity were

Farm biosecurity is also an important first step in

improved (Anon, 1999a,b, 2001a; Collins, 2000; Phillips

safeguarding the human food chain with benefits to the

et al. , 2000; Barrett et al. , 2001), reducing both cattle-to-community at large. It is an important part of any

cattle (Menzies & Neill, 2000) and badger-to-cattle

hazard analysis and critical control point (HACCP)

transmission of Mycobacterium bovis (see p. 857). More plan to safeguard human health. Food retailers are

generally, much needed to be done at a herd level to *taking much more interest in this area as a means*

improve herd health and productivity by implementing

of combating potential risks to human health

well-designed 'biosecurity plans' that were proactive in

(Noordhuizen & Wentink, 2001), for example the pos-

preventing the spread of numerous infectious diseases

sible link between Mycobacterium avium subsp. paratu-endemic within the UK.

berculosis (Johne's disease) (p. 862) in cattle and

The 2001 outbreak of FMD, which affected France,

Crohn's disease in humans (Hermon-Taylor, 2000). The

The Netherlands and the Republic of Ireland as well as

general population is now much more sensitive to

the UK, emphasized the need to safeguard the national

disease epidemics and food scares, e.g. salmonella in

herd from exotic diseases, particularly in these times of

eggs and bovine spongiform encephalopathy (BSE) (p.

a single European Market. The last frontier for disease

909), and farmers may in future need to show that they

control must be the farm boundary; cattle farmers have

have adequate biosecurity measures in place to mini-

to take responsibility for disease control in their own *mize such risks in order to sell to certain retailers.*

herds, and, with advice from their veterinary surgeons,

decide what precautions they need to take to reduce the

risk of disease transmission.

Routes of infection

There are many ways in which an infectious agent can

enter a herd of cattle. These are summarized in Box 57.3.

Benefits of improved biosecurity

The greatest risk for most diseases is by contact with

infected cattle, either by the introduction of infected

Improving biosecurity on cattle units, both to control

cattle into a herd or by contact with neighbouring herds

infectious diseases already present and to prevent the

via cograzing or across boundaries. Attendance at shows

introduction of new infections, has a number of poten-

and the return of unsold cattle from sales also risks the

tial benefits at the farm level (Box 57.1). If improved

introduction of disease. These infected animals may be

biosecurity measures are widely adopted such that

either asymptomatic 'carriers' of a specific disease such

increased numbers of cattle herds become free of *as bovine herpes virus-1 (BHV-1), bovine virus diar-*

Box 57.3

Common routes by which infectious agents can

Box 57.4

Diseases endemic in the UK and elsewhere,

enter a herd of cattle.

which may be controlled in part by enhanced biosecurity

measures.

Introduction of infected cattle or direct cattle-to-cattle contacts Feed or water, contaminated with pathogens such as Sal-Bovine virus diarrhoea (BVD)

monella spp. or the prion responsible for BSE

Infectious bovine rhinotracheitis (IBR)

Visitors, including those regularly working with cattle on other Leptospirosisa

premises, such as relief milkers, foot trimmers, AI techni-

Salmonellosisa

cians and veterinary surgeons

Johne's diseaseb

Mechanical vectors such as vehicles and farm implements

Mastitis, e.g. Streptococcus agalactia

Wildlife, including badgers, rabbits, rodents, deer and birds

Digital dermatitis

Other species of livestock such as sheep

Parasitic diseasesa

Airborne transmission, notably FMD

Ringworma

Udder skin infections

Venereal Campylobacter spp. infection

Neospora infection (causing abortion)

rhoea virus (BVDV) (p. 853), Neospora caninum (p.

584), Streptococcus agalactiae (p. 333) or cattle incubat-a Zoonotic diseases transmissible to humans.

ing a particular disease such as Salmonella typhimurium

b There is some evidence that links this disease with Crohn's disease DT 104 (p. 850). In the case of cattle incubating disease,

in humans and its importance may therefore increase further in the it may be possible to prevent the introduction of a

future.

pathogen by imposing quarantine measures of a dura-

tion that exceeds the expected incubation period.

Box 57.5

Diseases notifiable in the UK.

However, some pathogens may not cause infected

These are the diseases subject to national control policies

animals to exhibit overt clinical signs, e.g. Leptospira

and/or international trade rules and include:

hardjo (L. borgpetersenii serovar hardjo and L. interro-Anthraxa

gans serovar hardjo). Others may have excessively long Aujeszky's diseaseb,c

incubation periods, making simple quarantine impracti-

Bluetonguea

cal without the use of accompanying diagnostic testing,

Bovine spongiform encephalopathy (BSE)b

e.g. Mycobacterium avium subsp. paratuberculosis

Brucellosisb,c,d

(Johne's disease). In the case of 'carrier' animals that do

Contagious bovine pleuropneumonia (CBPP)a

Enzootic bovine leukosis (EBI)a

not exhibit clinical signs, detection is reliant on diagnos-

Foot-and-mouth disease (FMD)a

tic testing, either of the individual animals or of the herd

Lumpy skin disease

from which they have been obtained. The reliability of

Rabies

diagnostic tests and the design and implementation of

Rift Valley fever

testing regimens have been discussed in detail by

Rinderpest

Caldow et al. , (2001). With or without adequate isolation Tuberculosis (TB)b

and quarantine measures, appropriate diagnostic tests

Vesicular stomatitis

will need to be undertaken to ensure, as far as is realis-

Warble flya

tically possible, freedom from disease in introduced

a

animals or at least to define their health status and prior

Those diseases considered by the authors to pose the greatest

threat of re-emergence or introduction into the UK.

exposure to certain pathogens.

b Diseases known to be present in the UK in early 2002 (cNorthern To prevent direct or indirect contact between herds

Ireland only).

of neighbouring cattle, there should be a 3 m gap

d Occurred in the UK in 2003.

between boundary fences and hedges. This should mini-

mize the risk of short-distance airborne disease trans-

gories: diseases endemic in the UK and elsewhere,

mission such as is possible for BHV-1, the cause of IBR.

examples of which are shown in Box 57.4, notifiable dis-

Long-distance airborne transmission, as is classically

eases both present in the UK and exotic (Box 57.5) and

seen with FMD, is almost impossible for an individual

other diseases not considered present in the UK (Box

farmer to guard against.

57.6).

Infectious diseases that can be

General principles of biosecurity

introduced into cattle herds

Biosecurity is not a new concept; the introduction of

The numerous infectious diseases that can be intro-

'cattle plague' (rinderpest) (p. 707) into the UK in 1865

duced into cattle herds can be divided into three cate-

resulted in the Cattle Disease Prevention Act of 1866.

Box 57.6

Other important diseases not widely present in

can present some risk (see Chapters 39 and 40). When *the UK that may be introduced.*

using ET, embryos must be transferred into home-bred

recipients; pregnant recipients or animals for use as

If cattle are purchased from another country, there are dis-

eases that are currently not present or at minimum levels

recipients must not be purchased. No animals must be

in the UK but which are also currently not subject to

loaned or hired out. No animals must be returned to the

national control measures or importation rules. For

herd from shows or sales. There must be no contact with

example:

other cattle when grazing.

Trichomoniasis

Some species of Leptospira

*Type 2 BVD virus**

Introduction of purchased stock

**Recently found in Great Britain.*

It will not be appropriate for many herds to be closed,

due to management constraints such as cograzing or a

This Act enforced the use of what we would now con-

production system based on the rearing of purchased *sider biosecurity measures to eradicate rinderpest from*

stock. It is therefore essential to minimize the risk of

the British Isles after an estimated 400 000 cattle had

introducing infectious diseases into the herd when

died of the disease; the last cases were seen in 1877

buying new stock. The introduced animals may bring

(Dunlop & Williams, 1996). The basic principles for the

with them an infectious organism not previously

prevention and control of many infectious diseases in

present on the unit, leading to disease in the indigenous

cattle have therefore been well recognized for over 125

population, e.g. Johne's disease. They may also intro-

years.

duce a different strain of a pathogen, e.g. anthelmintic-

Duncan (1990) set out the principles of infectious

resistant gastrointestinal nematodes, or virulent BHV-1,

disease control in cattle in the early 1990s. At a meeting

or may themselves succumb to a disease endemic in the

of the British Cattle Veterinary Association (BCVA) in

indigenous population. Even where there is no desire

1994, three papers related to this subject were pre-

to achieve or maintain a high health status herd, the risk

sented (Duncan, 1994; Taylor, 1994a,b), followed by a

of introducing more virulent strains of a pathogen, or

further paper in 1996 (Pritchard, 1996). Duncan (1990)

drug-resistant pathogens, is a very real threat whenever

set out a seven-point plan, subsequently modified

cattle move between herds.

slightly as follows:

The safest source for new stock is a herd certified free

of specific diseases, usually by a cattle health scheme. If

(1)

Maintain a closed herd, with no introduction of

such stock are not available, the next safest route is to

animals and no contact with outside cattle.

buy from farms of known health status. In order of

(2)

If introduction of cattle is unavoidable, operate an

increasing risk:

isolation and testing policy for introduced stock,

including other species such as sheep.

(1)

A health scheme herd being monitored for speci-

(3)

Ensure feed and water are free from

fied diseases.

contamination.

(2)

A single source herd of known disease status.

(4)

Control visitors and vehicles, and operate a policy

(3)

Multiple source herds of known disease status.

to reduce the risk of transmission of pathogens

from visitors and vehicles.

The highest risk is to purchase from multiple sources of

(5)

Control direct and indirect contact between

unknown disease status or herds in which the disease

wildlife and cattle, particularly rodents and birds.

is known to have occurred. Animals from livestock

(6)

Define and monitor the health status of the herd.

markets or dealers where cattle from multiple sources

(7)

Establish and operate an agreed disease control

are mixed together should be considered a very high

programme or biosecurity plan.

biosecurity risk.

Unless from certified disease-free herds, incoming

animals should be isolated and tested before they enter

The 'closed' herd

the herd, preferably on the farm of origin before pur-

chase. Use of the farmer's own transport minimizes the

Maintenance of a closed herd is the main plank of a

risk of contact with sources of infection in transit, par-

biosecurity programme. No animals must be purchased,

ticularly if the haulier cannot guarantee not to mix

borrowed or hired. New genetic material must only be

stock in the lorry. The incoming animals should ideally

introduced to the herd by artificial insemination (AI)

be isolated on arrival and tested according to a specific

or embryo transfer (ET), but even these introductions

pre-agreed protocol before entering the herd.

Some suggested control measures for diseases that

with the use of certain management practices in rela-

may be introduced to a UK herd with the introduction

tion to the target infections. The next step is to assess

of cattle are outlined in Table 57.1.

the benefits of risk reduction within the specific biose-

curity plan. In an ideal world, this would involve a quan-

titative risk analysis for each target infection. However,

Risk of disease in the herd affecting

this is usually not practical on an individual herd basis,

as many of the required data are often unavailable and

an incoming animal

gathering these data and undertaking the required

modelling would not be cost-effective. This is not the

While many farmers will realize that introduced cattle

case at a national level and it is now the norm when

may transmit disease to their herd, few consider the risk

policy decisions are made on international live-

to the incoming animals from pathogens within the

stock trade to employ quantitative risk assessment

indigenous population. This can be a particular problem
(Wooldridge, 1996; Murray, 2002). Nevertheless, a qual-
with breeding bulls, as breeding capacity can be
itative risk assessment, using what limited information
severely depressed by many generalized illnesses as
is available for an individual herd, may be very helpful
well as by specific infections of the reproductive tract.
when beginning to construct a biosecurity plan. The
In addition, pregnant females may abort if infected with
basis for risk assessment is not to eliminate all risk, but
many pathogens during gestation. For this reason, the
to divide risks into various levels to assist informed
disease status of all incoming animals should be estab-
decision-making (Wells, 2000). Focusing on the major
lished with regard to pathogens endemic in the herd
hazards and major areas of risk will allow the cost-
and, whilst in isolation, they should be treated and/or
benefits of a biosecurity plan to be maximized.
vaccinated as necessary.

In the specific case of an introduced bull, it is worth
remembering that there is a time lag of approximately

Producing a biosecurity plan

two months from the start of spermatogenesis to the

ejaculation of the sperm. This means that an insult to

A farmer needs help and advice from his veterinary

the testes may not result in deterioration in semen

surgeon if he is to make rational decisions to protect

quality for many weeks and, conversely, it can take

the health of his herd. This advice is best given in the

months for semen quality to recover following a disease

form of a written biosecurity plan for the farm. This

episode. Many diseases may also reduce conception

could be a stand-alone document or a component of a

rates in cows and heifers if they become infected

general Herd Health Plan such as the BCVA Herd

around the time of conception. Therefore new bulls

Health Plan (Anon, 2001b).

should be introduced to a herd only after an appropri-

The safest policy will always be to ascertain the

ate isolation and testing regimen has been undertaken.

disease status of the indigenous herd and then produce

However, this may prove extremely difficult to achieve *a considered biosecurity plan based on a qualitative (or*

when bulls are purchased through commercial sales, as

if possible quantitative) risk assessment, looking at all

the timing of bull sales is often very close to the time

likely hazards for disease transmission. Particular care

they are required for breeding, especially in seasonally-

needs to be taken when animals are to be introduced

calving suckler herds.

into a herd or where members of the herd are known

to have had contact with outside animals, such as at a

show. The action to be taken when new stock are to be

Principles of biosecurity planning

introduced to the herd must be decided in advance.

This should include details of where animals are to be

An effective biosecurity programme needs to be

obtained from, the provision and management of isola-

decision-focused and flexible enough to adapt to the

tion facilities, the testing, treatment and vaccination

unique situation of the individual enterprise. This

strategy and what is to happen if an animal fails to meet

requires an understanding of biosecurity principles and *the predetermined health criterion.*

the goals of disease prevention, as well as specific infor-

The written plan must have some flexibility built into

mation relating to the biology and epidemiology of the

it and it must be agreed by both the farmer and his

particular pathogens of interest.

veterinary surgeon. It must be reviewed regularly and

When considering the construction of a biosecurity

both parties must work together to maintain interest

plan, it is important to establish which infections are

and motivation.

worth concentrating on, to ascertain the current disease

A possible future aid to biosecurity planning in Great

status of the herd and then to assess the risks associated

Britain may come from the British Cattle Movement

Table 57.1

Examples of infectious conditions likely to be introduced to UK herds with added animals, with brief suggestions of measures to prevent disease introduction. (Modified and extended from Pritchard, 1996.)

Disease/infection

Preventive measure

Vaccines

Comments

available in

Clinical

Prophylactic

Laboratory

UK

examination

treatment

tests

BVDV

(+)

~

+

Yes

It is essential to test for BVD virus (up to 1.8% of cattle may be virus positive); serology also useful. Calve pregnant females in isolation and test calves at birth for virus if dam seropositive; or isolate calves and test when over 4 months of age for virus and antibody. Bulk milk tests available.

IBR (BHV-1)

(+)

~

+

Yes

Significance of adding seropositive (potentially infectious) animals depends on virus strain, vaccination type if used, existing herd status and possible implications for sale of cattle, semen and embryos. Bulk milk tests available.

Leptospirosis

(+)

+

+

Yes

Test animals using ELISA, 25 mg/kg dihydrostreptomycin given twice within 14 days of entry reduces risk of excretion. Bulk milk tests available. Zoonotic.

Salmonellosis

(+)

(+)

+

Yes

Repeated culture of faecal samples should help to detect carriers.

Positive SAT titre for S. dublin/ S. typhimurium on serum may indicate recent exposure. Zoonotic.

Johne's disease

(+)

~

(+)

Yes

Individual animal screening to detect subclinical infection is hampered by a lack of suitable tests. Tests such as adsorbed ELISA may be useful on a group basis. Request certification of clinical freedom in the herd of origin for a substantial period of time, e.g. 5 years. If diarrhoea develops in isolation examine faeces repeatedly for acid fast organisms and undertake culture. Consider rejecting animals with intermittent/

persistent diarrhoea regardless of test result. (Zoonotic?)

Streptococcus agalactiae

(+)

+

+

No

Should be readily preventable by using CMT, culturing positive quarters and/or treating. Bulk milk screening may be of use.

Digital dermatitis

+

(+)

~

No

Good clinical examination. If in doubt treat with topical antibiotic spray/

footbath.

Ectoparasites

+

+

(+)

No

Use appropriate treatment.

Gastrointestinal parasites

~

+

(+)

No

Use carefully selected, appropriate anthelmintics.

Lungworm

~

+

(+)

Yes

Use carefully selected, appropriate anthelmintics. Vaccine will not totally prevent infection.

Liver fluke

~

+

(+)

No

Use carefully selected, appropriate treatment.

Ringworm

+

(+)

(+)

Yes

Can cause quite serious problems in naïve herds, particularly amongst adult animals. Zoonotic.

Miscellaneous udder/skin

+

(+)

(+)

No

Troublesome and best avoided. Some are zoonotic.

conditions

Venereal campylobacteriosis

~

+

(+)

No

Treatment probably more cost-effective than laboratory tests, although not 100% effective especially in older bulls.

Trichomoniasis

~

~

(+)

No

Probably absent from UK, but check imported bulls and remain vigilant.

Tuberculosis

(+)

~

(+) Skin test

No

Increasing incidence in UK making the introduction of infected cattle into a herd more likely than in the past. Consider isolation and private testing.

Brucellosis

~

~

+

No

Present in Northern Ireland but absent from Great Britain except for a small outbreak in 2003.

Neospora caninum

~

?

(+)

No

Problematic, epidemiology complex and not fully understood. Consider not retaining calves from seropositive cows and not introducing seropositive cows or youngstock into a herd. Antibody titres wax and wane, likely to be highest around time of calving. Control dogs on farms.

Other exotic diseases, e.g.

Foot-and-mouth disease

+

~

+

No

Major threat if national biosecurity is breached.

Contagious bovine

(+)

~

+

No

Threat if national biosecurity is breached.

pleuropneumonia (CBPP)

Enzootic bovine leukosis

(+)

~

+

No

Threat if national biosecurity is breached.

(EBL)

Warble fly

(+)

+

+

No

Threat if national biosecurity is breached.

Biosecurity

CMT, California mastitis test; ELISA, enzyme linked immunosorbent assay; SAT, serum agglutination test.

+, Indicated; (+), possible benefit; ~ not indicated.

Note: All animals entering a herd should have a period in isolation; this is assumed in the table.

Service (BCMS). Introduced in 1998, it gave British

animals, but even when animal movements were

farmers, for the first time, information on the origin and

banned in the early days of the outbreak, the disease

movement of all cattle they may be considering pur-

continued to spread due to movement of people and

chasing. This allows some assessment of disease risk to

vehicles (Gibbens et al. , 2001). Increasingly stringent be made based on the animal's movement history. This

rules were introduced in the worst affected areas and it

can be enhanced by declarations of health status by

was only when these rules were rigidly enforced that the

farmers, supported where applicable by veterinary cer-

spread of the disease was stopped.

tificates and copies of laboratory test results. In future,

Elimination of the FMD virus from the UK and the

there may be an opportunity to include health infor-

EU does not, however, reduce the need for good biose-

mation on cattle passports, including vaccination

curity. On the contrary, it emphasizes the need for

history and the health status of all herds in which the

continued vigilance so that the impact of any future out-

animal has previously resided.

breaks of disease, whether at farm, local or national

level, is kept to a minimum.

Herd biosecurity: where is

the final frontier?

Conclusions

For many years, efforts to use biosecurity principles to

In an ideal world all herds would be maintained as

control diseases of cattle in the UK were largely con-

closed units of known and preferably high health status,

fined to control and eradication of statutory diseases.

with the introduction of genetic material only by the use

Cattle imported into the UK were required to be kept

of AI and ET following strict quality control standards

in official quarantine premises before being allowed

to minimize the disease risk. However, we do not live

to move to the destination farm. The general attitude *in that world. We live in a world of widespread, fre-*

therefore was that the frontier was the UK border.

quent, long distance transport of animals and animal

When the single European Market came into force

products, often with little regard for biosecurity.

in January 1993 the quarantine requirement was

Nevertheless, there is a lot that can be done, even on

dropped and it become much easier to import cattle, not

commercial units, to manage and reduce the risk of

only from other EU member states but also elsewhere.

infectious disease.

It was only then that farmers started to realize that 'The

The principles of biosecurity are applicable at some

farm gate is the frontier' (Taylor, 1994b). That principle

level to all cattle units and each and every one stands

still holds today, 'The primary frontier for disease

to gain by the implementation of a specific tailor-made

control must be the farm boundary' (Gibson &

biosecurity plan. However, it is important for veterinary

Andrews, 2000).

surgeons to evaluate the risks of various hazards on

Responsibility for biosecurity at farm level is the

each cattle enterprise and use this to design and imple-

joint responsibility of the farmer and his veterinary

ment an appropriate biosecurity risk management plan

surgeon. However, prior to the outbreak of FMD in

specific to the individual farm.

the UK in 2001, only a small number of herds were

members of voluntary non-statutory cattle health

References

schemes such as the Premium Cattle Health Scheme

and Herdcare. Standards for such schemes are set by

Anon (1999a) Farm biosecurity – protecting herd health, pp.

the Cattle Health Certification Standards (CHeCS),

1–5. MAFF PB 4517. MAFF, London.

which is a self-regulatory body established in 1999 by

Anon (1999b) TB in cattle – reducing the risk, pp. 1–5. MAFF

the UK cattle industry. The CHeCS technical document

PB 4516. MAFF, London.

(Anon, 2000) includes rules on biosecurity, which are

Anon (2000) Cattle Health Certification Standards (CHeCS).

mandatory for members in the accreditation and

Technical document. CHeCS, Dairy House, 60 Kenilworth

screening and eradication programmes and are recom-

Road, Leamington Spa, Warwickshire CV32 6JX.

mended as good practice for all cattle herds. Other

Anon (2001a) TB and cattle husbandry – government

high status herds include commercial bull studs, which

response to the report of the independent husbandry panel

(TBF 51). Available at http://www.defra.gov.uk/.

operate under EU Directives and UK Regulations

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assurance (revised), pp. 1–21. BCVA Office, The Green, The 2001 FMD outbreak in the UK brought home to

Frampton-on-Severn, Glos GL2 7EP.

the whole cattle industry the absolute necessity of good

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Chapter 58

Immunological Fundamentals

W.P.H. Duffus

Introduction

996

of molecules that make up the myriad of different types

Innate immunity

997

of 'non-self' material that individuals are exposed to

Humoral

997

constantly. These are termed antigens, each site on the Cellular

997

antigen that retains the ability to be recognized by the

Acquired immunity

998

immune system being termed an epitope. Note the use

Humoral

998

of the word 'non-self'; this is a useful term as 'self'

Cell-mediated immunity

1001

means the immune system has lost the ability to recog-

T lymphocytes

1001

nize that particular antigen within an individual and

B lymphocytes

1002

Maternal immunity

1002

therefore the latter remains free of potentially harmful

Homeostasis and stress

1003

effector mechanisms. Unfortunately this protection

can break down leading to an increasing plethora of

autoimmune disease. The third main concept is the divi-

Introduction

sion of both the acquired and innate immune response

into cellular (e.g. lymphocyte, etc.) and humoral (e.g.

What does the word 'immune' mean? The derivation of

antibody, etc.) components.

the word stems from 'exempt from burden'. In reality

A study of immunology as it relates to bovine medi-

the word was coined to explain what we now term

cine is artificially skewed towards two of the four main

immunological memory. Populations, both human and *areas that cause sickness/death: injury and infection.*

domestic stock, suffered and continue to suffer from

The other two main areas are degenerative disease and

epidemic disease; the old observation was that individ-

cancer but these are problems of the older individual;

uals recovering from a clinical syndrome were 'exempt'

subsequently defence mechanisms against these latter

at the appearance of the next epidemic.

two are not as important within a population, such as

This ability of the vertebrate immune system to

cattle, with a fast turnover of generations.

'remember' a previous exposure to a foreign or non-self

The majority of the mechanisms, both cellular and

material is at the very heart of preventive medicine.

humoral, that make up the ruminant immune system

The response is normally termed an adaptive immune

are common to all mammals. The highly developed

response. This is in contrast to the innate immune mammalian immune system is the culmination of evo-response which covers the mechanisms pre-existing

lutionary pressures with effector mechanisms that are

within an individual. The division between these two *traceable in the lower animal kingdom. However, there main areas of the immune system is not absolute; there are aspects of this mammalian immune system that are is much interaction and interdependence between specifically enhanced and specialized within ruminants effector mechanisms in both camps. What do we mean (such as the passive transfer of lactogenic antibody). by effector mechanisms? The term usefully describes These differences will be discussed within the relevant the sharp end of the immune response: the antibody sections. An important conceptual point to get across that actually causes the destruction of a bacteria, the early on is one of balance between two conflicting cell that actually destroys another, but potentially points of view. On one side is the animal trying to pre- malignant, cell.*

serve its integrity against a variety of potential

There are three other broad concepts to consider at pathogens by utilizing the effector mechanisms them- an early stage. First, the immune response can itself be selves comprising the innate and adaptive immune

harmful. The millions of individuals suffering from
response. On the other side are the organisms that are
allergy will know this fact only too well. The second
trying to survive in the face of these mechanisms,
main concept is one of specificity/recognition. The
relying on a fast turnover of generations and natural
immune system is exquisitively specific and has the
selection. This balance is at the heart of almost all host
ability to recognize millions of different combinations
–pathogen interrelationships. With cattle and intensive

husbandry we are tilting this balance in favour of the
pathway going, an important point in assessing com-
organism and allowing them to replicate and cause dis-
plement as a defence mechanism.
eases such as mastitis, enzootic pneumonia, etc. Inten-
sive husbandry is here to stay for production reasons
Lysozyme and other serum proteins
and we will have to turn to artificial means to restore
the balance. This scenario will involve research to ascer-

Lysozyme, a protein with a molecular weight of approx-

tain which 'batch' of effector mechanisms is applicable

imately 14 000, is highly active against bacteria and is

to a particular pathogen, and then how can we artifi-

found in many biological fluids and is sometimes called

cially boost this immunity.

the 'natural antibiotic'. It is not often realized that

Fleming discovered both penicillin and lysozyme!

Neutrophils can be stimulated to produce lactoferrin.

Innate immunity

This protein works by competing with bacteria for the

available iron molecules. Milk contains approximately

These immune mechanisms pre-exist in an individual

6 mg/ml.

and are not improved by repeated infection. Like

Acute phase proteins appear within hours of tissue

acquired immunity they can be divided up into humoral

damage or infection. The best known one is C reactive

and cellular components.

protein which binds to phosphorylcholine on the

surface of certain bacteria thus promoting phagocytosis

Humoral

by complement fixation.

Complement

Interferon (IFN)

The word ‘complement’ is a collective term for 15 or so

plasma proteins (enzymes) which can be activated

These glycoproteins are a family of cell-regulating

sequentially into functional units that then have three

proteins produced by many cell types in response to

major effects:

stimuli. Although viruses are well known as interferon

(IFN) inducers, others include endotoxin, bacteria and

(1)

Production of peptides which are active in inflam-

a variety of other antigenic stimuli. Interferons are clas-

matory processes.

sified as follows:

(2)

Production of C3b which, by its ability to

‘opsonize’ micro-organisms or other particulate

(1)

IFN-a is produced by leucocytes.

matter, is a powerful incentive for phagocytosis.

(2)

IFN-b is produce by fibroblasts.

(3)

Attachment to cell membranes to create lysis and

(3)

IFN-g is produced by T lymphocytes.

destruction of the target.

Interferon offers a rapid protection to viral infection.

After immunoglobulins, albumin and transferrin, C

It induces an antiviral state in cells by firstly triggering

3 is

the most abundant of bovine serum proteins (in excess

a receptor (IFN-ab share a receptor, IFN-g remains sep-

of 1 mg/ml).

arate). This stimulates the cell itself to produce proteins

How is complement activated? The combination of

to block the transcription of viruses, so protecting them

immunoglobulin with antigen will often cause activa-

from infection.

tion, but enzymes such as trypsin and bacterial compo-

Interferon can be produced within hours of stimula-

nents such as endotoxin will all activate complement.

tion and the antiviral state can last several days. Inter-

The normal route of activation by such agents is termed

feron also has a number of other effects both on the

the classical pathway and as far as the antibody–

immune system (such as stimulation of cytotoxicity

antigen reaction is concerned it relies on the availabil-

and increased expression of major histocompatability

ity of the Fc portion of the antibody molecule. In the

complex (MHC) products), as well as other functions

cow it used to be thought that of the two major sub-

such as cell division.

classes of IgG (IgG

All three types of bovine IFN have now been genet-

1 and IgG2) only IgG1 could fix

complement by this route. Recent research using a

ically engineered and are being investigated for their

homologous bovine IgG

potential as therapeutic agents. There may well be a

2/complement system,

has

clearly shown that both subclasses can fix complement.

role in diseases such as enzootic calf pneumonia.

Another pathway of complement activation is via the

alternative route. This is a more primitive pathway and

Cellular

does not require the Fc portion of the antibody and can

Phagocytic cells

indeed be activated by antibodies such as IgA which is

not effective by the classical route. Certain isolates of

These include neutrophils, macrophages and other cells

E. coli and virus-infected cells can all set the alternative of the reticuloendothelial system. Free-living bacteria

are fairly easy to kill without antibody or complement,

of 'policing' role within the body, ready to destroy spon-

but bacterial pathogens such as streptococci with large

taneous tumour cells when they arise or help clear up

capsules can alter the surface tension between the

virus infections. Cattle have NK cells, although the term *phagocyte and the bacteria so preventing phagocytosis.*

almost certainly covers a heterogeneous population.

It is for this reason that specific antibody and/or com-

Natural killer cells can easily be recruited (stimulated

plement is needed to 'coat' or 'opsonize' the bacteria,

by cytokines such as IFN and IL-2). Interestingly in

altering the surface tension and allowing phagocytosis

cattle, NK activity is quite low in stock reared outside

to proceed. Bovine neutrophils and macrophages/

in extensive systems but is often very high in intensive

monocytes have C3 and Fc membrane receptors.

systems. Whether this is caused by the greater preva-

Cattle have unusually high numbers of monocytes in

lence of microbial infection in such individuals is not

circulation.

clear.

The phagocytic cells have several agents such as acid

Natural killer activity can also be down-regulated by

hydrolases, peroxidase and cationic proteins which can

agents such as prostaglandins. Do NK cells have any in

kill micro-organisms after phagocytosis. The cationic *vivo relevance? They certainly will kill virus-infected proteins come into play first when the pH goes up and*

cells such as IBR-infected fibroblasts and tumour cells,

in fact these mechanisms are now thought to be at least

but the real clinical relevance requires further research.

or even more important than the traditional peroxi-

dase-dependent pathways involving H2O2.

Several pathogens such as Brucella abortus, Salmo-

Acquired immunity

nella spp., Listeria spp. and Mycobacterium spp. can live intracellularly and thus pose a problem for the immune

Humoral

system. The solution is by activation of the macrophage,

usually by specific protein messengers released espe-

Acquired humoral immunity is mediated through

cially by T lymphocytes, called cytokines. Activated

immunoglobulin, or antibodies as they are commonly

macrophages are basically a lot 'meaner', more efficient

known. These are a group of glycoproteins that have

and, for example, contain more lysosomes; they are

combinations of incredible variety and specificity. The

quite capable of dealing with these more awkward *basic units are two identical polypeptide chains, termed*

pathogens.

light chains, linked to two further identical polypeptide

We must also consider another vital, indeed pivotal,

chains, heavy chain, by several disulphide bonds (Fig.

role for macrophages. This is one we term antigen pres-

58.1).

entation. These antigen presenting cells (APCs) are

The Fc portion of the molecule is responsible for

found throughout lymphoid tissue, the archetypal one

linking to the Fc receptor on leucocytes, while the other

being the Langerhans' cell in the skin. Other special-

end, Fab, carries the actual antigen-combining site itself.

ized APCs are found in the gut, respiratory tract and

This latter site is also called the hypervariable region

mammary gland. These cells basically phagocytose the

simply because it is variation in amino acid sequence in

antigen, process it and then deliver it as a neat package

this region that produces the incredible diversity of

to lymphocytes of the immune system. They combine

antibodies.

this ‘antigen presentation’ with MHC products on their

An explanation of the plethora of titles that accom-

membrane and by the release of a soluble mediator

pany a description of immunoglobulins is given in Table

such as interleukin-1 (IL-1).

58.1.

Natural killer (NK) cells

IgM

It is only in the last five years or so that natural killer

IgM has five of the basic units forming a pentamer

or NK cells have come into their own. They are basi-

structure and represents an early stage in the evolution

cally lymphocytes with a separate lineage from T and

of antibodies. All vertebrates (with the exception of

B lymphocytes. The genealogy of NK cells remains

cyclostomes such as the lamprey) have an IgM closely

unclear: they share membrane determinants with both

resembling that of mammalian IgM except for the

monocytes and lymphocytes. They have Fc receptors

number of units polymerized into the complete mole-

and are quite large cells, often with noticeable granules.

cule. The level of IgM in normal cattle is in the range

Two fascinating things about NK cells are that: (i) they

of 2–3 mg/ml from the age of 4 months. Levels of IgM

pre-exist within individuals and do not require anti-

in calves is complicated by the amount absorbed in

genic stimulation; (ii) they can kill innumerable targets

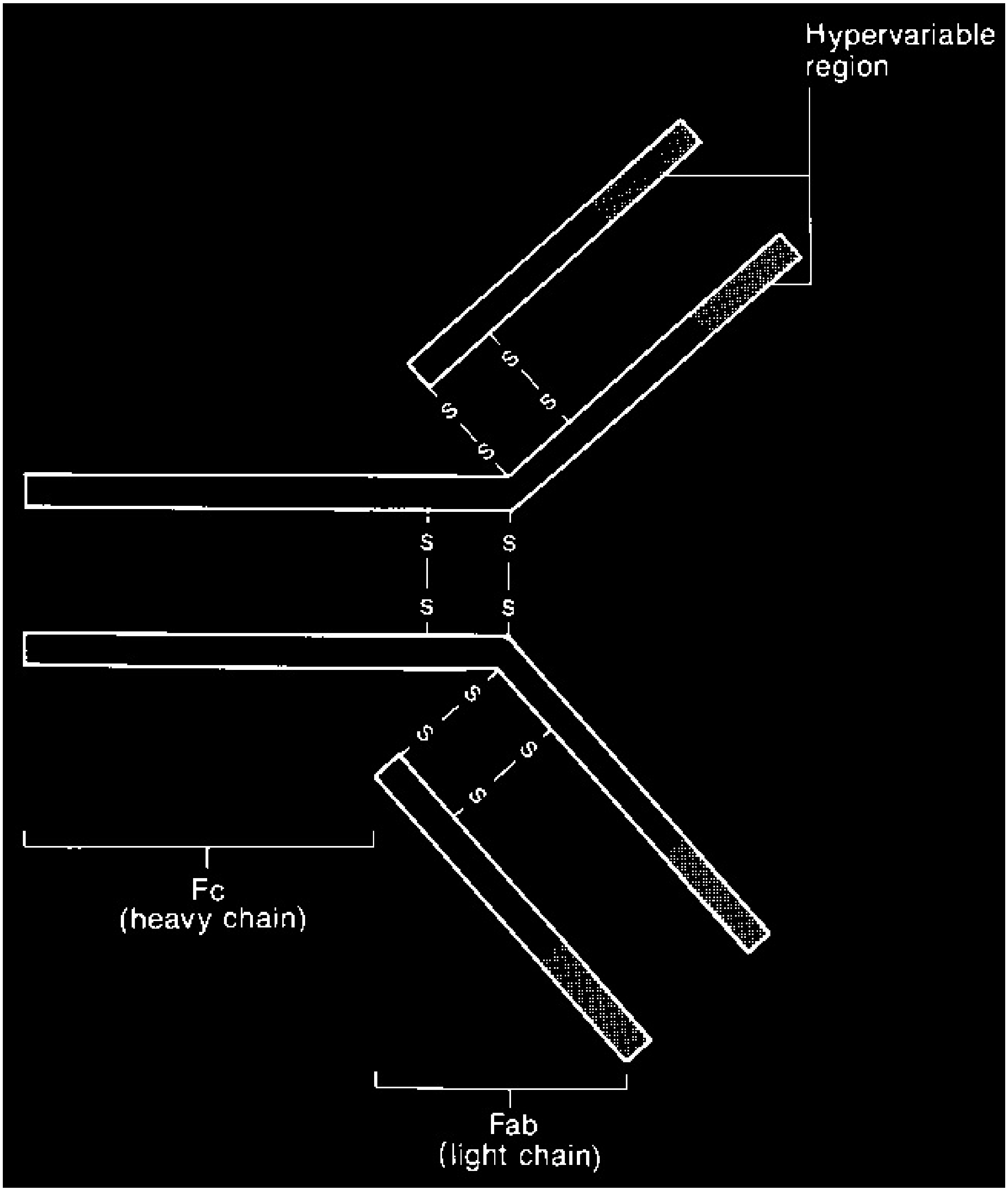
colostrum. The actual amount in bovine colostrum is

from virus-infected cells to tumour cells without the

about 6 mg/ml which drops to approximately 0.1 mg/ml

need for antibody. Therefore, they could operate a type

in milk. Interestingly the bovine fetus is quite capable



tions and stimulate B cells directly. Such antigens,

including bacterial lipopolysaccharides, normally stim-

ulate only IgM production. The efficacy of specific IgM

should not be underestimated. Not only is IgM highly

efficient at aggregating antigen, it can bind with the

secretory component (see below under IgA) and act as

a protective antibody at mucosal surfaces. In diseases,

such as Escherichia coli enteritis in calves, IgM has been shown to be a major protective mechanism.

In cattle suffering from infection with trypanosomes,

IgM levels can rise in serum to over 20 mg/ml, although

the majority of this overproduction is not particularly

useful against the trypanosomes. On the other hand, in

bovine leukaemia IgM levels can fall quite dramatically.

IgG

IgG predominates over other immunoglobulin classes

in serum and contributes in excess of 85 per cent of all

circulating immunoglobulins. Its structure is based on

the usual immunoglobulin model, and it has a molecu-

lar weight of approximately 180 000.

IgG occurs in two subclasses: IgG1 and IgG2. Adult

serum contains approximately 11 mg/ml of IgG1 and

Fig. 58.1

Descriptions used for immunoglobulins.

9 mg/ml IgG2. In colostrum the figure is well in excess

of 50 mg/ml IgG1 and 3 mg/ml IgG2; this reflects the

incredible selective concentration of IgG1 in colostrum

(more details are given in the section Maternal im-

Table 58.1

Descriptions used for immunoglobulins.

munity, p. 1002). Twenty-four hours after successful

Class

Five major classes are distinguished in

suckling the calf has approximately 20 mg/ml IgG1 and

mammals: IgM, IgG, IgA, IgE and IgD. These

1 mg/ml IgG2, underlining the obvious and often reiter-

are distinguished in structure and major

ated importance of successful colostral transfer.

variations within the heavy chains.

As mentioned above, both subclasses can fix bovine

Subclass

Several of the individual classes are further

complement; IgG1 somewhat more so than IgG2. As for

split into subclasses, e.g. IgG1 and IgG2.

their reaction with leucocytes exhibiting Fc receptors, a

These are very similar in structure, but vary

somewhat paradoxical situation exists. In experiments

in the amino acid sequence of the heavy

involving freshly purified monocytes or neutrophils,

chain.

IgG2 was always much more efficient at mediating

Allotype

This is a term used to refer to genetic variation

phagocytosis or antibody-dependent cell-mediated

within a given animal species involving alleles

at a given locus; the variants normally occur

cytotoxicity (ADCC). Yet IgG1 is the predominant sub-

within heavy chains. Allotypes in domestic

class that the calf receives from the dam.

animals could well be linked to disease

In the cow and calf IgG1 has a highly significant pres-

resistance/production efficiency.

ence at the mucosal surfaces. While IgA is the pre-

Idiotype

This term describes the product of a single *dominant immunoglobulin in nasal secretions in the*

clone of B cells, a unique antibody with

adult, IgG1 is the predominant immunoglobulin in the

a unique antigen combining site. Monoclonal

calf up to at least the 6th week of life. In the lower res-

antibodies consist of a single idiotype.

piratory tract, for instance the bronchoalveolar secre-

tions, IgG1 becomes the dominant immunoglobulin

in all ages. Even infections at mucosal surfaces will

of producing IgM from about the third or fourth month

produce high levels of circulating and specific IgG1

of gestation.

equal to those achieved by intramuscular injection.

It is, of course, well established that in a primary

When one considers that the main site of the IgG1 syn-

immune response the major antibody produced early

thesis is in the respiratory tract mucosa, it underlines

on is IgM. What is not so well recognized is that certain

the important potential of this immunoglobulin sub-

antigens can bypass many of the normal T cell interac-

class in local defence mechanisms.

IgA

coli. So by a simple steric hindrance such microbes are unable to attach and are excreted.

IgA is recognized as a major immunoglobulin associ-

This local stimulation does underline the necessity to

ated with mucosal surfaces. It is basically a dimer (con-

consider vaccination via a local mucosal route when

sisting of two of the basic units) joined by another

dealing with diseases where a major defence mecha-

molecule called the J chain (molecular weight of

nism involves secretory immunoglobulin. Many of the

approximately 15 000). This structure is combined with

currently successful vaccines are given via the mucosal

a secretory component (molecular weight of approxi-

route and even more are under active research.

mately 60 000) to form secretory IgA or SIgA for short.

Another property of IgA lies in the dimer itself

Individuals with mucosal surfaces have to have a

rather than the complete SIgA, or as one famous immu-

selective system that can decide which antigen to ignore *nologist put it 'IgA can be more important beyond its*

and which to respond to. It is not in the animal's inter-

laudable but essentially unglamorous role in intestinal

est to respond to dietary antigens, although of course

sanitation'. Thus, if a dietary or microbial antigen pen-

this can occur, leading to disease. Conversely the

etrates the mucosal barrier, a high-affinity IgA attaches

mucosal immune system must be able to respond

to it. There is no complement fixation or inflammatory

quickly and effectively against a pathogen. One of the

process, so the whole complex is carried off in the blood

most important mechanisms in this decision-making

to the liver where the IgA dimer reacts with the

process is distinctive epithelial cells called 'M cells' that

secretory component on hepatocytes with subsequent

overlie Peyers patches and other mucosal lymphoid

release into bile.

aggregates. These cells have a tubulovesicular system

with pits in the lumen surface and cytoplasmic

IgE

processes on the opposite surface enfolding lympho-

cytes and other mononuclear cells. These cells can

This immunoglobulin was first described for humans in

actively 'sample' the micro-environment within the

the mid 1960s, and is sometimes called the reaginic anti-

lumen and pass information on to the proactive cells of

body. It is, of course, associated with immediate hyper-

the lymphoid system.

sensitivity reactions. The structure of IgE is based on

The stimulation and subsequent expansion of the

the usual immunoglobulin model but has a higher

plasma cells that are responding to a particular antigen

molecular weight than IgG (196 000 as compared with

take place within the local lymphoid tissue itself. These

180 000). This is due to an additional structure in the

IgA-producing cells migrate to the submucosa where

heavy chain, which is thought to help in the high affin-

they assemble and secrete the complete dimer and J

ity this immunoglobulin has for Fc receptors on mast

chain. The epithelial cells on the microvilli have a recep-

cells. IgE normally exists in very low concentrations in

tor for IgA on their internal side that is probably the *serum (e.g. 20–400 ng/ml in dogs). Reliable and specific*

secretory component itself. The whole molecule, now

reagents are not yet available for the cow but by sensi-

the complete SIgA, is transported across the cell in

tive in vivo tests like the passive cutaneous anaphylaxis endocytic vesicles and discharged into the mucus itself.

(PCA) test, potent IgE-like activity can be demon-

This process can also take place in the liver where hepa-

strated in cattle.

tocytes can make secretory component; therefore bile

The antigens that can elicit a specific IgE response

has high levels of SIgA.

are called allergens. The allergens are processed in the

What is the function of the secretory component? It

normal way and plasma cells in lymph nodes local to

can be found free within normal gut contents or saliva,

the area through which the allergen gained access,

with large amounts in the newborn calf when very little

produce the specific anti-allergen IgE. Mast cell pre-

IgA is being produced. It seems to increase the resist-

cursors also migrate to the lymph node and they take *ance of the complete SIgA to proteolytic enzymes,*

up the IgE via their Fc receptors. The mast cells now

although there is little evidence for any direct antipath-

coated with the IgE migrate back to areas underlying

ogenic role. One of its major roles may be to help

the skin and/or mucosal surfaces. When the allergen

anchor the SIgA on the mucous layer on top of the

again gains access it reacts with the IgE and this causes

epithelium, creating a high concentration of antibody

the mast cell to release the contents of its granules, a

activity at this crucial site.

whole range of pharmacologically active substances.

The IgA part of the SIgA is not particularly effective

These latter include 5-hydroxytryptamine, histamine,

at 'traditional' roles of antibody such as opsonization,

prostaglandins and cytokines such as eosinophil chemo-

aggregation and complement fixation. Its major, and

tactic factor. The outcome is smooth muscle contrac-

highly successful role, is simply to block adherence.

tion, increased permeability of capillaries and, through

Micro-organisms must attach before penetration of *the chemotactic agents, migration of leucocytes. In fact*

mucosal barriers, e.g. the filamentous K antigen of E.

the latter function is a component of the mechanisms

that 'dampen down' the reaction: eosinophils contain

monoclonal antibodies has meant a highly specific and

many factors such as phospholipase D and histaminase

accurate assessment of these lymphocyte subpopula-

that will inactivate the products of the mast cells.

tions. These are in today's parlance called CD (or

Although such IgE reactions are considered a real

cluster determinant) markers, each CD classification

clinical nuisance both by humans and their animals,

describing an identifiable membrane molecule which

there must have been an evolutionary advantage to

helps identify subpopulation. The major groups of

develop and then retain this hypersensitivity reaction.

lymphocytes to consider are:

One clue for this is a possible mechanism against para-

sites, especially intestinal nematodes. Although there is

(1)

T lymphocytes, especially the major subsets coded

a lot of experimental evidence in rodents, using para-

for by the CD4 (T helper) and CD8 (T cytotoxic)

sites such as Nippostrongylus brasiliensis, there is

markers.

some evidence for nematodes of ruminants such as

(2)

B lymphocytes; lymphocytes involved in delayed-

Haemonchus spp. The antiparasite mechanism works by

type hypersensitivity.

antigens secreted by the nematode (often those associ-

(3)

An increasingly well-researched group of lym-

ated with their mouth parts) being recognized as aller-

phocytes lacking the classical T and B cell

gens by the host. This results in suitably and specifically

markers. The average human adult has about 1012

sensitized mast cells migrating back to the gut. When

lymphoid cells, representing approximately 20 per

the worm feeds again the freshly released allergens acti-

cent of all leucocytes.

vate the mast cells. The resultant smooth muscle con-

tractions, and increase in permeability allowing through

T lymphocytes

other factors such as IgG, and the possible direct action

of the mast cell mediators themselves, cause a mass

The thymus is central to immunological function. The

expulsion of the worms. Prostaglandin might be one of

T-cell precursors migrate there from the bone marrow

the important effector mechanisms. A lot of research

via the blood. The thymus extends a complicated but

needs to be done to extend our knowledge of this

highly effective 'education' of these immature T cells,

intriguing immunoglobulin before it could be confi-

after acting through a cascade of thymic-derived hor-

dently stated that it is a main mediator of intestinal

mones such as thymosin and thymopoietin. The pre-

immunity.

cursor T lymphocytes undergo about eight to ten cell

divisions before they leave the thymus. A lot of the cells

die within the thymus (maybe up to 90 per cent) and it

IgD

would be a neat solution to claim that this is how the

A brief and quite basic chapter such as this cannot go

host rids itself of all potential self-reactive lymphocytes.

into details of this immunoglobulin which, although

Unfortunately there is much conflicting evidence as to

presumed to occur in the cow, has yet to be convinc-

how exactly the thymus does its job.

ingly demonstrated. IgD is linked to B lymphocytes

What is certain is that when the lymphocytes even-

and appears on the surface of B cells after the initial

tually leave the thymus they can be classified as

expression of IgM. The IgD will co-express with IgM

CD4+ve or CD8+ve cells, two populations that are

and subsequently other immunoglobulin classes. The

mutually exclusive in peripheral blood. The lympho-

IgD is lost when the B cells respond to antigen by dif-

cytes have an amazing ability to migrate from blood to

ferentiating into immunoglobulin-producing plasma

secondary lymphoid tissue (within lymph nodes, spleen,

cells or memory B cells. The exact role of IgD remains

gut, skin, respiratory tract, etc.) and often back again to *unclear.*

blood. This thorough 'mixing and movement' of lym-

phocytes is essential for them firstly to respond to

antigen when it first appears, and then to be able to

Cell-mediated immunity

contact other cells with a view to initiating and finally

curtailing an immune response. T lymphocytes tend to

This is an often used 'catch-all' phrase that by strict def-

mass into their own areas within secondary lymphoid

inition could cover most of the immune system. Early

tissues, quite distinct from B lymphocytes.

on in fetal development the ubiquitous haemopoietic

CD4 T cells are often called 'helper T cells', which

stem cells produce two distinct progenitors: a common

does underlie their important role. The antigen-

myeloid and a common lymphoid. It is the eventual off-

presenting cells or APCs are responsible for the initial

spring of the latter cell population that are often con-

processing and presentation of antigen to the CD4 cells.

sidered to constitute cell-mediated immunity.

The latter then further present the antigen to other lym-

The lymphoid progenitors produce several different
phocytes such as the CD8 population and B lympho-
populations of lymphocytes. The rapid development of
cytes. The whole business of presentation is not only

dependent on cytokines such as Il-1 and Il-2 but it is

Maternal immunity *(see p. 211)*

also MHC-restricted at the class II level. Crucial to the
immune reaction is the T-cell receptor (TCR). The iden-
This is an important area for cattle. In the harsh eco-
tification of the TCR remained a mystery until a few
nomics of farm animal practice, death in the neonate is
years ago when the TCR was shown to consist of two
a major problem, and the passive protection provided
chains which clearly belong to the immunoglobulin
by the mother is vital. Ruminants have five tissue layers
supergene family. This structure is closely linked to
between maternal and fetal circulation, so there is little
another CD marker: CD3. The human immunodefi-
or no transfer of immunoglobulin during pregnancy.
ciency virus (HIV) preferentially binds to CD4 cells and

In bovine colostrum the level of IgG is up to a

it is the gradual destruction of this population that is an

massive 75 mg/ml with 4 mg/ml IgA and 6 mg/ml IgM.

important factor in the marked immunosuppression

Why does the neonate actually need all this antibody?

that is such a feature of HIV infection.

The newly born calf has a somewhat limited capacity

The CD8 population is also MHC restricted but at

to mount a fully effective immune response. It can

the MHC class I level. This is useful as a major function

produce IgM and some IgG1 at birth; from 36 hours old

of CD8 cells is cytotoxicity. Like other T cells, CD8 cells

it will start producing a lot of IgG1 at a rate of approx-

are highly specific for antigen, and for cytotoxicity to

imately 1 g/day (depending on antigenic challenge).

occur the CD8 cell needs to recognize antigen and

From one to two weeks SIgA starts production and

MHC. As most body cells express MHC class I then any

it is several weeks before IgG2 production starts in

cell expressing say a virus antigen could be attacked and

earnest.

destroyed by the appropriate CD8 effector cell. In

The neonate is thus basically immunocompetent but

cattle diseases such as Theileria parva or IBR infection, has not 'tuned' its immune system to deal with the envi-these CD8 effector cells, or cytotoxic T lymphocytes

ronment, and it is in this period of tuning and massive

(CTL), have been shown to be important.

primary antibody responses that the neonate needs

A single CTL can kill several individual target cells

passive protection. How does this concentration of

and there is evidence that in virus infection, for

immunoglobulin in the bovine colostrum occur? The

example, recognition and then destruction of the target

major constituent of the immunoglobulins in colostrum

cell can occur before fully infectious virus is assembled

is IgG1 which is selectively transferred from serum. For inside the cell. The molecular basis behind the actual

example, a sheep can produce up to 2500 g of colostrum

destruction itself remains poorly understood. Certainly

in the first 48 hours after parturition of which 90 g will

it is vital to have the all-important recognition and close

be IgG1. When one considers that the concentration of *contact. The killing probably involves the release of*

IgG1 in her own serum is probably less than 0.015 g/ml,

more than one soluble 'mediators'.

it is a major transfer. This transfer of IgG1 occurs via

receptors on the heavy chain which binds to the acinar

epithelial cells. This receptor interaction is under hor-

B lymphocytes

monal control and only occurs during late pregnancy.

B cells develop initially in the fetal liver but production

There is no such selective concentration for the much

then shifts to the bone marrow. The pre-B cell has IgM

smaller amounts of IgG2, IgM and IgA.

heavy chains within the cytoplasm. On a commitment

The specificity of the immunoglobulins is also of

to B cell lineage the B cell acquires surface IgM, the

obvious importance, not only reflecting the microenvi-

initial antigen receptor. A second phase of development

ronment of the dam herself, but also as a result of delib-

allows the B cells to express immunoglobulins of a

erate immunization policy. The neonatal calf has a

different class or subclass (plus IgD). On meeting its *greatly increased intestinal permeability due to special-*

pre-ordained antigen the B cell retains only the

ized epithelial cells capable of pinocytosis. These cells

immunoglobulin it is programmed actually to produce

are activated by the presence of macromolecules and

and then enters the terminal stage of immunoglobulin-

eventually slough off after releasing their contents into

secreting plasma cells. A proportion of the antigen-

the circulation. This spontaneous closure starts in the

specific cells remain as an enlarged population of

calf at 12 hours postparturition with a mean complete

memory cells.

closure time of approximately 30 hours. Degradation of

Although B and plasma cells produce the

this colostrum in the neonatal calf is minimal because

immunoglobulins, they are under the tight control of

it contains a trypsin inhibitor, and pancreatic activity

the CD4 helper T cells for the majority of antibodies; a

itself is low. Abomasal pH is between 6 and 7 due to the

proportion of T-independent antigens can avoid this

delayed development of parietal cells, but by 36 hours control but at a cost of only IgM production and no

postparturition the pH has dropped to between pH 3.0

immunological memory.

and 4.0, and pepsin is then active. A final point con-

Immunological Fundamentals • 1003

cerning immunoglobulin in colostrum/milk is that in

and, perhaps most importantly it is to a large extent

some diseases in cattle, such as rotavirus in calves, the

an automatic response. The response is switched on in passive protection is better obtained by the ingested

three main areas:

immunoglobulin rather than systemic immunoglobulin

being re-excreted into the gut. Therefore, it would make

(1)

A voluntary motor response, which operates via

more sense to feed diluted colostrum from vaccinated

the lower brain centre Æ spinal cord Æ peripheral

dams during the first week of life rather than relying

nerves and results in fight/flight, etc.

totally on the protection acquired passively during the

(2)

The adrenal medulla. This works via the auto-

first 24 hours of life.

nomic nervous system and adrenal medulla

As well as the immunoglobulins in colostrum there is

releasing catecholamines, inducing the alarm

a high concentration of other effector proteins such as

reaction.

lactoferrin. In addition, there are leucocytes, with the

(3)

The hypothalamus, which is probably the most

macrophage and other mononuclear cells predominant

important for cattle.

in the resting mammary gland and at parturition.

During lactation, however, the predominant leucocyte

This latter mechanism involves the neuroendocrine

is the neutrophil, possibly reflecting the constant,

system, with the hypothalamic stimulating adeno-

although usually non-clinical, bacterial presence. The

hypophysis, which in turn stimulates (via ACTH) the

importance of leucocytes in mammary secretions is as

adrenal cortex, which releases cortisol. The latter *yet unclear for the neonate, but of obvious use for the*

hormone has an alarmingly high number of effects such

mammary gland itself; the area of local and effective

as vasoconstriction in skin and intestine, vasodilatation

immunity in the working mammary gland will continue

in muscles, raising blood glucose, raising pain threshold,

to be a goal for researchers.

reducing secretions, etc. The integrity of lysosomal

membranes is enhanced by cortisol, so although phago-

cytosis of bacteria and other particulate matter still

Homeostasis and stress *(see Chapter 67)*

occurs, it is more difficult for the enzymes to be released

from the lysosomes into the phagosomes. Clinically this

In any book involving diseases of cattle, environmental

can manifest itself as muscle weakness, trembling,

stress must be a major consideration. Every living

impaired immune response, poor wound healing,

organism in an effort to cope with its environment

weight loss, etc. Cortisol normally inhibits the produc-

attempts to reach homeostasis which can be defined as tion of adrenocorticotrophic hormone (ACTH) in a *the steady state achieved by the optimum action of*

feedback mechanism; however, this latter mechanism

physiological regulation. Stress can be achieved by

can be overridden by highly stressful conditions.

changes in the animal's environment such as restraint,

Summing up this section: the body attempts to

handling, housing, weather, etc. Although there are

respond to stress by a variety of means to restore home-

many definitions of stress, one of the most useful is 'the

ostasis. These responses evolved to occur in an open

cumulative response of an animal resulting from inter-

environment where the individual can move, seek

action with its environment via receptors'.

shelter, etc. But in a crowded calf pen there is no escape,

This is therefore an adaptive response and is prima-

the stress conditions remain with the inevitable

rily directed at coping with changes in the environment

consequences.

Chapter 59

Vaccines and Vaccination of Cattle

I.D. Baker

Definitions

1004

of infectious disease. In cattle practice a vaccine should

Anthrax

1005

produce herd resistance to minimize the economic

Clostridial disease

1005

effects of infectious diseases. They are usually adminis-

Salmonellosis

1006

tered to healthy animals. There are various types of

Neonatal calf diarrhoea

1006

vaccine.

Respiratory disease

1007

Bovine respiratory disease complex

1007

Modified live vaccines (MLV): There produce high

PI3 and IBR

1007

levels of immunity from a single inoculation. Their

Bovine respiratory syncytial virus (BRSV) and

Mannheimia haemolytica

1009

virulence is reduced by attenuation, which is achieved

Infectious bovine rhinotracheitis

1010

by either serially passaging the organism through tissue

Haemophilus somnus infection

1010

cultures or by genetic manipulation when those genes

Contagious bovine pleuropneumonia

1011

associated with virulence are removed. These types of

Parasitic bronchitis

1011

vaccine induce immunity by causing a mild infection in

Bovine virus diarrhoea

1011

animals, often showing mild disease signs and occa-

Johne’s disease

1012

sionally causing unwanted side-effects.

Rinderpest

1013

Brucellosis

1013

Inactivated vaccines: These are killed vaccines; the

Strain 19 vaccine

1013

infectious agent is inactivated but retains its antigenic

Strain 45/20 vaccine

1014

properties, although these are often weaker than live

Louping-ill

1014

Papillomatosis (warts)

1014

preparations. As a result, two inoculations are needed

Erysipelas

1014

initially to provide adequate immunity. The antigenicity

Leptospirosis

1015

is often enhanced by using various adjuvants. These

Mastitis

1016

adjuvants may cause a local reaction at the site of the

Coliform mastitis

1016

injection.

Foot-and-mouth disease

1016

Ringworm

1017

Genetically modified vaccines: These are vaccines

Rabies

1018

where specific genes have been removed or added to

Other vaccines

1018

the DNA of the infectious agent. Apart from the atten-

There are many vaccines available for use in cattle in

uation of vaccines these techniques have enabled the

the UK and worldwide. This chapter is an attempt to

development of marker vaccines. These are useful in

summarize some of those available.

distinguishing between vaccine protected and infected

animals.

Definitions

Autogenous vaccine: This is a vaccine prepared from

cultures of material derived from a lesion of the animal

Vaccination is the introduction of a vaccine into the

to be vaccinated.

body to produce immunity to a specific disease. The

vaccine may be administered by subcutaneous, intra-

Toxoid: This is a toxin that has been treated by heat or dermal or intramuscular injection, by mouth, by inhala-chemical agents to destroy its deleterious properties

tion (intranasal) or by scarification.

without destroying its abilities to stimulate the forma-

tion of antibody.

Vaccine

A vaccine is a suspension of attenuated or killed micro-

Serovaccine: This is a combination of an antiserum with organisms administered for the prevention or treatment

a vaccine to produce passive and active immunity.

Anthrax *(see p. 717)*

Table 59.1

Clostridium spp. and disease syndromes in cattle.

Causative organism

Disease

Many types of vaccines are available internationally. No

commercial vaccine is currently available in the UK.

Cl. chauvoei

Blackleg

The disease is notifiable and DEFRA should be con-

Postparturient gangrene

tacted if emergency supplies of this vaccine are needed.

Cl. septicum

Braxy

The vaccine that was available was a live vaccine

Cl. novyi type B

Black disease

prepared from a suspension of living spores of an

Cl. haemolyticum type D

Bacillary haemoglobinuria

encapsulated strain of Bacillus anthracis. The vaccine Cl. tetani

Tetanus

was stable for long periods.

Cl. botulinum

Botulism

Vaccines have been produced by overcoming viru-

Cl. perfringens (welchii)

Enterotoxaemia

lence using saponins or saturated saline to delay

Mixed species of Clostridium

Gas gangrene

absorption (Carbozo vaccines). In the UK the Stern

vaccine contained an avirulent strain.

Dosage and administration

toxoid. Vaccines for Cl. chauvoei are often a mixture of formalin-killed cells and a purified toxoid.

A dose usually of 1 ml is given by subcutaneous injec-

tion. This confers an immunity in seven to ten days that

lasts for nine months. Annual booster doses are rec-

Dosage and administration

ommended except in areas of increased risk when they

Usually 2 ml is give by subcutaneous injection. The

should be given at six-monthly intervals.

initial course is two inoculations separated by four to

six weeks followed by an annual booster unless there is

Contraindications

great risk, when it should be every six months.

The use of antibiotics should be avoided from shortly

before to 14 days after vaccination to avoid any inter-

Specific vaccines

ference in the production of immunity. Animals in the

last stages of pregnancy should not be vaccinated unless

Blackleg (see p. 723): If this disease is identified at there is a serious risk of infection.

pasture then cattle should be removed from the pasture

There may be a slight reaction at the site of injection

until the vaccination course is complete. Some veteri-

and animals may have a mild pyrexia for one to two *narians give a concurrent dose of long-acting procaine*

days and milk yield may be depressed. These side

penicillin at the same time as the initial vaccination to

effects will subside.

avoid further disease outbreaks during the period of

Empty or part-filled vials must be destroyed by

developing immunity.

incineration.

Tetanus (see p. 733): Immunity usually lasts for three years following an initial course of vaccination and one

Other vaccines

annual booster. For especially valuable animals, there is

Another vaccine incapable of producing disease is a

a tetanus vaccine that carries a minimum risk of hyper-

cell-free filtrate of a culture of a non-encapsulated

sensitivity; whilst primarily designed for horses it can be

spore-forming strain of B. anthracis. This requires two used in cattle. It is prepared from purified tetanus toxin

injections to produce immunity but it is long lasting.

converted to toxoid by treatment with formalin and

then adsorbed onto aluminium phosphate. A polyvalent

vaccine that is commonly available contains the fol-

Clostridial disease *(see pp. 719, 725, 733)*

lowing organisms: Cl. chauvoei, Cl. septicum, Cl. novyi, Cl. haeamolyticum and Cl. tetani. It seems eminently The clostridial organisms are common and responsible

sensible to use a polyvalent vaccine such as this instead

for many serious diseases in cattle (see Table 59.1).

of an individual vaccine since all these diseases occur

Vaccines against these diseases are available individu-

commonly.

ally, for example blackleg and tetanus, but they are

often combined as polyvalent vaccines. In general, the

Botulism (see p. 721): Vaccination is practised in

vaccines are prepared from formalin-killed cells

enzootic areas with either a combined Cl. botulinum

adsorbed on to aluminium hydroxide producing a

types C–O or a type-specific toxoid vaccine.

Salmonellosis *(see also Chapter 15)*

Dosage and administration

For prophylaxis in calves, up to 20 ml is given subcuta-

Many species of Salmonella can cause disease in cattle, neously and repeated at 10–14-day intervals during the *e.g. S. dublin, S. typhimurium, S. newport and S. arizona.*

period of risk. For therapy up to 40 ml is given sub-

The two commonest species in the UK are S.

cutaneously and repeated at 24 hours if required. In the

typhimurium and S. dublin and these can be endemic in author's experience these products are not always

a herd. The so-called exotic Salmonella species are not cost-effective.

usually endemic.

Neonatal calf diarrhoea

Live vaccine

A live Salmonella dublin vaccine prepared from an

Neonatal calf diarrhoea is a multifactorial disease

avirulent strain (HWS 51) used to be available in the

complex involving managemental and infective factors.

UK. It was a freeze-dried vaccine, which was reconsti-

Several bacteria, viruses and protozoa are associated

tuted immediately before use. This vaccine was very

with the disease, for example enterotoxigenic E.coli

effective both in calves and in adults. It was especially

(ETEC) (see p. 201), Salmonella spp. (see p. 215),

useful in controlling the disease in the face of an *rotavirus (see p. 191), coronavirus (see p. 199) and cryp-*

outbreak.

tosporidia (see pp. 204, 282). Pathogenic infections with

E. coli are most common in the first four days of life, Inactivated vaccine

whereas rotaviruses are most pathogenic from 7–14

days and coronavirus causes disease from 7–21 days.

An inactivated vaccine containing S. dublin and S.

Vaccines are available (Table 59.2) and are very suc-

typhimurium is licensed in the UK and can be used in

cessful in practice; they contain inactivated strains of

the face of a disease outbreak. When the disease has

bovine rotavirus with coronavirus and E. coli K99 anti-been confirmed, all at-risk stock not showing overt clini-

gens. It is important that the E. coli component contains cal salmonellosis can be vaccinated. Calves are given a

both K99 pilus antigen and K99 capsular antigen. The

2 ml dose subcutaneously and can be vaccinated from

K99 antigen enables E. coli to adhere to the villi of the 21 days old. A second dose must be given after 14–21

calf's small intestine where rapid bacterial multiplica-

days. Adult cattle require a 5 ml dose; again this is

tion causes the production of toxins that are responsi-

repeated after 21 days.

ble for the diarrhoea.

Pregnant cows should be vaccinated six and three

weeks before calving. All cows that have not calved

Dosage and administration

within eight weeks of the second inoculation should be

vaccinated again three to four weeks before calving.

The pregnant cow is vaccinated between 12 and 4 weeks

This will then confer passive immunity to the calves via

of the expected calving date. Calf protection is depend-

the colostrum.

ent upon the calf receiving adequate (3 litres)

colostrum within the first six hours of life. They must

then continue to receive colostrum or milk from vacci-

Risks

nated cows for the first two to three weeks. This is no

A small number of animals may not show an adequate

problem in the suckler herd. In the dairy herd, milk

response to vaccination. Ideally, healthy animals should

from the first six to eight milkings should be collected,

be vaccinated. Adequate immune levels will not be *pooled and stored in a cool place. The calves should*

reached until two weeks after the second injection.

then be fed, according to size, 2.5–3.5 litres/day of this

Avoid stress when vaccinating pregnant cows or abor-

milk for the first two weeks of life. In a seasonal calving

tion or metabolic disease may occur.

dairy herd with a close calving pattern it is common

practice to vaccinate one cow in four and use her

colostrum and milk for the calves. However, the best

Serovaccines

results are achieved if all the cows in the herd are vac-

Commercial serovaccines have been available contain-

cinated; in this way infection and the level of excretion

ing mixed antisera to S. dublin and S. typhimurium of infected organism are kept to a minimum.

together with polyvalent strains of E. coli and P.

Oral vaccines have been used and are available in

multocida. These are designed to give passive immunity some countries (for example the USA). They are com-to calves for prophylaxis and treatment of enteric and

bined MLV of rotavirus and coronavirus and must be

pneumonic infections caused by E. coli, S. dublin, S.

given as soon as possible after birth. The suggestion

typhimurium and Pasteurella multocida.

that colostral antibody may interfere with these oral

Table 59.2

Neonatal calf diarrhoea vaccines available in the UK, 2003.

Vaccine

Manufacturer

Type of vaccine

Dosage and

Vaccination

Duration of

administration

programme

immunity

Lactovac

Intervet

Inactivated strains bovine

5 ml sc

2 doses 4–5 weeks

Single annual booster

rotavirus (str 1005/78 and

apart to pregnant cows

given 2–6 weeks

Holland), bovine coronavirus

and heifers, 2nd dose

before calving

(str 800)

2–3 weeks before

E. coli K99 and F41

calving

Rotavec K99

Schering-

Inactivated strains bovine

1 ml sc in neck

Single injection 12–4

Single annual booster

Plough

rotavirus, E. coli K99

weeks before calving

Rotavec

Schering-

Inactivated strains bovine

2 ml im in neck

Single injection 12–3

Single annual booster

Corona

Plough

rotavirus (str UK –

weeks before calving

Compton) serotype G6P5

bovine coronavirus

(str Mebus)

E. coli F5 (K99)

Trivacton 6

Merial

Inactivated strains bovine

5 ml sc

2 doses to pregnant

No data but suggested

rotavirus, bovine coronavirus

cows and heifers, 1st

annual single dose

E. coli – enterotoxogenic

dose 4–8 weeks

booster given 2 weeks

(ETEC) strains K99,

precalving, 2nd dose

before calving

F17 (= Y), F41

2–4 weeks later – at

– septicaemic strain 31A

least 2 weeks before

calving

All these vaccines depend upon the calf receiving passive immunization from the cow via the colostrum – adequate colostrum must be fed for at least 10–14 days.

im, intramuscular; sc, subcutaneous.

vaccines has cast doubt on their effectiveness. The in

Following these primary pathogens, damaged lungs

utero vaccination of the fetus has been achieved exper-are invaded by secondary bacterial pathogens of which

imentally with some success, but this is not a practical

the principal organism is Mannheimia haemolytica

method at present.

(formerly Pasteurella haemolytica) which causes severe Serovaccines containing

mixed antisera to E. coli,

lung damage, pneumonia and even death. Further bac-

Salmonella dublin and Salmonella typhimurium used to terial involvement follows, usually Pasteurella multo-be available and details of their use can be found under

cida and Arcanobacterium (Actinomyces) pyogenes, salmonellosis in the first edition of Bovine Medicine.

resulting in chronic lung pathology.

BRD can be controlled by the strategic use of vac-

cines. There are many and those that are available in

Respiratory disease

the UK are summarized in Table 59.3. Often the use of

one or two vaccines is sufficient to control the disease.

***Bovine respiratory disease complex** (see*

Chapter 17)

PI3 and IBR

Bovine respiratory disease complex (BRD) is a multi-

There are individual live vaccines available against PI3

factorial disease which can be summarized as follows.

and IBR. These are freeze-dried preparations which are

The disease complex is triggered by various stresses

administered intranasally. The calf is held with its head *such as transport, housing, the weather, general cattle*

inclined and the 2 ml reconstituted dose is instilled into

handling or by immunosuppression by bovine virus

one nostril. A short time is allowed for the vaccine to

diarrhoea virus (BVDV). These stresses lead to infec-

flow into the upper respiratory tract where it stimulates

tion by primary pathogens which cause lung damage

the development of local immunity (IgG) in the upper

and disease. These primary pathogens are bovine res-

respiratory mucosa. These vaccines are temperature

piratory syncytial virus (BRSV), parainfluenza-3 virus

specific and will not replicate at the high temperatures

(PI3), infectious bovine rhinotracheitis virus (IBR) or

of the inner tissues. The live PI3 vaccine can be used in

Mycoplasma bovis.

the face of an outbreak as a therapeutic agent.

Table 59.3

Vaccines against BRD complex available in the UK, 2002.

Name of

Company

Type of

Method of

Vaccination

Comment

Duration

vaccine

vaccine

administration

programme

of immunity

Bayovac

Bayer

Live IBR marker (gE

in

Calves from 2 weeks

Intranasal dosage Booster every

IBR-Marker

negative)

im

of age 2 doses 3–5

if specific local

6 months

Vivum

weeks apart

protection needed

(1 ¥ in, 1 ¥ im) in

acute

infections

Calves from 3 months

For use in herds

of age 2 doses 3–5

with uncertain

weeks apart (2 ¥ im)

infection status

and new reactors

Bayovac

Bayer

Inactivated IBR

sc

Cattle from 3 months

For use in non-

Booster every

IBR-

marker (gE

of age 2 doses 3–5

infected herds

6 months

Marker

negative)

weeks apart

Inactivatum

Bovilis

Intervet

Live avirulent strain

in (preferred)

From 4 weeks of age,

Full protection

Annual booster

IBR

of IBR virus

or im

2nd dose at 12 weeks

in 2 days (in), 7

or single dose from

days (im)

12 weeks

Bovilis

Intervet

Live avirulent strains

in

From 4 weeks 2nd

Annual booster

IBR and PI3

of IBR and PI3

dose at 12 weeks

or single dose from

12 weeks, special

situation for early

protection from 1 week

Bovilis

Intervet

Live IBR marker

in or im

From 2 weeks with

Booster every 6

IBR-Marker

(gE negative)

second dose at or

months

after 3 months, or single

dose given if over 3–4

months old

Bovipast

Intervet

Inactivated strain

sc

From 2 weeks of age

BRSV – 5

RSP

BRSV

2 doses separated

months

PI3

by 4 weeks

M. haemolytica

Mannheimia

6 weeks

haemolytica

serotype AI

Immuresp

Pfizer

Live PI3 virus strain

in

From 3 weeks with

RLB 103

second dose at 10

weeks or single dose

after 12 weeks,

special situation from

1 week

Immuresp

Pfizer

Live PI3 virus strain

in

From 3 weeks with

Animals may

RP

RLB 103 live IBR

second dose at 10

remain

virus strain RLB 106

weeks or single

seropositive to

dose after 12 weeks

IBR

Pastobov

Merial

Inactivated

im or sc

From 4 weeks with

Booster dose

adjuvanted

second dose 3–4

before each risk

Mannheimia

weeks later

period at least

haemolytica type AI

annually

Rispoval

Pfizer

Modified

im

From 7 days of age,

RS

live bovine

repeat doses at

respiratory

intervals of 3 weeks

syncytial

and then at 16 weeks

virus

or over 16 weeks with

second dose after 3

weeks

Table 59.3

Continued

Name of

Company

Type of

Method of

Vaccination

Comment

Duration

vaccine

vaccine

administration

programme

of immunity

Rispoval

Pfizer

Inactivated

im

Single dose from 12

Full protection in

4 Months

Pasteurella

adjuvanted

weeks of age

7 days

Mannheimia

haemolytica biotype

A serotype 1

Rispoval 4

Pfizer

Live strains of BRSV

im

From 3 weeks of age

Full protection in

and PI3 virus inactived

with 2nd dose 3 weeks

2 weeks

adjuvanted IBR

later and 3rd dose at

and BVD virus

12 weeks or from 12

weeks 2 doses 3–4

weeks apart

Tecvax

Vetoquinol Inactivated

im

From 4 weeks, 2

6 Months

Pasteurella

Mannheimia

doses separated by 3

1/6

haemolytica

weeks, vaccination of

serotypes

pregnant or lactating

A1 and A6

animals is not

recommended

Torvac

Vericore

inactivated

sc

Calves under 9 weeks

ajuvanted

3 doses at 3 week

BRSV

intervals

Calves over 9 weeks 2

doses 3 weeks apart

Tracherine

Pfizer

Live IBR virus

in

From 3 weeks with

Annual booster

strain RLB106

2nd dose at 10–12

weeks or single dose

after 12 weeks

Grovax

Intervet

Polyvalent

sc

Calves from 1–2 days

serovaccine

old or on arrival also

containing

weaner calves

serotypes of E.

Pregnant cows, dosages

coli, Salmonella

repeated at 10-14 days

dublin, Salmonella

or 14 days before

typhimurium

calving, provides active

Pasteurella

and passive immunity,

multocida (Roberts)

increase dose to

type 1, 2, 3 and 4)

debilitated or infected

calves

in, intranasal; im, intramuscular; sc, subcutaneous.

Bovine respiratory syncytial virus (BRSV)

transit or shipping fever . M. haemolytica is a common

and Mannheimia haemolytica

commensal of the pharynx of normal calves. Stress

and viral infection lead to the invasion of the lung by

There are both live and attenuated vaccines available

this organism. Multiplication of the organism causes the

against BRSV.

release of leucotoxin which lyses responding leucocytes

Mannheimia haemolytica types A1 and A6 are the

with the corresponding release of toxic cytoplasmic

principal secondary invaders of damaged lung and also

proteins which cause further lung damage. There are

the most frequently isolated organisms from cases of

vaccines available against M. haemolytica. They are

vivum

form 2 weeks of age im (from 3 months of age in or im)

(live vaccine)

in

3–5 weeks

6 months

6 months

im

apart

inactivatum

form 3 months of age

(killed vacc)

sc

3–5 weeks

6 months

6 months

apart

INITIAL

BOOSTER VACCINATION

Fig. 59.1

The vaccination schedule

IMMUNISATION

EVERY 6 MONTHS

with IBR marker vaccines.

inactivated, can be used at various ages and produce

The vaccine is based on a glycoprotein E (gE) deleted

immunity of varying duration. They are all effective.

herpesvirus 1 strain. A killed virus as well as a modified

Combined and multifactorial vaccines are also pro-
live virus marker vaccine have been developed; this
duced. The live vaccines for PI3 and IBR are combined.
enables differentiation between immunized and BHV-
These are very useful and can be used in conjunction
1 infected cattle. The vaccine is based on the principle
with the live BRSV vaccine to give a more complete
that animals do not form antibodies to the deleted gly-
cover. From Table 59.3 it can be seen that there are
coprotein whilst animals infected with the field strain
several multifactorial vaccines available. From the
do produce antibodies to gE. By using a gE antibody
author's experience these are all very effective and a
ELISA test, animals can be distinguished by testing
vaccination programme can be produced to cover most
serum or milk. This marker vaccine and the serological
on-farm situations. It is important to be sure that full
diagnostic kit can be used to eradicate IBR both on
protection is in place before the period of stress or risk;
farms and nationally.
for example, before the housing of spring born suckler

There are four steps to establishing an IBR-free herd:

calves and their dams in the autumn in the UK.

(1)

Determine the status quo – all animals are tested

using gE-ELISA to ascertain the serological status

Infectious bovine rhinotracheitis *(see p. 289)*

of the herd.

(2)

Immunization – all animals are vaccinated with the

Infectious bovine rhinotracheitis (IBR) is caused by

marker vaccine and so given protection against

bovine herpesvirus 1 (BHV-1) and is responsible for

clinical signs (Fig. 59.1). Where there is an acute

enormous economic loss in worldwide cattle produc-

risk of infection the live vaccine should be used.

tion.

BHV-1 is responsible for various clinical

(3)

Stabilization – natural wastage steadily reduces

syndromes:

the number of 'field virus' infected animals in the

• Infectious bovine rhinotracheitis (IBR)

herd. The natural herd replacements are ‘field

• Infectious pustular vulvovaginitis (IPV)

virus’ free.

• Infectious balanoposthitis (IBP)

(4)

IBR freedom – once the last serological positive

• Abortion

animals leave the herd, the herd is IBR negative

• Conjunctivitis and keratoconjunctivitis

but protected by the vaccine.

• Meningo-encephalitis (now classified BHV-5)

• Enteritis

• Dermatitis

Haemophilus somnus infection

Vaccines against IBR have been available for some

(see pp. 240, 737, 907)

years and are listed in Table 59.3. Whilst they are useful

for the protection of all ages of cattle, they will not

Haemophilus somnus is considered by many to be the

protect cattle incubating the disease and animals may aetiological agent of Haemophilus septicaemia in cattle.

remain seropositive after vaccination. The latter point

The disease is recognized in the USA and also in the UK

is important when the animal's disease status needs to

and Europe. A vaccine is available in America. It is a

be considered in the future, for example with the export

killed bacterin containing whole bacteria adhered on to

of animals or in cattle health schemes.

an aluminium hydroxide adjuvant. It is administered by

The recent development of IBR-Marker vaccine is a

subcutaneous injection and two doses are given at a two

real step forward in the control and eradication IBR.

to three week interval. Immunity is not long-lasting.

Various vaccination programmes have been tried in

least eight weeks old when dosed and a second dose is

feedlot conditions and their efficacy is difficult to evalu-

given four weeks after the first. Calves should not be

ate. Some success is claimed for protection in the face of

exposed to any potential source of lungworm infection

an outbreak. No claims are made on the efficacy of the *for at least two weeks after the second dose. During*

vaccine in the reproductive form of the disease.

the following grazing season exposure to lungworm

infection reinforces this initial immunity. Vaccinated

stock should not be grazed with unvaccinated animals

Contagious bovine pleuropneumonia

or follow behind unvaccinated stock in a grazing system

(see p. 868)

since any increase in pasture lungworm burden

may cause a vaccine breakdown. Only healthy calves

Contagious bovine pleuropneumonia (CBPP) is a

should be vaccinated. Careful consideration should be

highly infectious disease causing septicaemia with local-

given to calves suffering from any respiratory disease

ization in the lungs and pleura. It is common in many

before dosing. It is advisable not to use any other live

countries of the world. Control by vaccination is possi-

vaccine for a period of two weeks either side of

ble and several vaccines are available. They are all live

vaccination.

vaccines and are considered by some people to be

The use of anthelmintics should be avoided for at

responsible for some spread of the disease. The vaccines

least two weeks after the second dose, particularly the

(p. 873) available include the following:

use of sustained-release boluses. Similarly, the use of

• Pleural exudate from natural cases. This is not a

any avermectin must be avoided for eight weeks before

satisfactory vaccine since it can cause severe reac-

and ten days after the dosing regimen is complete. The

tion and spreads natural disease.

routine use of other anthelmintics and parasiticides

• Vaccines produced from culturing the organism

must also be avoided for seven days before and at least

Mycoplasma mycoides var. mycoides.

ten days after treatment. This is due to the residual

• Vaccines produced by attenuating the organism in

effects of modern anthelmintics.

avian egg cultures.

Following vaccination it is not uncommon for there

to be transient periods of coughing; this occurs after

Administration

some seven to ten days. Indeed on rare occasions
vaccination can initiate an outbreak of calf pneumonia
Vaccination in the tail is the route of administration
by activating latent infection (see p. 239).
using a high pressure syringe. Severe reactions can
It has been suggested that where ivermectin is used
occur in the tail, both generalized and localized.
to control lungworm and gastrointestinal worms in a
Intranasal vaccination is now being developed with
control programme then cattle may enter the second
some satisfactory results. Antimycoplasmal drugs
grazing year with no immunity to lungworm. In this
should not be used during vaccination as they will pos-
case vaccination against lungworm may be carried out
sibly reduce the immune response. However, if the side-
before the second grazing season. This is a suggestion
effects are very severe then treatment may be essential.
only as, at present, no trial work on this has been carried
The immunity to the vaccine varies from six to ten
out.
months for some of the cultured broth vaccines to three

to four years for the avian egg attenuated vaccines. All

vaccines against CBPP are light susceptible and should

Bovine virus diarrhoea *(see pp. 579, 853)*

therefore be stored in the dark.

Bovine virus diarrhoea virus (BVDV) is widespread

Parasitic bronchitis

throughout the UK. At the present time there are two

(see p. 272)

vaccines available (see Table 59.4), both containing

inactivated strains of BVD virus, and one combined

There is a very successful oral vaccine available. It is a

vaccine where inactivated BVDV is combined with

live vaccine consisting of an aqueous suspension of

IBR, PI3 and BRSV (see Respiratory disease on

third-stage infective larvae of Dictyocaulus viviparus

p. 1007).

partially inactivated by exposure to ionizing radiation.

BVDV is endemic in the UK and in many if not most

Each dose contains at least 1000 irradiated larvae (see

countries of the world. The arrival of the inactivated

p. 274).

BVDV vaccines has allowed the development of control

programmes. The BVDV status can be established by

Administration

the ELISA testing of bulk milk or blood samples and

Each dose comes in a bottle that should be shaken well

the results of these tests can direct the control/vaccina-

and the contents then given orally. Calves should be at

tion strategy. Table 59.5 shows the interpretation of bulk

Table 59.4

Bovine virus diarrhoea vaccines available in the UK, 2003.

Vaccine

Company

Type of vaccine

Route of

Vaccination programme

Duration of immunity

administration

Bovidec

Vericore

Inactivated non-

sc

Two doses 3 weeks apart, to

14 Months – booster

cytopathic strain

protect the fetus the vaccination

vaccination

of BVDV

programme should start in the 3

recommended annually

months prior to service and be

completed 1 week before service

Bovilis

intervet

Inactivated cytopathogenic

im

From 8 months of age 2 doses

Annual

BVD

BVD virus strain C86

4 weeks apart; fetal protection

if primary inoculation is at least 4

weeks before gestation

Rispoval 4 Pfizer

See Table 59.3

im, intramuscular; sc, subcutaneous.

Table 59.5

Interpretation of bulk milk BVDV serology and appropriate action. (After Pritchard, 1998.) ***Category***

OD ratio

Approximate %

Interpretation

Action

seropositive

Negative

<0.10

<5

Naive

Maintain high level of herd biosecurity;

test all new arrivals in herd; monitor herd

every 3 months; vaccinate if biosecurity poor

Low positive

0.10–0.35

<25

Basically naive; few

As above; test pooled samples from 1st and

older animals immune

2nd calved cows; if naive, vaccinate them

Mid positive

0.35–0.70

25–65

Some naive animals

(probably youngest half

of herd); some immune

animals (probably older

cows)

Positive

>0.70

>65

Likelihood of PI animals

Check for active Infection by checking each

increases with increase

age group; bulling heifers using paired

in OD ratio

serology of 6 animals; 1st, 2nd, 3rd calvers

using pooled milk samples; vaccinate

whole herd if active infection found

OD, optical density.

milk serology and possible action to be taken. Serology

Johne's disease *(see p. 857)*

in BVD-positive herds (suckler or dairy) interpretation

and action are given in Table 59.6.

Vaccines are available for the control of the disease. Two

In all circumstances if herd biosecurity is poor con-

vaccines are commonly available: the Vallee vaccine,

sider vaccinating the whole herd. After several years of

which contains live Mycobacterium paratuberculosis

vaccination the older cows, some of which would be

organisms in a paraffin oil/pumice stone vehicle, and the

persistently infected, will have left the herd and the

Sigurdsson killed vaccine. In the UK the only vaccine

temptation would be to stop vaccinating. If this happens

available contains live non-pathogenic strains of

the herd soon becomes naive and unprotected. Under

Mycobacterium avium subsp. paratuberculosis. This these conditions there must *be complete confidence in*

vaccine is only available from the Veterinary Laborato-

the biosecurity of the herd or regular booster vaccina-

ries Agency in Weybridge. The vaccine causes inter-

tion must continue. In Europe and the USA live vac-

ference in the interpretation of the tuberculin test. It

cines, which have originated from strains of cytopathic

causes a positive reaction to tuberculin, particularly to

BVDV, are in use and there is evidence that these

the avian component. It obviously also causes a positive

vaccines can precipitate mucosal disease.

reaction to the Johne's intradermal test where it is used.

Table 59.6

Results of cohort serology in BVD positive herds. (After Pritchard, 1998.) ***9–18 m Heifers***

1st Lactation cows

2nd Lactation cows

Interpretation and action

All negative

All negative

Some or all positive

Active infection unlikely unless 1st lactation cows are recently calved; PI animals probably died or culled from herd; monitor 1st lactation cows – maintain biosecurity

All negative

Some or all positive

Most or all positive

Active infection (acute infection/PI animals in milking herd but no PI heifers):

(1) vaccinate heifers

(2) test milking herd for PI animals

Some or all positive

Most or all positive

Most positive

Active infection in herd, as above; PI animals present in heifers:

(1) screen heifers for PI animals

(2) test milking herd for PI animals

(3) vaccinate herd

PI, persistently infected.

The vaccine is given to calves under one month of

not cause severe side reactions, but then is not effective

age. It is given by subcutaneous injection, usually in the

in Zebu-type cattle.

dewlap. The dewlap is used as an injection site because

the vaccine usually produces a localized reaction;

indeed such a reaction should be looked for two weeks

Chicken embryo vaccine

after inoculation as it indicates that the vaccine has

A cheap, stable and safe vaccine that is unfortunately

'taken'. Johne's disease vaccine has a very short shelf

difficult to manufacture and produces variable degrees

life of 14 days.

of immunity.

***Rinderpest** (see Chapter 43d; pp. 707–10)*

Measles vaccine

Vaccination against this disease is common practice in

Measles, rinderpest and distemper are antigenically

areas where it is endemic. There are several good

related and human measles vaccine will produce good

vaccines available and in theory complete eradication immunity to rinderpest in all ages of cattle. It is espe-

is possible with a vaccination programme.

cially useful in very young calves, which can be vacci-

nated at an earlier age than with normal vaccines.

Tissue culture vaccine

Measles vaccine is not affected by the calf's colostral

immunity.

Attenuated vaccines manufactured from cell culture

have largely replaced other attenuated vaccines. They

are safe and effective and produce a long-lasting immu-

nity suitable for all cattle.

Brucellosis (see p. 580)

Abortion and infertility in cattle caused by Brucella

Goat-adapted vaccine

abortus can be very successfully controlled by

This is an attenuated vaccine that produces life-long

vaccination. There are two vaccines available, strain 19

immunity. It is useful for Zebu-type cattle. It is a fairly

(S19) and strain 45/20 (45/20). Once eradication is in

virulent vaccine, which produces severe generalized

progress the use of either is limited or prohibited as it *reactions in susceptible stock. The signs seen are*

interferes with the interpretation of blood and milk

severe gastroenteritis with high temperatures and loss

antibody tests.

of milk.

Strain 19 vaccine

Rabbit-adapted vaccine

S19 is a live vaccine and is presented in freeze-dried

This vaccine produces a good immunity that lasts for

form, which is reconstituted with diluent immediately

two years. It can be attenuated to a point where it will

prior to use.

Dosage and administration

never reach conclusive levels. Brucellosis has been

eradicated from many countries by a programme of

The dosage is 5 ml given subcutaneously. It can be given

initial vaccination followed some years later by sero-

to any age of stock from two months of age onwards.

logical screening.

The ideal time is in calves from two to six months of *age; at this time it confers a good immunity for approximately seven years.*

Louping-ill *(see p. 770)*

Inoculation of adult cattle is very successful in controlling severe outbreaks of abortion. In an infected

A vaccine is available for use in cattle in tick-infested

herd the incidence of abortion will begin to subside

areas where louping-ill is a problem. It is an inactivated

40–60 days after vaccination and most herds will be free

tissue culture vaccine prepared from the arbovirus and

of infection within two years.

is a thick oily emulsion.

Bulls should not be vaccinated with S19; it does not seem to protect them from infection and has been known to be responsible for the development of an

Dosage and administration

orchitis with Brucella abortus S19 present in the semen.

A dose of 2 ml is given subcutaneously. Because of the thickness of the vaccine, prewarming can facilitate its

Side-effects

use. This prewarming must not exceed 37°C for 30 *minutes because the vaccine is heat labile. Initially, two*

Vaccination reactions: Localized swellings at the site of inoculations are given, not less than three weeks and

injection can occur, especially in adult cattle. These

not more than six months apart, with annual boosters.

reactions are sterile, do not rupture and persist for

The initial course should be completed at least two

many months as fibrous nodules. Generalized systemic

weeks before exposure and in pregnant cows before the

reactions can also occur with high temperatures and

last month of pregnancy.

loss of milk in lactating cows. Heavily pregnant cows

Accidental injection of the vaccine into the operator

have been known to abort and should not be vacci-

can cause severe localized reactions and immediate

nated. Idiopathic gonitis (see p. 458) may be caused by

medical attention should be sought. The oily vehicle can

vaccination.

sometimes cause localized vaccination reactions in

animals, which may persist for some time.

Serological reactions: Following vaccination the sero-

logical titres can remain very high for a long period of

time and therefore they can interfere with the inter-

Papillomatosis (warts) *(see p. 883)*

pretation of serological testing in an eradication

programme. The complement fixation test becomes

Autogenous vaccines can be prepared for the treatment

negative sooner than the serum agglutination test and

of warts in individual animals. In the author's opinion

can be used to identify a post vaccinal reaction from an

their efficacy is doubtful as warts have a tendency to

uninfected cow.

regress spontaneously. Individual vaccines can be pre-

pared by removing 5 g of the lesion from the animal,

Zoonotic risk: The vaccine is live and accidental injec-grinding it up and extracting the virus using glycerine.

tion into cattle handlers and veterinary surgeons can

After sterilization the autogenous vaccine is adminis-

cause severe illness (undulant fever) and so great care

tered to the affected animal in two doses, one month

must be taken when handling the vaccine.

apart.

Strain 45/20 vaccine

Erysipelas *(see p. 455)*

Strain 45/20 is a killed vaccine.

Erysipelas is a rare disease of cattle but has been

associated with clinical arthritis of calves and isolated

Dosage and administration

on post mortem from adults. In an outbreak of disease,

Two inoculations are given by subcutaneous injection

vaccination is possible using the available porcine

to animals over six months of age. There are often

vaccines. The vaccine is killed and produced from

large localized reactions at the site of injection.

cultures of Erysipelothrix insidiosa inactivated with Although said to be non-agglutinogenic there is usually

formalin and adsorbed on the aluminium hydroxide

a rise in serum titres, but these are such that they

gel.

Table 59.7

Vaccines against leptospirosis available in the UK.

Vaccine

Company

Type of

Route of

Vaccination programme

Duration of immunity

vaccine

administration

Leptavoid-H Schering-Plough

Formol killed

sc

For vaccination against

Annual; give booster before

L. interrogans

neck, chest

Leptospira interrogans

period of risk, maternal

serovar hardjo

wall

serovar hardjo, prajitno and

immunity interferes

Leptospira borgpetersenii

before 5 months so if very

serovar hardjo bovis; two

young calves are vaccinated

doses 4–6 weeks apart

the complete course must

completed before period

be repeated at 5 months

of risk; calves from

5 months old

Spirovac

Pfizer

Inactivated

sc

For vaccination against

Annual; give booster before

L.

neck

leptospirosis caused by

period of risk

borgpetersenii

Leptospira borgpetersenii

serovar hardjo

serovar hardjo bovis; 2 doses

4–6 weeks apart before

period of risk, calves from

4 weeks old

sc, subcutaneous.

Dosage

spring before turn-out. If it is necessary to vaccinate a

herd at other times of the year the first booster dose

A dose of 2 ml is given by subcutaneous injection. Two

should always be given the following spring and there-

doses are given, separated by two to six weeks. If

after repeated annually. Calves can be vaccinated, but

pregnant cows are vaccinated, with a second dose being

if they are less than five months old then a further initial

given three weeks before the expected calving date,

course must be given after five months as maternal anti-

then there is good passive immunity in the calves via

bodies may interfere with their immune response. All

the colostrum.

stock (including bulls) of unknown leptospiral immune *status which are brought into a vaccinated herd should*

Leptospirosis

be isolated, treated with antibiotics and vaccinated.

(see p. 735)

Antibiotics are used to remove leptospiral infection

from the kidneys. The recommended antibiotic is dihy-

Leptospira serotypes are found in all farm animals; they

drostreptomycin at a dosage rate of 25 mg/kg (not cur-

are distributed worldwide and are an important zoono-

rently available in the UK) or amoxycillin at a dosage

sis. In cattle the important species are Leptospira inter-

rate of 15 mg/kg of the long acting preparation. Ideally

rogans serovar hardjo (hardjo prajitno) and Leptospira the new stock should be kept isolated until seven days

borgpetersenii serovar hardjo (hardjo bovis) of which L.

after the second vaccination.

borgpetersenii serovar hardjo is the predominant strain.

It has been suggested that the two vaccines are not

It is only recently, using genetic typing techniques, that

compatible and it is not possible to predict what pro-

the strains previously classified as hardjo prajitno and tection will be afforded when there is a switch from one *hardjo bovis have been identified as separate species.*

to another. Cows can be vaccinated during an outbreak

They are both responsible for abortion and they have

to good effect; they are less likely to become infected

been identified as one cause of the milk drop syndrome

and shed organisms in their urine. The time for immu-

and can also be involved as a cause of infertility. In the

nity to develop and have its effect on the syndromes

UK there are two vaccines available, both are in-

associated with leptospirosis varies:

activated. These vaccines are summarized in Table 59.7.

When planning a vaccination programme ideally

• *The response with milk drop is rapid.*

cattle should be vaccinated before the period of great-

• *Abortions may continue for some months – as the*

est risk, which in the UK is when they are out at grass.

incubation period associated with leptospiral abor-

Cows in the UK should, therefore, be inoculated in the

tion is 3 months.

• *Infertility – once diagnosed as a cause of infertility* *clinical signs. It is best considered as an aid to the*

the herd should be vaccinated as soon as possible

control of coliform mastitis, but there will never be a

but it can be 12 months for the full effect to develop.

substitute for good dairy cow management. The cost-

benefit of its use has been assessed. Herd vaccination

Cattle that have been vaccinated may still be carriers of

has been shown to be profitable when more than 1 per

leptospires as a result of prevaccination infection and

cent of cows in the herd are affected with clinical col-

as such are still a zoonotic risk. They will also show

iform mastitis.

positive to diagnostic serology, which may be important

when cattle are to be exported or screened in a health

scheme.

Foot-and-mouth disease

(see Chapter 43c; pp. 700–707)

Mastitis

This is an acute and very contagious viral disease of

Coliform mastitis *(see pp. 334, 383)*

cloven footed animals. The aetiological agent of foot-

and-mouth disease (FMD) is a picornavirus of which

The development in the USA in the early 1990s of the

there are seven serotypes and very many subserotypes

E. coli J5 vaccine and its subsequent release in the UK

(>80). The three commonest serotypes are A, O and C,

in 2000 has been a great advance in the control of

whilst the others are SAT1, SAT2, SAT3 and Asia1.

coliform mastitis. The principle of the J5 vaccine is the

Vaccines are available and many cattle throughout the

mutation of E. coli 0111:B4. This strain lacks the O

world are vaccinated. All the vaccines are produced

antigen found in the outermost part of the cell wall and

from virus grown in tissue culture, on bovine tongue

so the core polysaccharide antigen is exposed. This core

epithelia or more commonly on baby hamster kidney

antigen is strongly immunogenic and is common to

cells. The virus is inactivated using formalin or other

many Gram-negative bacteria. The bacteria most often

agents and adjuvanted.

associated with coliform mastitis are Escherichia coli, A single dose gives immunity in 7 to 21 days; this is

Klebsiella species and Enterobacter aerogenes, but E.

followed by a booster after one month and then immu-

coli is predominant.

nity lasts from four to eight months. Young stock can

The vaccine is given by subcutaneous injection in the

be vaccinated from a very early age (<3 months).

neck and three doses are recommended (see Fig. 59.2).

However, if they come from vaccinated cows they

The first dose is given to cows at drying off and heifers

two months before calving. This is followed by a second

dose four weeks later and a third dose two weeks

after calving. The protection afforded by this regime

Table 59.8

The response to vaccination with J5. The trial

increases with each inoculation and is 10 per cent, 30–40

involved 460 cows in the first 90 days of lactation.

per cent and 60–80 per cent, respectively. Field studies

in the USA have demonstrated the value of this vaccine

Vaccinated J5

Non-vaccinated

(see Tables 59.8 and 59.9). In another trial involving 845

cows over one year after vaccination relatively similar

No. of cows

233

227

results were obtained (see Table 59.9).

No. of cows showing

6

29

The vaccine does not claim to totally prevent

clinical coliform

intramammary infection in the first 100 days of lacta-

mastitis

tion, but it does significantly reduce the severity of

Incidence (%)

2.57

12.77

DRYING OFF

CALVING

1st dose

2nd dose

3rd dose

Fig. 59.2

Vaccination schedule for J5

–2 months

–1 month

+2 weeks

Time

vaccine.

Table 59.9

The number of coliform cases in 845 cows over a

is considered to be sufficient for strategic vaccination

one-year period with or without use of the J5 vaccine.

purposes.

Vaccinated J5

Non-vaccinated

(placebo)

Disadvantages of vaccination

No. of cows

424

421

(1)

Current vaccines are sometimes not very effective.

No. of confirmed

16

45

A high challenge may overcome immunity and

cases of E.

there can be partial vaccination breakdown. This

coli mastitis

has occurred in Saudi Arabia where vaccinated

Incidence (%)

3.77

10.69

animals were found to have oral lesions.

(2)

Symptomless carriers can occur, especially where

the disease is very common.

(3)

It is difficult to distinguish the immune titre

should be revaccinated again at four and five months

derived from vaccination from that produced by

and possibly again at six months of age. This is due to *natural infection. It is possible, however, by meas-*

maternally derived colostral antibody.

uring non-structural protein antibody which is

The vaccines are usually marketed as monovalent

produced in greater amounts following infection,

vaccines, for example type A or type O. Ideally, the

but this is not always reliable.

vaccine used should be homologous with the serotype

(4)

Vaccination only protects against FMD for a short

or strain of the virus found in an outbreak. In many

time (two to six months). The time varies with

cases, where a new virulent subserotype is isolated

different vaccines and with individual response.

the vaccine may be manufactured specifically from this

(5)

Repeated vaccination can lead to anaphylactic

locally isolated virus. In countries where more than

reactions in some cases, although the reported

one serotype causes disease then bi- and trivalent

incidence is low.

vaccines are used. Live vaccines are available but

(6)

On occasions following vaccination lesions similar

are not in common use since there is a narrow safety

to FMD may develop.

margin between loss of virulence and loss of

(7)

In an FMD-free country when vaccination is used

immunogenicity.

to control and eradicate the disease then the time

taken for international recognition of disease-free

Vaccination programmes

status is extended. There are agreed definitions for

the designation of FMD disease-free status. These

These need to be planned with specific local knowledge.

are laid down in Articles of the Office Interna-

In some countries adult stock are vaccinated annually

tional des Épizooties (OIE). Many countries with

and young stock every six months, whereas in others

endemic FMD have no alternative but to control

such as South America or Saudi Arabia all cattle are the disease by mass vaccination.

inoculated every four months or less.

Where an outbreak of FMD occurs within a disease-

free area a ring vaccination policy can be employed to

prevent the spread of infection – for example Holland

Ringworm (see pp. 878–80)

in 2001. Following a single dose of vaccine, immunity

will develop in 7 to 21 days, but if a high potency vaccine

A vaccine is available in Europe; it was originally devel-

is used immunity to aerosol challenge can develop

oped in Russia. It is a live attenuated strain (LTF-130)

within four days. This immunity would be short lived

of Trichophyton verrucosum, presented in a freeze-

but may be sufficient to control the disease for long

dried form. Calves as young as two weeks can be

enough to consider the next steps, which may be to give

vaccinated. The inoculation is given by intramuscular

a second dose of vaccine or to slaughter out all the ‘ring

injection; the neck is the recommended site and two

vaccinates’.

doses are required, 10–14 days apart. Initially the whole

Frontier vaccination can also be employed to prevent

herd should be vaccinated and then, in a closed herd,

transmission from one country or area to another. A

only the young calves need to be injected. All new

buffer zone is created between an infected and a non-

animals introduced to the herd should be given a full

infected area.

vaccination course. Once vaccinated, booster injections

In Europe, in January 2000, a European vaccine bank

are not required. Heavily pregnant cows (7 months +)

was established to hold stocks of FMD virus antigen.

should not be vaccinated. Occasionally a small crusty

Originally in three locations, but now in two, it holds in

lesion may develop at the site of injection. Cattle

stock five million doses of type O Manisa vaccine. This

infected with or exposed to ringworm should not be

vaccinated, as such animals can develop very severe

Vesicular stomatitis (see Chapter 43e; pp. 710–13)

signs of ringworm.

Vesicular stomatitis (VS) is endemic in Central and

South America and also occurs in the southern and

western states of the USA. Its importance really lies in

***Rabies** (see Chapter 70; p. 908)*

its confusion with FMD. Serologically there are two

principal strains, New Jersey (NJ) and Indiana (IND).

Rabies is an invariably fatal neurotrophic disease of all

Modified live virus and formalin-killed virus vaccines

warm-blooded animals. A vaccine is available, prepared

are available against VS-NJ. The dead vaccine reduces

from inactivated rabies virus adjuvanted with alu-

clinical disease whereas the live vaccine conveys better

minium phosphate. It is used in dogs, cats and horses as

immunity. Inactivated autogenous vaccines prepared

well as cattle. Vaccination is advised from six months of

from clinical outbreaks have also been used.

age. The primary dose is given by intramuscular injec-

tion and boosters are given annually. Calves can be

vaccinated from two months of age, but at this age a

booster at six months of age is recommended. Immu-

References and further reading

nity develops in 30 days. In cattle, treatment with rabies *vaccine after exposure to infection is not successful as*

Andrews, A.H. (2000) The Health of Dairy Cattle, pp. 1–359.

death usually intervenes before an effective immunity

Blackwell Science, Oxford.

develops.

Andrews, A.H. Blowey, R.W., Boyd, H. & Eddy, R.G. (1992)

Bovine Medicine, Diseases and Husbandry of Cattle, pp.

1–922. Blackwell Scientific Publications, Oxford.

Bishop, Y.M. (1996) The Veterinary Formulary, 3rd edn, pp.

Other vaccines

413–25. Royal Pharmaceutical Society of Great Britain and

British Veterinary Association, London.

Infectious bovine keratoconjunctivitis (see p. 921)

Blood, D.C. & Studdert, V.P. (1988) Bailliere's Comprehensive Veterinary Dictionary, pp. 1–1124. Ballière Tindall, London.

A vaccine against Moraxella bovis is available in some Brownlie, J. (1985) Clinical aspects of the bovine diarrhoea–

countries. It is made by exposing the pili of Moraxella

mucosal disease complex in cattle. In Practice, ***7****, 195–*

bovis to high frequency sound waves (sonification) and 202.

is used to give passive protection. It is not available in

Brownlie, J., Thompson, I. & Curwen, A. (2000) Bovine virus the UK.

diarrhoea virus – strategic decisions for diagnosis and

control. In Practice, ***22****, 176–87.*

Gonzalez, R.N. Cullor, J.S., Jasper, D.E., Farver, T.B., Bushnell, Bluetongue (see Chapter 43a; pp. 691–3)

R.B. & Oliver, M.N. (1989) Prevention of clinical coliform mastitis in dairy cows by a mutant Escherichia coli vaccine.

Modified live virus vaccines against bluetongue virus

Canadian Journal of Veterinary Research, ***53****, 301–305.*

are available in some countries. Ideally, the specific

Kahrs, R.F. (2001) Viral Diseases of Cattle, 2nd edn. Iowa State serotype vaccine should be used. The practice of using

University Press, Ames.

one serotype followed by a different serotype one

National Office for Animal Health (2001–2002) Compendium

month later is adopted and is more effective than using

of Data Sheets for Veterinary Products, pp. 1–866. NOAH, mixed vaccines. However, vaccination interferes with

Enfield.

diagnostic serology used in health schemes and for

Pritchard, G.C. (1998) Making the best use of bulk milk anti-

export purposes.

body tests. Cattle Practice, ***6****, 133–7.*

Radostits, O.M., Gay, C.C., Blood, D.C. & Hinchcliff, K.W.

(2000) Veterinary Medicine, 9th edn. pp. 1–1877. W.S.

Rift Valley fever (see pp. 769–70)

Saunders, London.

Rinehart, C.L., Lucas, M.J., Cornell, C.P., Rzepkowski,

This is a condition found only in Africa, where vaccines

R.A., Ho, C.H., Peñaredondo, C.C. & Simonson, R.R.

are available. One vaccine is prepared from neuro-

(1996) Efficacy against bovine mastitis using a J5

trophic virus passaged through mouse brain. It is known

Escherichia coli bacterin: Enviracor. In Proceedings of the to cause abortions. A killed vaccine is also available and

XIX World Buiatric Congress, Edinburgh, 8–12 July 1996, is said to produce good immunity.

Vol. 1, pp. 285–8.

Chapter 60

Antiparasitics

M.A. Taylor

Introduction

1019

recently introduced anthelmintics have a broad spec-

Endoparasiticides

1019

trum of activity against a wide range of target helminth

Anthelmintics

1019

parasites.

Classification of anthelmintics

1019

The external ectoparasites affecting cattle are pre-

Others (group 5)

1024

dominantly arthropods and include insects (flies and

Treatment of parasitic gastroenteritis in cattle

1025

lice) and arachnids (ticks and mites). Ectoparasitic

Treatment of parasitic bronchitis

1027

treatments (ectoparasiticides) can be classed as pesti-

Treatment of trematode infections in cattle

1028

Treatment of cestode infections in cattle

1028

cides, insecticides or acaricides according to their activ-

Antiprotozoals

1029

ity. The more recent introduction of the endectocide

Ectoparasiticides

1030

antiparasitics, which have activity against both endo-

Introduction

1030

and ectoparasites, has led to new approaches in the

Ectoparasiticide groups

1030

treatment and control of parasite infections.

Introduction

ENDOPARASITICIDES

The control of parasitic diseases in cattle, as with other

Anthelmintics

domestic animals, relies heavily on the use of antipara-

sitic drugs. A vast array of drugs has been developed

Anthelmintics are widely used in both the treatment

for their antiparasitic activity and these are often clas-

and prevention of internal parasite infections of cattle.

sified according to the target parasites they control. For

Their use has been documented from ancient times

the purposes of this chapter, parasites are classed as

when it was first recognized that certain disease condi-

either internal parasites (endoparasites) or those on the

tions were associated with parasitic helminth infections.

outer body, the skin, dermal tissues or hair (ectopara-

Up to 1938, before the discovery of phenothiazine, few

sites). Endoparasites include a wide and diverse range

useful drugs existed for the treatment of nematode and

of organisms from simple, single-celled protozoa

trematode infections of domestic animals. Since then,

through to large metazoan helminths.

and particularly over the last 30 years, considerable

Protozoan parasites are responsible for several major

advances have been made in the development of safer

economic diseases globally and are classified into

and more effective drugs. Modern, highly effective

several main groups, the most important of which are

anthelmintics with increased safety margins and ease of

the Sarcomastigophora (flagellates and amoebae) and

application have superseded the potentially toxic
Apicomplexa (coccidia). Protozoa are found in the
chemicals in use less than half a century ago. The intro-
blood, muscles, internal organs and the gastrointestinal
duction in 1961 of thiabendazole, the first of the
(GI) tract of cattle. Antiprotozoal agents are generally
benzimidazoles, saw the beginning of broad-spectrum
referred to by target parasites and include anticoccidi-
anthelmintic therapy that has since led to the develop-
als, trypanocides, theilericides, babesicides, etc.
ment of drugs with activity against GI nematodes, lung-
Helminths are divided into three main groups:
worms, tapeworms and liver fluke. The discovery of the
roundworms (nematodes), which parasitize the GI tract
avermectins in 1976 has led to the subsequent intro-
and lungs, the flukes (trematodes), which parasitize the
duction of a number of endectocidal compounds that
GI tract and liver, and the tapeworms (cestodes), which
has taken parasite therapy one step further.
parasitize the intestines as adult stages or the muscles
and viscera as larval forms. Drugs used in the treatment

of helminth infections are generally referred to as

Classification of anthelmintics

anthelmintics, although these can be further subdivided

into nematocides, flukicides or taenicides according to

On the basis of chemical structure and mode of action,

the target parasites they control. Some of the more

anthelmintics can be divided into several main groups

(Table 60.1). These include the broad-spectrum groups

mical compounds, with the exception of clorsulon

comprising the benzimidazoles (group 1), imidazothia-

(available in combination with ivermectin) which is a

zoles and tetrahydropyrimidines (group 2) and aver-

sulphonamide derivative. Flukicides may be formulated

mectins and milbemycins (group 3).

with a broad-spectrum anthelmintic to increase their

Broad-spectrum anthelmintics are highly effective

range of activity to include nematodes and flukes.

against the majority of nematode species reported in

cattle (Table 60.2). Some of the benzimidazoles may

Benzimidazoles and probenzimidazoles

also have activity against liver fluke (Fasciola hepatica) (group 1-BZ)

and cestodes (Moniezia spp.). Avermectins and milbe-

mycins (often collectively referred to as endectocides)

Most anthelmintics available for cattle belong to a

are active against both endoparasites (nematodes and

group of chemicals referred to as the benzimidazoles.

some larval insects) and certain ectoparasites (species

Since their appearance in the early 1960s, the benzimi-

of mites and lice) of cattle.

dazoles have been subjected to continuous structural

Narrow-spectrum anthelmintics are more specific in

modifications to improve their safety and spectrum of

their activity, and are available specifically for liver

activity. Thiabendazole was the first to be introduced

fluke, although individual compounds may also have

in 1961 and was followed by parbendazole (1967),

activity against some nematode species (Table 60.2).

oxibendazole (1973), fenbendazole (1974), oxfendazole

Anthelmintics in this group mainly belong to the

(1975), albendazole (1976), triclabendazole (1981) and

salicylanilide and substituted phenol groups of che-

ricobendazole [albendazole oxide] (1987). Three other

chemicals, febantel, netobimin and thiophanate, usually

referred to as probenzimidazoles, are also included in

this group because they are metabolized in the body by

Table 60.1

Broad-spectrum anthelmintic groups.

ruminal and hepatic pathways to active benzimidazole

metabolites. Netobimin is unusual because, as an ionic

Group 1

Benzimidazoles

1-BZ

Affect tubulin

salt, it shows good solubility in water, which offers flex-

Probenzimidazoles

polymerization

leading to cell

ibility for its administration. The benzimidazole group

starvation

is derived from substitution of various side chains and

Group 2

Imidazothiazoles

2-LM Act on

radicals on the parent benzimidazole nucleus, giving

Tetrahydropyrimidines

acetylcholine

rise to individual members of the group. Modification

receptors causing

of a particular benzimidazole can affect the pharmaco-

paralysis

kinetic behaviour of the drug through changes in rela-

Group 3

Avermectins

3-AV

Affect glutamate-

tive insolubility, slowing the elimination of the parent

Milbemycins

gated Cl- channels

drug and/or active metabolites (Fig. 60.1). The greater

and GABA

efficacy, and wider spectrum of activity, of the most

receptors causing

recently introduced (second-generation) benzimida-

paralysis

zoles appears to be due to the relative insolubility of

Table 60.2

Classification and activity of anthelmintics available for cattle.

Chemical group

Gut worms

Lungworms

Liver flukes

Tapeworms

Ectoparasites

Broad-spectrum

Benzimidazole and

+

+

±

±

-

probenzimidazole

Imidazothiazoles

+

+

-

-

-

Tetrahydropyrimidines

+

-

-

-

-

Avermectins/milbemycins

+

+

-

-

+

Narrow-spectrum

Salicylanilides and

±

-

+

±

±

substituted phenols

Diphenoxyalkyl ethers

-

-

+

-

-

Organophosphates

+

-

-

-

+

Chlorinated hydrocarbons

-

-

+

-

-

Piperazines

±

±

-

-

-

Others

-

-

-

+

-

clabendazole lacks activity against roundworms and

FEBANTEL

OXFENDAZOLE

(Fenbendazole sulphoxide)

tapeworms but is highly effective against immature and

adult liver fluke. All benzimidazoles and probenzimida-

zoles are ovicidal to nematode eggs. This group of chem-

FENBENDAZOLE

Fenbendazole sulphone

icals is amongst the least toxic of all the anthelmintics

available. However, several members of the group have

been found to be teratogenic in cattle (parbendazole,

NETOBIMIN

ALBENDAZOLE

oxfendazole, albendazole and netobimin) and therefore

Albendazole sulphoxide

Albendazole sulphone

have limitations on their use in pregnant animals.

RICOBENDAZOLE

Benzimidazoles are poorly soluble and are generally

given orally as a suspension or as an active ingredient

Fig. 60.1

In vivo metabolic pathways of the common benz-

imidazole and probenzimidazole anthelmintics in cattle.

in a bolus. Netobimin can be solubilized and adminis-

tered via drinking water. Fenbendazole can also be

incorporated into drinking water using specialized

these chemicals, which affects the absorption, transport,

metering equipment. Benzimidazoles have also been

passage along the GI tract and metabolism within
incorporated into a range of controlled release devices,
the host, and ultimately the final excretion of the
which will be discussed in more detail later (see section
anthelmintic compound from the host. The longer
on Anthelmintic delivery devices; p. 1026); these
the persistence in the animal body, the more effective
include pulse-release devices, containing oxfendazole,
the anthelmintic appears to be.
and several sustained-release devices available in
various countries that contain either fenbendazole or
Pharmacokinetics: Following oral drenching, benzimi-
albendazole.
dazole anthelmintics usually pass to the rumen which
acts as a reservoir, allowing gradual release and absorp-
Mode of action: All members of the benzimidazole
tion of the drug into the bloodstream. Thereafter, con-
(BDZ) class have a similar mode of action and act by
centrations of the principal circulatory metabolites can
disrupting energy metabolism in worms by binding to
be found in the plasma from where they are extensively

parasite tubulin, a constituent protein present in micro-
recycled between the circulation and the gut wall, along
tubules (MT) and in plasma and mitochondrial mem-
the whole length of the intestinal tract. Nematodes
branes. The formation of MT is a dynamic process
attached to the gut wall may be more exposed to the
involving the polymerization of tubulin rings at one end
recycled drug than to a drug present in the digested
(Fig. 60.2) and depolymerization at the other end. BDZ
food passing down the intestinal tract.

anthelmintics bind to b-tubulin causing capping and
Host physiological factors may affect the efficacy of
inhibition of further MT formation. The resultant effect
benzimidazoles administered orally. For example, the
is starvation of the parasite due to inhibition of glucose
oral administration of anthelmintic solutions may result
uptake, protein secretion and MT production. There is
in closure of the oesophageal groove in some animals,
also a reduction in enzyme activity such as acetyl-
with subsequent bypass of the rumen and delivery of
cholinesterase secretion and in carbohydrate catabo-

the anthelmintic to the abomasum. From here absorp-

lism by the fumarate reductase system.

tion, metabolism and excretion of the drug may be

The mode of action of triclabendazole on Fasciola

rapid, resulting in reduced exposure of the parasite to

hepatica is at present unknown. It appears to have

the drug and lowered efficacy. In some disease and

limited tubulin-binding properties, unlike other mem-

nutritional states, the pH of the abomasum may be

bers of this group, and it must therefore act along alter-

altered. This may not only reduce exposure of parasites

native pathways.

in the abomasum to some of the anthelmintics, but it

may also reduce solubilization of relatively insoluble

Imidazothiazoles (group 2-LM)

drugs and thus reduce absorption.

Benzimidazoles are highly effective against most of

The two anthelmintic drugs in this chemical group are

the GI nematodes of cattle. The range of activity

tetramisole and levamisole. Tetramisole is a racemic

of second-generation benzimidazoles available for mixture of dextro and levo forms; levamisole is the

cattle, notably albendazole, fenbendazole, netobimin,

levo-isomer and it is with this form that anthelmintic

oxfendazole and ricobendazole (albendazole oxide),

potency resides. The dose rate of levamisole is therefore

also includes arrested (hypobiotic) larvae of nematodes

half that of tetramisole, and it has twice the safety index.

such as Ostertagia and also lungworms and tapeworms.

Levamisole has good activity against a range of adult

Albendazole, netobimin and ricobendazole have activ-

and developing larval stages of GI nematodes of cattle,

ity against adult liver fluke at increased dose rates. Tri-

but not against arrested larvae. It is also highly

Tubulin

polymerization

Benzimidazoles prevent the

polymerization of b-tubulin to

microtubules leading to

cellular dysfunction, inhibition

of glucose uptake, glycogen

Fig. 60.2

Benzimidazoles – mode of

depletion and death

Benzimidazole

action.

effective against lungworms. Unlike the benzimidazoles

anthelmintic properties, levamisole has been shown to

it is not ovicidal. Levamisole is non-teratogenic and is

stimulate the mammalian immune system by increas-

therefore safe to use in pregnant animals. The thera-

ing cellular activity. The relationship between the

peutic index in relation to other anthelmintics is,

immunostimulatory and nematocidal properties of lev-

however, low. Animals given levamisole may be hyper-

amisole is unknown.

active for a few minutes after receiving the recom-

mended therapeutic dose. Toxic signs, due to a stimulant

Tetrahydropyrimidines (group 2-LM)

effect on nerve ganglia, may manifest as salivation,

bradycardia, muscular tremors and, in extreme cases,

Pyrantel and morantel are the only members of *death from respiratory failure. Injectable levamisole*

the tetrahydropyrimidine group available for cattle.

may cause inflammation at the site of injection.

Morantel, as its tartrate salt, is the more potent and the

Levamisole can be administered orally, by injection

most widely available in the form of a sustained-release

or pour-on, according to the formulation, and is active

bolus. Morantel has higher activity against adult gut

against GI worms and lungworms, but not against tape-

worms and luminal stages, but not against mucosal or

worms or liver fluke. A levamisole sustained-release

arrested stages or against established lungworm infec-

bolus is also available in certain countries. It is com-

tions. Like levamisole, it has no activity against tape-

bined in a number of products with a specific flukicide

worms and flukes. Neither morantel nor pyrantel are

(oxyclozanide or triclabendazole) to form a broad-

particularly toxic and can be used safely in pregnant

spectrum drench for worms and fluke.

and young animals.

Pharmacokinetics: Levamisole is rapidly absorbed and

Pharmacokinetics and mode of action: The pharmaco-

excreted, most of the dose being lost from the system

kinetics and mode of action of this group of chemicals

within 24 hours of administration. Because of the mode

are similar to those of levamisole. They act as nerve gan-

of action of these compounds nematode paralysis

glion stimulants, causing a spastic reversible paralysis of

occurs quickly and removal of the worms is rapid.

the worms that results in rapid expulsion from the host.

Unlike the benzimidazoles it is therefore not as essen-

tial to maintain high drug levels over a protracted

Macrocyclic lactones: the avermectins and

period.

milbemycins (group 3)

Mode of action: Levamisole appears to act as a selec-

Avermectins, and the structurally related milbemycins,

tive agonist, mimicking the action of acetylcholine

are macrocyclic fermentation products of Streptomyces

(Ach), and affecting transmission of nerve impulses at

avermilitis and Streptomyces cyanogriseus, respectively.

synaptic and extrasynaptic nicotinic Ach receptors on

Avermectins differ from each other chemically in side

nematode muscle cells, causing a rapid, reversible

chain substitutions on the lactone ring, whilst milbe-

spastic paralysis (Fig. 60.3). Paralysed worms are

mycins differ from the avermectins through the absence

expelled by normal gut peristalsis. At high concentra-

of a sugar moiety from the lactone skeleton. The aver-

tions, it has also been shown to affect nematode metab-

mectins include abamectin, doramectin, eprinomectin

olism by inhibition of the fumarate reductase system.

and ivermectin, and are active against a wide range of

The extent to which this contributes to overall

nematodes and arthropods. Moxidectin is a milbemycin

anthelmintic efficacy is unknown. In addition to its

and has a similar wide ranging activity.

Nicotinic acetylcholine (Ach)

Presynaptic neuron

neuromuscular synapse in

nematode muscle cell

Release of Ach causes depolarisation

of the post-synaptic membrane

leading to influx of Na+ and muscle

Imidazothiazoles mimic the

contraction. Ach is removed by the

Ach

action of Ach causing an

action of acetylcholinesterase

Ach receptor

open channel block and

allowing membrane repolarisation

Na+

depolarisation of the post-

Acetylcholinesterase

synaptic membrane leading

to (reversible) paralysis

Fig. 60.3

Mode of action of imidazothia-

Postsynaptic neuron

zoles.

With the exception of eprinomectin, which is only

Injectable and pour-on preparations provide protec-

available as a pour-on formulation, these groups

tion of 7–42 days for lungworms and 7–35 days for

of drugs are available as both injectable and pour-

stomach worms, depending on the product and formu-

on preparations for cattle. Drench formulations of

lation. The ivermectin bolus provides protection against

abamectin, and a sustained-release device containing

GI worms and lungworms for up to 135 days following

ivermectin, are also available for cattle in some

administration. The prolonged half-life of these com-

countries. As well as being effective against adult and

pounds also determines levels of residues in meat and

larval GI roundworms (including arrested Ostertagia

milk, and subsequent compulsory withdrawal periods

ostertagi) and lungworms, most have activity against

following treatment. For meat these may vary between

other helminths of cattle such as the eyeworm,

14 and 42 days according to the product and method of

Thelazia rhodesii, and the filarial parasite, Parafilaria administration. With the exception of eprinomectin,

bovicola. None of these compounds has activity against which has a zero milk withdrawal period, treatment tapeworms or liver fluke, although ivermectin is avail-

with this class of compounds cannot be given to

able in combination with the flukicide clorsulon to

lactating cows, or during the last two months of

broaden the spectrum of activity. Ectoparasite activity

pregnancy.

includes warbles (Hypoderma spp.), sucking lice

(Haematopinus, Linognathus, Solenopotes spp.) and Mode of action: The mode of action of the avermectins

mange mites (Psoroptes, Sarcoptes, Chorioptes). More has been studied but has still not been completely elu-detailed information on the efficacy of the endectocides

cidated. Ivermectin is known to act on g-aminobutyric

against ectoparasites is provided in the section on

acid (GABA) neurotransmission at two or more sites

ectoparasiticides (see p. 1030).

in nematodes, blocking interneuronal stimulation of

excitatory motor neurones and thus leading to a flaccid

Pharmacokinetics: Avermectins and milbemycins are

paralysis (Fig. 60.4). It appears to achieve this by stim-

highly lipophilic and, following administration, are

ulating the release of GABA from nerve endings and *stored in fat tissue from where they are slowly released,*

metabolized and excreted. Ivermectin is absorbed

systemically following oral, subcutaneous or dermal

administration, but is absorbed to a greater degree, and

Presynaptic neuron

has a longer half-life, when given subcutaneously or

These compounds act on

glutamate-gated chloride

dermally. A temporary depot appears to occur in the fat

ion channels on post-

and liver, from which there is a slow release. Excretion,

synaptic membrane of

of the unaltered molecule, is mainly via the faeces, with

inhibitory neurones

less than 2 per cent excreted in the urine. The reduced

Glutamate

or neuromuscular end plate

GABA

absorption and bioavailability of ivermectin when given

Cl–

GABA receptor

Glutamate receptor

orally in cattle may be due to its metabolism in the

rumen. The affinity of these compounds to fat explains

their persistence in the body and the extended periods

of protection afforded against lungworms and stomach

worms. Individual variances in these periods of protec-

Postsynaptic neuron

tion reflect differences in drug distribution, metabolism

and excretion.

Fig. 60.4

Mode of action of avermectins/milbemycins.

enhancing the binding of GABA to its receptor on

Mode of action: Salicylanilides and substituted phenols the postsynaptic membrane of an excitatory motor

uncouple oxidative phosphorylation and therefore

neurone. The enhanced GABA binding results in an

decrease the availability of high-energy phosphate

increased flow of Cl- ions into the cell, leading to hyper-

compounds such as adenosine triphosphate (ATP) and

polarization. In mammals, GABA neurotransmission *reduced nicotinamide-adenine-dinucleotide (NADH-)*

is confined to the central nervous system; the lack of

in the mitochondria. They have also been shown to

effect of avermectin on the mammalian nervous system

inhibit succinate dehydrogenase activity and the

at therapeutic concentrations is probably because,

fumarate reductase system, which is associated with

being a large molecule, it does not readily cross the

oxidative phosphorylation. Because of the long half-life

blood–brain barrier. More recent evidence suggests

of the plasma protein-bound molecules, the parasites

that ivermectin may exert its effect through action on

experience prolonged exposure to the drugs which

glutamate-gated Cl- ion conductance at the postsynap-

reduces the energy available to the parasites. Plasma

tic membrane or neuromuscular end plate.

binding reduces incorporation of the drugs into host

tissues and accounts for the selective parasite toxicity.

Looseness of faeces and slight loss of appetite may be

Salicylanilides and substituted phenols (group 4)

seen in some animals after treatment at recommended

With the exception of niclosamide, the salicylanilides

dose rates. High doses may cause blindness and signs of

and substituted phenols are usually marketed as

uncoupled oxidative phosphorylation, i.e. hyperventila-

flukicides, being highly effective against adult and, to a

tion, hyperthermia, convulsions, tachycardia and ulti-

lesser extent, immature F. hepatica. Some also possess mately death.

activity against blood-sucking nematodes such as

Haemonchus. Most drugs in this group are given orally

to cattle, although nitroxynil is usually given by subcu-

taneous injection.

Others (group 5)

The salicylanilides,

substituted phenols and

Piperazines

bisphenols can be regarded as close analogues and

include the bromsalans, clioxanide, oxyclozanide, bro-

Diethylcarbamazine is still marketed in certain parts of

tianide, rafoxanide and closantel (salicylanilides),

the world, for the treatment of lungworm infections

nitroxynil (substituted phenol) and bithionol, hexa-

in cattle. It is primarily active against immature
chlorophene, niclofolan (bisphenols).
Niclosamide
lungworms and because it has to be given over a period
(salicylanilide) is highly effective against tapeworms
of three days to achieve its effect, more modern
and possibly against immature paramphistomes.
anthelmintics such as the benzimidazoles, levamisole
and the avermectins/milbemycins have tended to
Pharmacokinetics: Salicylanilides and substituted
replace it. It is also active against microfilariae, the
phenols appear to be extensively bound to plasma
mode of action being incompletely understood, but it is
proteins (>99 per cent), which may explain their high
thought to enhance phagocytosis of the microfilariae by
efficacy against blood-feeding parasites. Fasciolicidal
the host immune system. The action of diethylcarba-
activity is dependent on the extent to which these drugs
mazine on immature lungworm larvae is thought to be
persist in the plasma. Rafoxanide and closantel have
a flaccid paralysis due to hyperpolarization of neuronal

long plasma half-lives when compared with oxy-

postsynaptic membranes resulting from an increased

clozanide. Evidence suggests that the apparent efficacy

flow of Cl- ions into the cell. This mode of action, similar

of these drugs, particularly against immature F.

to the GABA agonist action of piperazine, is probably

hepatica, may be due more to their persistence in the

unrelated to its antifilarial action.

plasma and the effect they have on maturing adult flukes

when they reach the bile ducts, rather than the effect

Organophosphates

they have on the immature stages themselves. Young

flukes probably ingest mainly liver cells, which contain

Several organophosphorus compounds have been mar-

little anthelmintic. As they grow and migrate through

keted for use in cattle and are still available in a limited

the liver they cause extensive haemorrhage and come

number of countries for the treatment of GI nematode

into contact with anthelmintic. Finally, when the flukes

infections. Haloxon and metriphonate are usually effec-

reach the bile ducts they are in contact with even greater *tive against the adults of some species of GI nematodes,*

concentrations of anthelmintic as the bile ducts are

but not against arrested larvae and lungworms. The

important in the excretion of these compounds, as evi-

mode of action of the organophosphates is discussed in

denced by the high proportion of these, and their

greater detail in the section on ectoparasiticides (see p.

metabolites, excreted in the faeces rather than the urine.

1032).

Clorsulon

Strategies for controlling helminth infections

of cattle (see p. 271 onwards)

The sulphonamide clorsulon is available as an

injectable solution for cattle and is highly effective

Strategies for the control of parasitic GI nematode

against both adult and immature liver flukes over eight

infections of cattle are generally targeted at the first

weeks of age. It has been shown to inhibit the glycolytic

year grazing animal, although increasingly control

enzyme phosphoglyceromutase in F. hepatica by *measures are being applied to cattle in their second*

competition with 3-phosphoglycerate and 2,3-

grazing season. Currently employed control strategies

diphosphoglycerate, leading to a gradual suppression of

are based on detailed epidemiological studies con-

motility and paralysis.

ducted over several decades. Calves can either be dosed

at the onset of disease or used preventatively in the

Praziquantel

early part of the grazing season, as a means of limiting

pasture contamination and subsequent exposure to

Praziquantel is a quinoline-pyrazine compound and is

infective larvae later in the season. This approach is

a highly effective cestodicidal and trematocidal drug for

particularly used in temperate climates where there is

use in both human and veterinary medicine. The drug

a fairly predictable cyclical appearance of GI nematode

appears to modulate cell membrane permeability,

species on the herbage throughout the year. The major

leading to both spastic muscle contraction and disinte-

disadvantage of strategic single-dose treatments is *gration of the parasite tegument. Praziquantel is active*

the labour costs involved in gathering and handling

against larval cestodes and schistosomes found in cattle,

the cattle. As such, the advent of novel methods of

but the high dosage required is probably uneconomic

presentation of anthelmintics and those with greater

in these infections.

persistence in the body has meant that strategic

control of PGE in calves can be achieved with the

Treatment of parasitic gastroenteritis in

minimal handling of stock. The use of pour-on prepa-

cattle *(see pp. 267–72)*

rations, for example, is convenient, less traumatic to

both animal and handler and is gaining widespread

The activities of the available anthelmintics have been

acceptance. The most important development over

described under their respective anthelmintic groups

recent years, and for the foreseeable future, has been

and are summarized in Tables 60.2 and 60.3. All are

the introduction of controlled-release devices which

highly effective against adult and developing larval *deliver anthelmintic at targeted times throughout the*

stages of the common GI nematodes. When selecting an

grazing season.

anthelmintic for treatment of parasitic gastroenteritis

(PGE) in calves during the summer months there is

little difference, in terms of efficacy, between any of

Strategic anthelmintic dosing (see p. 271 onwards)

the currently available anthelmintics. Abamectin,

doramectin, eprinomectin, ivermectin and moxidectin

On farms where 'clean grazing' in the form of new leys

injections and respective pour-on formulations have

or aftermaths is available, GI nematodes can be con-

persistent anthelmintic activity against abomasal nema-

trolled by integrating systems of grazing management

todes and lungworms and can be used at extended

with parasite control strategies. These clean grazing

treatment intervals in strategic dosing strategies. For

systems can be designed for the effective control of

treatment of type II ostertagiosis, or for treating

PGE, but offer little protection for the control of lung-

animals on housing, it is advisable to use a product with *worm because of the unpredictable nature of the*

high activity against arrested fourth-stage larvae. An

disease. On many conventionally managed enterprises,

anthelmintic that lacks such efficacy may necessitate

where cattle are grazed on permanent pasture, control

repeated treatment as it will only remove adult worms

can be achieved through strategic anthelmintic dosing

and developing larvae, leaving arrested larvae to

at three and six weeks post turn-out (sometimes

resume development and cause damage to the abo-

referred to as to the 'poor man's clean grazing system').

masal wall. Here there is some variability in efficacy

Further developments of this system include the 3, 8, 13

between products and evidence suggests that at

strategy for ivermectin, the 0, 8 dosing strategy for

recommended dose rates, albendazole, fenbendazole,

doramectin, and the use of boluses (see p. 271). Calves

netobimin, oxfendazole, ricobendazole, abamectin,

dosed with a bolus or treated strategically with

doramectin, eprinomectin, ivermectin and moxidectin

anthelmintic should remain set-stocked on the pasture *are more active against arrested fourth-stage larvae*

or moved to clean pasture, when available, for

than other anthelmintics. The activities of the probenz-

maximum benefits. Many of the anthelmintic strategies

imidazoles, febantel and thiophanate are increased if

described claim to protect calves against lungworm

they are given in feed over several days.

disease during their first season at grass. There is much

Table 60.3

Anthelmintics effective against helminth parasites of cattle.

Parasite group

Parasite genus/species

Anthelmintics

Gastrointestinal worms

Ostertagia, Trichostrongylus, Cooperia, Albendazole, ricobendazole, febantel, fenbendazole,

Haemonchus, Nematodirus, Chabertia,

netobimin, oxfendazole, thiophanate, levamisole, morantel,

Bunostomum, Oesophagostomum,

abamectin, doramectin, eprinomectin, ivermectin, moxidectin

Strongyloides

Closantel and nitroxynil (Haemonchus, Bunostomum,

Oesophagostomum only)

Lungworms

Dictyocaulus viviparus

Albendazole, febantel, fenbendazole, netobimin, oxfendazole,

levamisole, abamectin, doramectin, eprinomectin, ivermectin,

moxidectin

Diethylcarbamazine (available in some countries)

Cestodes

Moniezia expansa, M. benedini

Albendazole, febantel, fenbendazole, netobimin, oxfendazole

Oxyclozanide (some activity against proglottids)

Taenia saginata (metacestode

Praziquantel

Cysticercus bovis)

Echinococcus granulosus (hydatid)

Praziquantel

Trematodes

Fasciola hepatica (adults)

Albendazole, ricobendazole, netobimin, triclabendazole, *nitroxynil, oxyclozanide, clorsulon, closantel*

Rafoxanide, bithionol, niclofan

Fasciola hepatica (immatures)

Triclabendazole, nitroxynil (>6 weeks), closantel

Fasciola gigantica

Triclabendazole, clorsulon

Fascioloides magna

Triclabendazole, clorsulon, closantel

Dicrocoelium dendriticum

Netobimin

Schistosoma spp.

Praziquantel

debate as to whether these strategies compromise

an ideal site for the location of these devices, which

immunity to both GI worms and lungworms and, in

can release anthelmintic over an extended period

part, explain the increasing reports of lungworm in

either continuously (sustained-release devices, SRD),

older animals seen over the last few years in parts of

or at pulsed intervals (pulse-release devices, PRD).

western Europe. On farms where lungworm is endemic, *Ruminal retention is achieved either on the basis of*

or if there is a high risk of introduction of disease,

density or the variable geometric configuration of the

then vaccination is the recommended method of

device.

control (see p. 1011).

Several devices are available for cattle in certain

The two grazing strategies commonly used for the

countries and include:

control of PGE in first-year cattle are commonly

referred to as ‘preventative’ and ‘evasive’. In a preven-

• A morantel sustained-release device (MSRD);

tative strategy clean grazing is provided at the start of

• A levamisole sustained-release bolus (LSRB);

the grazing season, usually in the form of new leys.

• A fenbendazole sustained-release bolus (FSRB);

When weaned, parasite-naïve calves are turned out

• An ivermectin sustained-release bolus (ISRB); and

onto the clean pasture where they should remain set-

• Oxfendazole pulse-release devices (OPRB).

stocked for the whole grazing season and should not *require any anthelmintic dosing. In an evasive strategy,*

These range in shape and design, each being adminis-

animals are dosed and moved onto clean aftermaths

tered by the use of specially provided dosing guns. Care

from mid-summer onwards (see p. 271).

is required when administering as dosing injuries can

easily occur or the bolus may be regurgitated if not

swallowed properly.

Anthelmintic delivery devices

The MSRD consists of a coiled trilaminate sheet

Intraruminal devices represent a new approach to

composed of a central core matrix of morantel tartrate.

administering anthelmintics for the control of parasitic

The entire sheet is punched with holes which allow the

helminths and are becoming a popular labour-saving

controlled release of morantel into the rumen from the

means of worming cattle. The reticulo-rumen provides

edges of the perforation as well as the perimeter.

The device is retained in a rolled shape by a special

cal disease in the following spring. In this situation *tape. Following administration, the tape releases and*

calves may require dosing in the autumn while still at

the device unrolls and is retained in either the first or

grass, or on housing, to remove arrested burdens.

second stomach of the animal. The device remains

With some delivery system designs the dose/weight

active for about 90 days, after which it gradually dis-

ratio reduces as the animals grow, whilst at the same

integrates and is eliminated.

time release rates may decline with time. Both of these

The LSRB bolus consists of a compressed polyvinyl

factors may result in considerable selection pressure

chloride (PVC) matrix containing levamisole encased

for the development of drug resistance and since these

in an outer impermeable shell. Anthelmintic is released

systems are recommended as a form of clean grazing

from the internal surface area through a single outer

system, the build-up of resistant over susceptible

pore over a period of up to 90 days.

species could rapidly occur.

The FSRB is a cylindrical bolus consisting of ten flat-

faced tablets in two magnesium alloy tubes joined and

enclosed by alloy rings. The bolus is designed to release

Anthelmintic resistance

fenbendazole by galvanic erosion over a period of 140

Although widely reported in sheep, anthelmintic resist-

days.

ance appears less of a problem in cattle. This may be a

The ISRB consists of an external semipermeable

reflection of the relative frequency of treatment and

membrane surrounding a semisolid formulation of iver-

also of differences in parasite population dynamics

mectin. The bolus is retained in position in the first or

between the two hosts. It may also reflect the prolonged

second stomach by the presence of an iron densifier at

survivability of free-living larval stages within the

one end. The bolus is designed to release anthelmintic

bovine faecal pat, thus ensuring a supply of susceptible

over a period of up to 135 days.

worms.

The OPRB consists of either five or seven annular

The effects of intraruminal devices on the develop-

tablets of oxfendazole, mounted on a central metal ment of resistance, given the selection pressures they core with a stainless steel weighted end. The release exert, are not yet apparent. Until the inheritance of of each annular tablet is determined by the corrosion anthelmintic resistance is completely understood, this rate of the central core. The first dose of oxfendazole will remain a matter for speculation. In the meantime, is either released within 24 hours (for use in animals recommendations aimed at limiting the development of already at grass) or at approximately three weeks after resistance in sheep nematodes should be followed administration for either first (seven tablet) or second wherever possible. The ultimate choice of anthelmintic year animals (five tablet) prior to turnout. Remaining product may therefore be influenced by a number of doses are released at regular intervals thereafter factors of which group type or mode of action may (approximately 21 days) giving the boluses active lives become one of the overriding factors, when considered of 105, 126, or 147 days depending on the number of *as part of an anthelmintic rotation programme designed*

tablets and release profile. Devices of this nature are

to delay the onset of resistance.

subject to some variation in release intervals depend-

ent on factors such as diet, rumen pH and gut motility,

so that release may vary by a few days either side of the

***Treatment of parasitic bronchitis** (see pp.*

optimum.

273–4)

A novel development from this type of corrosion-

based pulse-release system is the electronic bolus based

The anthelmintics fenbendazole, oxfendazole, albenda-

on microchip technology. As well as offering the poten-

zole, ricobendazole, febantel, levamisole, ivermectin,

tial of multiple anthelmintic therapy, the system could

abamectin, doramectin, eprinomectin and moxidectin

be used to pulse release other drugs such as growth

are all highly effective against developing fourth-stage

promoters and mineral supplements.

larvae and adult Dictyocaulus viviparus. Diethylcarba-

Bolus devices are normally administered at the start *mazine (available in some countries) is primarily active*

of the grazing season, although some can be given later

against immature larvae if given over a three-day period.

in the season. If the animals are turned out early, or

Some degree of control of parasitic bronchitis in

moved to pasture grazed by untreated animals during

calves can be achieved by early season suppression of

late summer, subsequent protection from infective

pasture contamination in much the same way as for the

larvae may be lost, as will any benefits of anthelmintic

control of GI nematodes. However, the epidemiology

treatment. The result may be that either the calves

of lungworm infection is complex and still not fully

experience sufficient challenge to develop clinical

understood, and it is the opinion of the author that the

disease in the autumn or, alternatively, they acquire

vaccination of calves with an irradiated larval vaccine

large numbers of arrested larvae that may cause clini-

is the most reliable form of control (see p. 1011).

Treatment of trematode infections in

of F. gigantica. Only triclabendazole and clorsulon are

***cattle** (see pp. 276–80)*

effective against both mature and immature stages of

F. gigantica. Fascioloides magna, a parasite of deer that Fasciolosis

can affect cattle, is susceptible to triclabendazole, clor-

Table 60.4 shows the comparative efficacy of flukicidal

sulon and closantel.

drugs against F. hepatica. All are effective against adult Only limited information is available on the treat-fluke and are therefore suitable for the treatment of

ment of paramphistomes in cattle (see p. 279). Niclo-

chronic fasciolosis in cattle. Few compounds have activ-

folan or albendazole has been recommended, but these

ity against immature fluke stages, limiting the choice in

have only variable activity against intestinal juvenile

suspect cases of acute fasciolosis. As a general recom-

forms. Oxyclozanide given on two occasions, three days

mendation for cattle in temperate countries, housed

apart, has been shown to be effective against adult

cattle should be dosed once in mid-winter in average

flukes in the rumen.

rainfall years. Wherever possible, the most effective *drugs with efficacy against mature and immature flukes*

Schistosomes (see p. 280)

should be used. Further treatment should then be

unnecessary. If a flukicide with activity against mature

In contrast to the chemotherapy of schistosomes in

flukes only is used, a second dose at turnout may be

humans, little information is available on the treatment

necessary to remove any fluke missed by the first

of schistosomosis in cattle. For economic reasons,

treatment. Where animals were housed for at least eight

anthelmintic treatment is not suitable for the control

weeks prior to the first treatment, the second dose

of schistosomosis in cattle, except during clinical out-

should be unnecessary.

breaks when praziquantel may be administered orally

In outwintered stock, two doses of anthelmintic may

at 15–20 mg/kg. Repeat doses two to three days apart

be necessary. The first is given in early winter to remove

are usually required or high dose rates (25/mg per kg)

adult and immature fluke burdens acquired from the

at three to five weeks apart.

autumnal flush of pasture metacercariae. A second

dose in early spring may be required to prevent heavy

Treatment of cestode infections in cattle

pasture contamination and infection of the intermedi-

ate snail host, especially if rainfall has been heavy in

Adult stages of tapeworms parasitizing cattle are

previous years. In these situations the treatment inter-

usually of little consequence. Several of the benzimida-

val will depend on the activity of the flukicidal drug

zoles used in the treatment of GI nematodes are also

against immature stages.

effective against cestodes (Tables 60.2 and 60.3).

Certain flukicidal drugs also have cestocidal activity

(Table 60.4). Larval stages of cestodes affecting cattle,

Other Fasciola spp. (see p. 277)

notably Echinococcus spp. and Taenia saginata, are The drugs and dose rates given for the treatment of F.

generally refractory to treatment with anthelmintics.

hepatica are also generally applicable for the treatment However, praziquantel has been shown to have activity

Table 60.4

Activities of anthelmintics against liver fluke in cattle.

Chemical group

Chemical

Recommended

Active

Comments

dose rate

against

(mg/kg)

A

B

C

Salicylanilides

Rafoxanide

7.5

+

+

-

No longer available in many countries

Closantel

NR

+

+

±

Available for cattle in some countries

Oxyclozanide

10

+

-

-

Some activity against tapeworm segments

Substituted phenols

Nitroxynil

10

+

+

-

Also active against blood nematodes

Bithionol

30

+

-

-

Also has anticestodal activity

Niclofolan

3

+

-

-

Benzimidazoles

Albendazole

10

+

-

-

Also active against nematodes and cestodes

Triclabendazole

12

+

+

+

Do not give to dairy cows within 7 days of calving

Probenzimidazoles

Netobimin

20

+

-

-

Do not administer to cattle in the first 7 weeks of

Sulphonamide

Clorsulon

7

+

+

±

pregnancy

A, adult fluke; B, 6–12 week old fluke; C, 1–6 week old fluke.

NR, no recommended dose rate.

against the intermediate stages of both these parasites,

causative organism, Cryptosporidum parvum (see

although the cost of treatment may preclude its use.

pp. 204, 286), is a significant cause of disease in neona-

tal calves and is also an important zoonosis.

Antiprotozoals

Haemoparasites

Ruminants carry large numbers of protozoa in their

Cattle are infected with a number of haemoprotozoa

stomach and intestines, the vast majority of which are

that include some highly pathogenic species, e.g. the

entirely harmless. Some species of protozoa, however,

piroplasms (Babesia and Theileria) (see p. 748) and the are significant as causes of disease in cattle or because

haemoflagellates (Trypanosoma) (see p. 756). Trans-

of their potential for zoonotic transmission. Antiproto-

mission of these blood parasites normally occurs via a

zoal compounds are listed in Table 60.5.

biting tick or insect vector. Babesia species occur in Protozoal diseases of economic importance through-most parts of the world where there are ticks. They are

out various regions of the world include trypano-

of greatest importance in the tropics, but some species

somosis, theileriosis, babesiosis and trichomoniasis.

occur in temperate climates where they can cause

Coccidiosis in cattle is caused by parasites of the genus

disease in non-immune cattle. The merozoites of

Eimeria spp. and can be a serious cause of disease

Babesia occur in the erythrocytes of infected animals in young animals (see p. 282). A protozoan disease

where they multiply asexually by binary fission and

of increasing importance is cryptosporidiosis. The

are described as 'large' and 'small', depending on size.

Table 60.5

Antiprotozoal compounds for cattle.

Compound

Trade name

Manufacturer

Dose rates

Comments

(mg/kg)

Route

Diminazene aceturate

Berenil

Intervet

3.5–7.0

For treatment of typanosomosis (T. congolense,

im or sc

T. brucei, T. vivax [nagana]) and babesiosis (B.

bigemina, B. bovis and B. divergens)

Imidocarb

Imizol

Schering-Plough

1–3

For treatment of babesiosis (B. bigemina, B.

(Mallinckrodt

sc

bovis and B. divergens). Prophylactic effect for up Veterinary)

to 8 weeks depending on dose and species

involved. Causes cholinergic effects and is slowly

metabolised and excreted

Homidium chloride

Novidium

Merial

1.0

Treatment of trypanosomosis (T. congolense,

im

T. brucei, T. vivax [nagana])

Isometamidium chloride

Samorin

Merial

0.25–1.0

Treatment or prevention of typanosomosis

im or iv

(T. brucei, T. congolense, T. vivax [nagana]).

Toxic above 2 mg/kg

Suramin

Naganol

Bayer

10

Treatment of typanosomosis (T. brucei, T.

iv

congolense, T. vivax [nagana])

Amicarbalide

Diampron

Merial

5–10

Treatment of babesiosis (B. bigemina, B. bovis, im

B. divergens)

Buparvaquone

Butalex

Schering-Plough

2.5

Treatment of East Coast fever (Theileria parva)

(Mallinckrodt

2 doses at 48 h

and Mediterranean Coast fever (T. annulata)

Veterinary)

intervals

Parvaquone

Clexan

Schering-Plough

10–20

Treatment of East Coast fever (T. parva) and

(Mallinckrodt

2 doses at 48 h

Mediterranean Coast fever (T. annulata)

Veterinary)

intervals

Halofuginone

Stenoral

Intervet

1.2

Treatment of East Cost fever (T. parva) and

po 2 doses at

Mediterranean Coast fever (T. annulata)

48 h intervals

im, intramuscular; sc, subcutaneous; iv, intravenous; po, per os (oral).

Several species are highly pathogenic in cattle and

tion to hygiene. Raising of food and water troughs, for

include Babesia bigemina, found in Africa, Australia,

example, can help avoid contamination by reducing the

Europe and Central and South America, and B. bovis,

levels of infection. Young animals should be kept off

found throughout most of the world and being particu-

heavily contaminated pastures when they are most

larly common in southern Europe. Transmission occurs

susceptible. The anticoccidial decoquinate is licensed

following a bite from an infected tick of the genera

in many countries for the prevention of coccidiosis

Boophilus, Rhipicephalus, Haemaphysalis and Ixodes, in calves. Other compounds, such as monensin and *the species involved varying with geographical location.*

amprolium, are available is some countries.

The species found throughout temperate Europe is

Babesia divergens (a small piroplasm), transmitted by

Cryptosporidiosis (see pp. 204, 286)

the tick Ixodes ricinus. Clinically affected animals

develop a haemolytic anaemia leading to haemo-

Bovine cryptosporidiosis is often seen as part of the

globinuria, fever and death.

neonatal diarrhoea complex, symptoms of which are

A number of Theileria species have been reported in

profuse watery diarrhoea, dehydration, and death if left

cattle and are significant causes of disease in many tropi-

untreated. Infections are usually, although not always,

cal countries. The parasites occur within lymphocytic

associated with the presence of other pathogens such

and erythrocytic cells and are transmitted by the bites

as Salmonella spp., E. coli, rotavirus and coronovirus.

of various species of ticks. T. parva (the cause of East Specific antiparasitic therapy is not available for

Coast fever) and T. annulata (Mediterranean Coast *cryptosporidiosis and treatment relies on the use of*

fever) are the main pathogenic species occurring in East

supportive antidiarrhoeals and fluid therapy for animals

and North Africa, southern Europe and parts of the

showing dehydration. Recently halofuginone lactate

former Soviet States, respectively. Transmission of these

has been licensed for the prevention of diarrhoea

parasites occurs following the bite from an infected tick

caused by Cryptosporidium parvum by treating daily

belonging to various species of the genus Hyalomma.

for seven consecutive days.

Trypanosomosis is one of the most important dis-

eases of domesticated cattle in central parts of Africa.

ECTOPARASITICIDES

Trypanosomes are broadly divided into two groups

Introduction

depending on the site of development in the insect

(see Chapters 45, 50)

vector. The salivarian trypanosomes, transmitted in the

saliva of biting flies, are responsible for 'nagana' in

Ectoparasites can cause intense irritation leading to loss *domestic ruminants (see p. 757), as well as diseases such*

of condition and effects on performance such as weight

as 'surra' of horses and other animals, and African

loss, reduced milk yield or hide damage. In addition

Sleeping Sickness in humans. The stercorarian try-

they may be responsible for transmission of disease.

panosomes are transmitted by contamination with

The choice and use of ectoparasiticide chemicals and

infected insect faeces and include diseases such as

the method for their control depend to a large extent

Chagas disease in humans in Central and South

on husbandry and management practices as well as the

America, which is transmitted by reduviid bugs.

type of ectoparasite causing the infestation.

Parasites that live permanently on the host, such as

lice and mites, are relatively easily controlled and, once

Coccidiosis (see p. 282)

eradicated, reinfestation only occurs from contact with

At least 18 different species of coccidia are known to

infested stock. Non-permanent parasites (ticks and

infect cattle worldwide. Bovine coccidiosis is primarily *flies) are less easily controlled because only a small pro-*

a disease of young animals aged between three weeks

portion of the population can be treated at any one time

and nine months, but can occur in older cattle. The

and other hosts may maintain them.

disease is usually associated with a previous stressful

Most infestations in cattle are seasonal and pre-

situation such as shipping, overcrowding, changes of

dictable and can be countered by prophylactic use of

feed, severe weather or concurrent infections. Clinical

ectoparasiticides. For example, biting and nuisance flies

signs, often presenting as bloody diarrhoea, are associ-

occur predominantly from late spring to early autumn,

ated with the presence of Eimeria zuernii or E. bovis, tick populations increase in the spring and autumn, and

which occur in the lower small intestine, caecum and

lice and mites may increase in winter-housed stock.

colon. Another species of coccidia, E. alabamanesis, has been reported to cause enteritis in yearling calves in

Ectoparasiticide groups

some northern European countries.

The incidence of coccidiosis can be reduced by avoid-

Available ectoparasiticides act either systemically or by

ance of overcrowding and stress and increased atten-

direct contact with the target parasites and have an

effect on the ectoparasite's nervous system. Systemic

facilities, in addition to labour requirements for such

ectoparasiticides may be given parenterally or applied

operations.

topically to the skin from where the active ingredient is

absorbed percutaneously and taken up into the blood

circulation. Topical ectoparasiticides have a direct

Organochlorines

effect on the target parasite on the surface of the skin.

Organochlorines (OCs) are no longer in general use but

Different formulations of a drug preparation may be

several compounds are still available in some countries.

indicated for different target parasites (Table 60.6).

OCs fall into three main groups:

Both topical and systemically acting formulations can

be applied by various methods including dips, sprays,

(1)

Chlorinated ethane derivatives such as

‘pour-ons’, ‘spot-ons’, dusting powders or ear tags. Typi-

DDT (dichlorodiphenyltrichloroethane), DDE

cally, a number of formulations are available as liquid

(dichlorodiphenyldichloroethane) and DDD

concentrates requiring dilution with water to produce

(dicofol, methoxychlor);

an emulsion for application by spray or dip. However,

(2)

The cyclodienes that include chlordane, aldrin,

more convenient ready-for-use pour-on and spot-on

dieldrin, hepatochlor, endrin, tozaphene;

application methods provide a broad choice of systems

(3)

Hexachlorocyclohexane (HCH), also known as

depending upon individual circumstances, for example

benzene hexachloride (BHC), which includes the

availability of spraying, dipping and animal handing

g-isomer lindane.

Table 60.6

Chemicals active against cattle ectoparasites.

Ectoparasite

Parasite species

Ectoparasiticides

group

Biting flies

Haematobia (Lyperosia) irritans, horn fly

Ivermectin,a doramectin,a eprinomectin,a moxidectin,a

Stomoxys calcitrans, stable fly

cypermethrin, deltamethrin, fenvalerate, permethrin

Simulium spp., blackfly

Nuisance flies

Hydrotaea irritans, head fly

Cypermethrin, deltamethrin, fenvalerate, permethrin

Musca autumnalis, face fly

Musca domestica, house fly

Morellia simplex, sweat fly

Warble flies

Hypoderma bovis

Abamectin, doramectin, eprinomectin, ivermectin, moxidectin,

Hypoderma lineatum

famphur, fenthion, phosmet

Sucking lice

Haematopinus eurysternus

Abamectin, doramectin, eprinomectin, ivermectin, moxidectin,

Linognathus vituli

phosmet, cypermethrin, deltamethrin, fenvalerate, permethrin,

Solenopotes capillatus

Amitraz

Closantel

Biting lice

Bovicola (Damalinia) bovis b

Doramectin,b eprinomectin,b ivermectin,b moxidectin,b famphur, fenthion, phosmet, cypermethrin, deltamethrin, fenvalerate,

permethrin, amitraz

Mites

Psoroptes bovis

Abamectin,c doramectin,c eprinomectin,c ivermectin,c

Sarcoptes scabiei

moxidectin,c phosmet, amitraz

Chorioptes bovis

Ticks

Ixodes spp.

Amitraz

Boophilus spp.

Flubenzuron

Rhipicephalus spp.

Closantel

Ambylomma spp.

Dermacentor spp.

Hyalomma spp.

a Pour-on preparations with activity and protection against horn flies [Haematobia (Lyperosia) irritans]

b Efficacy varies depending on method of application. Injectable preparations aid in the control of biting lice.

c Efficacy varies depending on method of application. Injectable preparations aid in the control of chorioptic mange.

Chlorinated ethanes cause inhibition of sodium con-

Pyrethrins and synthetic pyrethroids

ductance along sensory and motor nerve fibres by

Natural pyrethrins are derived from pyrethrum, a

holding sodium channels open, resulting in delayed

mixture of alkaloids from the chrysanthemum plant.

depolarization of the axonal membrane. This state

Synthetic pyrethroids (SPs) include bioallethrin, cyper-

renders the nerve vulnerable to repetitive discharge

methrin, deltamethrin, fenvalerate, flumethrin, lambda-

from small stimuli that would normally cause an action

cyhalothrin, phenothrin and permethrin. The content of

potential in a fully repolarized neuron.

some SPs is also expressed in terms of the drug isomers;

The cyclodienes appear to have at least two com-

for example, cypermethrin preparations may contain

ponent modes of action:

varying proportions of their cis and trans isomers. Thus,

• Inhibition of g-amino butyric acid (GABA)-

cypermethrin (cis : trans 60 : 40) 2.5 per cent is equiva-stimulated Cl- flux and

lent to cypermethrin (cis : trans 80 : 20) 1.25 per cent. In

• Interference with Ca2+ flux.

general terms, cis isomers are more active than the corresponding trans isomers.
The mode of action of SPs

The resultant inhibitory postsynaptic potential leads

appears to be an interference with sodium channels of

to a state of partial depolarization of the postsynaptic

the parasite nerve axons, resulting in delayed repolar-

membrane and vulnerability to repeated discharge. A

ization and eventual paralysis. The lethal activity of

similar mode of action has been reported for lindane,

pyrethroids seems to involve action on both peripheral

which binds to the picrotoxin side of the GABA recep-

and central neurones, while the knockdown effect is

tor resulting in an inhibition of GABA-dependent Cl-

probably produced by peripheral neuronal effects only.

flux into the neuron.

Pour-on, spot-on, spray and dip formulations are

available in many countries with activity against biting

and nuisance flies, lice and ticks. Some compounds are

Organophosphates and carbamates

active against sarcoptic and chorioptic mange mites.

For non-permanent ectoparasites, treatments are gen-

Organophosphates (OPs) are neutral esters of phos-

erally applied during periods of anticipated peak chal-

phoric acid or its thio analogue and act by inhibiting the

lenge. Treatments for lice are best administered in

action of acetylcholinesterase (AchE) at cholinergic

the autumn. Periods of protection against flies vary

synapses and at muscle end plates. This results in an
between products and methods of application, but gen-
accumulation of acetylcholine (Ach) at the postsyn-
erally last for up to one month for most species of flies.
aptic membrane, leading to neuromuscular paralysis.
Some SPs are also available as ear tags for use on cattle,
OP compounds include azamethiphos, chlorpyriphos,
providing protection against biting and nuisance flies
coumaphos, dichlorvos, diazinon, fenitrothion, hep-
for several months during the fly season. One tag is
tenophos, metriphonate, phoxim, propetamphos or
usually sufficient but in severe cases of head or face fly
tetrachlorvinphos and there are many preparations
attack, both ears can be tagged.
available worldwide for cattle. Carbamate insecti-
cides are closely related to the OPs and are also
anticholinesterases but, unlike OP compounds, are
Amidines
spontaneously reversible. The two main carbamate
The main member of this group is amitraz, which acts
compounds in use in veterinary medicine are carbaryl

at octopamine receptor sites in ectoparasites giving rise

and propoxur. OP compounds can be extremely

to increased nervous activity. When applied as a spray

toxic in animals and humans. Inhibition of AchE, and

it is active against mites, lice and ticks in cattle. In severe other cholinesterases, can occur in higher vertebrates as

cases of mange, lice and tick infestations, treatments

well and accounts for host toxicity seen at higher dose

may have to be repeated during the risk period.

rates. Typical signs of overdosage, or overexposure,

include salivation, miosis, diarrhoea and muscle

Avermectins and milbemycins

tremors. Death may occur through respiratory failure.

Toxic clinical signs can be treated with atropine.

Avermectins and the structurally related milbemycins

Chronic exposure may lead to damage to the nervous

have been discussed earlier under anthelmintics. As

system and clinical signs including headaches, anxiety

well as being effective against GI roundworms and

and irritability in operators. OP compounds are gener-

lungworms, all have activity against warbles, sucking *ally active against warble fly larvae, flies, lice, ticks and*

lice and mange mites. Control against the biting louse,

mites on cattle, although activity will vary between

Bovicola (Damalinia) bovis, the mite, Chorioptes bovis, compounds, formulations and against different target

and the hornfly, Haematobia (Lyperosia) irritans varies parasites.

between products and the method of administration.

Insect growth regulators

Caldow, G.L., Taylor, M.A. & Hunt, K. (1989) Comparison of two early season anthelmintic programmes on a commer-Insect growth regulators (IGRs) are a group of chemi-

cial beef farm. Veterinary Record, ***24****, 111–14.*

cal compounds that do not kill the target parasite

Campbell, W.C. (1985) Ivermectin: an update. Parasitology

directly, but interfere with growth and development.

Today, ***1****, 10–16.*

IGRs act mainly on immature stages of the parasite and

Campbell, W.C. (1986) The chemotherapy of parasitic infec-

as such are not usually suitable for the rapid control of

tions. Journal of Parasitology, ***72****, 45–66.*

established adult populations of parasites. Where para-

Craig, T.M. & Hucy, R.L. (1984) Efficacy of triclabendazole sites show a clear seasonal pattern, IGRs can be applied

against Fasciola hepatica and Fascioloides magna in natu-at the start of the grazing season as a preventative

rally infected calves. American Journal of Veterinary

*Research, **46**, 1644–5.*

measure. Based on their mode of action they can be

Donald, A.D. (1985) New methods of drug application for

divided into chitin inhibitors and juvenile hormone

*control of helminths. Veterinary Parasitology, **18**, 121–37.*

analogues. Chitin inhibitors appear either to interfere

Eagleson, J.S. & Bowie, J.Y. (1986) Oxfendazole resistance with the assembly of chitin chains and microfibrils or to

*in Trichostrongylus axei in cattle in Australia. Veterinary inhibit the deposit of chitin into the cuticle. The juve-Record, **119**, 604.*

nile hormone analogues mimic the activity of naturally

Egerton, J.R., Suhayda, D. & Eary, C.H. (1986) Prophylaxis of occurring juvenile hormones and prevent metamor-nematode infections in cattle with an indwelling rumino-

phosis to the adult stage.

reticular ivermectin sustained release bolus. Veterinary

IGRs are widely used for flea control in domestic pets

*Parasitology, **22**, 67–75.*

and for blowfly control in sheep, but have limited

Eysker, M. (1986) The prophylactic effect of ivermectin treat-

use in cattle. The phenoylbenzyl urea flubenzuron is

ment of calves three weeks after turnout, on gastro-

*intestinal helminthiasis. Veterinary Parasitology, **22**, 95–103.*

marketed in Australasia as a tick development inhibitor.

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Control of parasitic bronchitis and gastroenteritis by

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nematode infections in first-season cattle. Veterinary

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Chapter 61

Antimicrobial Agents

A.H. Andrews

Introduction

1035

on other organisms. These chemical compounds are

Identification of the causal agent

1035

the metabolic products of bacteria and fungi. Most

Sampling

1035

commonly, antibiotics are effective against bacteria

Sensitivity testing

1036

but some have activity against viruses, Rickettsia,

Penetration

1036

Mycoplasma, fungi and helminths (see Table 61.1).

Antibiotic resistance

1038

At present all prescribing of antimicrobial agents for

Dosage

1038

therapy, prophylaxis or control of disease is under vet-

Route of administration

1038

Duration of therapy

1038

erinary control and prescription in the UK. The level of

Spectrum of drug activity

1040

control in some countries is greater than in Britain, e.g.

Bacteriostatic or bactericidal activity

1040

Sweden, although in many parts of the world it is less

Drug combinations

1041

or almost non-existent.

Cost

1042

Toxicity

1042

Drug withdrawal times

1042

Identification of the causal agent

Legal considerations

1042

Frequency of dosing

1042

Some decisions regarding therapy can only be made

Possible antibacterial therapy for cattle

1044

once a diagnosis is reached. Clinical examination is *used to identify the nature of the infection, its site and*

Introduction

possible cause. The signs of some diseases are so clear-

cut that diagnosis is easy to establish and the organism

The choice of a suitable antimicrobial agent is very dif-

is readily identifiable, e.g. wooden tongue, actinomyco-

ficult. It first depends on deciding whether the problem

sis. In such cases the choice of drug is easy to make as

encountered is an infection and even then whether it

well as its dosage, rate and duration of treatment. The

warrants such therapy. The site of infection needs to be

likely outcome of therapy can also be predicted with

located and the type of microbe established. Then the

some confidence. However, in many cases the disease

in vitro antimicrobial sensitivity of the organism and the signs are not clear-cut, the area of infection is difficult

minimal inhibitory concentration need to be deter-

to localize or the sensitivity pattern of the organism is

mined. The likely ability to penetrate the area, the

irregular. In such cases the identification of the causal

action of the antibiotic in the local environment and the *agent is important not only for treatment of the*

maintenance of an effective concentration at the area

individual animal affected but also for possible future

must be considered. The selection also has to include

action on a herd basis. However, in many situations, the

the possibility of any potential toxic side-effects as well

site of infection and the cause of the condition are not

as the meat and milk withholding times. Once all these

known. In such instances laboratory diagnosis, other

factors have been taken into consideration, the drug to

than haematological examination to indicate that an

be used, its dosage, route and frequency of administra-

infection is present, is of no value. Therapy in these

tion can be determined. All the above, however, has to

cases usually involves the use of one or more anti-

be undertaken on an economic basis.

microbial agents to ensure a broad spectrum of activity.

There are various ways of defining antimicrobial

Subsequent progress will depend on evaluation of the

preparations. Chemotherapy can be defined as the use

effect of the chosen treatment.

in the treatment of a disease of pure chemicals that

have a special antagonistic effect(s) on the organism

causing the disease.

Sampling

Antibiotics are complex organic chemicals synthe-

sized by micro-organisms during their growth and

Wherever possible sampling should be undertaken to

which, in minute quantities, have a detrimental effect

try to determine the causal organism. This will be

Table 61.1

Non-antibacterial activity of some antibiotics.

Table 61.2

Drugs with reasonable penetration of various fluids

and tissues.

Mycoplasma

Chlortetracycline, doxycycline,

erythromycin, fluoroquinolones,

Bile

Erythromycin

lincomycin, methacycline,

Bone

Chlortetracycline, doxycycline, fucidin,

oleandomycin, oxytetracycline,

lincomycin, methacycline,

spiramycin, tetracycline, tylosin

oxytetracycline, tetracycline

Rickettsia

Chloramphenicol, chlortetracycline,

Cerebrospinal

Chloramphenicol, florfenicol,

doxycycline, fluoroquinolones,

fluid

fluoroquinolones, sulphonamides,

methacycline, oxytetracycline,

trimethoprim and sulphonamides

tetracycline

Eye

Amoxycillin, ampicillin, cephalexin,

Protozoa

Monensin, sulphonamides, tetracycline

cephaloridine, cephalothin,

Fungi

chloramphenicol, lincomycin

Candida albicans Amphotericin, nystatin

Milk

Benzylpenicillin, erythromycin, lincomycin

Dermatophytes

Griseofulvin, natamycin

(but toxic), oleandomycin, penethamate,

Ectoparasites and

Ivermectin

spiramycin, tylosin

endoparasites

Prostate

Erythromycin, trimethoprim

Serosal fluids

Chloramphenicol, dihydrostreptomycin,

erythromycin, framycetin, gentamicin,

kanamycin, lincomycin, neomycin,

paromomycin, streptomycin

considered academic by many, but if it is looked at *objectively, it has much to commend it. At the first*

Sensitivity testing

examination and, hopefully, before any therapy has

been initiated is the best time to obtain samples to

Identification of the causal organism allows a decision

establish the likely cause of the problem. In addition,

to be made as to whether or not to test for anti-

the cost of micro-organism determination is usually

microbial sensitivity. In many cases there is no need to

less, or at least no more, than the cost of appropriate

undertake this. Thus organisms of Clostridium spp. are therapy. In almost all cases the value of the individual

sensitive to high doses of penicillin G. However, in cases

animal will be sufficient to make it worthwhile and this

involving Escherichia coli and Salmonella typhimurium is multiplied many times when problems are encoun-there will be considerable variations in the sensitivity

tered on a herd basis. There is virtually no justification

pattern, bearing in mind the origin of the organism.

for not sampling problems of a herd nature when infec-

The Kirby–Bauer disc sensitivity test is that most

tions are suspected. In addition, the treatment of

commonly used for in vitro testing. The aim is to deter-chronic conditions or *those that have responded poorly*

mine if an organism is likely to be affected by specific

is important. Besides positively determining the cause,

antimicrobial agents at the usual therapeutic levels.

sampling may help to eliminate other potential agents.

While the drug concentration reflects levels achieved

The method of sampling is important in that it should

in the plasma, it does not take into account quantities

involve fresh clinical cases rather than those of a

in various tissues such as the brain or udder. The test

chronic nature. The sample should be taken from as

organism is usually classified as sensitive, intermediate

near the inflamed area as possible. This is difficult with

or resistant to the specific antimicrobial agent. The test

problems such as salmonellosis, as organisms in the

was produced for use in human medicine where it pro-

faeces may be diluted by those further down the gut,

vides a quantitative assessment. However, in animals

which in themselves may be much faster growing. Sam-

it is a useful guide. Quantitative tests involve determin-

pling of pneumonias is always difficult as the organisms *ing the minimal inhibitory concentration and usually*

present in the upper respiratory tract may be unrepre-

consist of tube sensitivity tests. In general, an organism

sentative of those in the lung.

sensitive in vitro may be sensitive in vivo, but one resist-Direct examination of the sample after staining is

ant in vitro is also likely to be resistant in vivo.

of use as in some circumstances organisms will not

subsequently grow. Rapid staining methods are now

available and these allow the shape of the organism

Penetration

and whether it is Gram-positive or Gram-negative to

be determined. This in turn can be useful in making a

The ability of a drug to penetrate the infected area needs

quick decision about the drug most likely to be

to be considered (see Table 61.2). Penetration depends

effective.

on the degree of the pathological process as is seen with

abscess or thrombus formation. It also depends on the

high turnover rate, usually in the lysis of cells and

tissue involved and whether there are natural limits to
release of the organisms into fluids containing the
penetration such as in the brain (see p. 897) or in milk.
antimicrobial agent. Lipid solubility does have advan-
The location of the organism is also important, i.e.
tages for organisms that spend most of their time within
whether it is intracellular or extracellular.
cells or behind tissue barriers. Inflammation can also
The ability of an antimicrobial drug to cross biologi-
alter penetration of drugs. Thus penetration of the
cal membranes depends on many factors. These include
central nervous system by many drugs is minimal in the
protein binding, lipid solubility, pH of the drug in rela-
healthy animal although penicillin G and other anti-
tion to environmental pH, molecular size and in some
biotics can enter during inflammation. However, the
cases specific cellular transport mechanisms. Antibiotic
effect of inflammation on the penetration of many
is absorbed into the circulation, partly becoming bound
drugs is unknown. Thus it can be the local environment
to plasma protein. Binding varies, e.g. from less than 50

in which the organism is present that is important.

per cent with amoxycillin, streptomycin or oxytetracy-

Most antimicrobial agents do maintain their activity;

cline to more than 80 per cent with cloxacillin or eryth-

however, aminoglycosides are more active in aerobic

romycin. Binding is readily reversible and the bound

conditions with a slightly alkaline pH. As such condi-

fraction is in equilibrium with the unbound (active)

tions do not exist around staphylococcal abscesses this

form. Protein binding can be a disadvantage, as with

group of drugs is relatively inactive in such circum-

sulphonamides, which are highly protein bound. As

stances. Activity of antibacterial agent in urine is often

purulent fluids often contain much protein, sulpho-

influenced by the pH (see Table 61.3.) The problem of

namides can be relatively inactive.

sulphonamides and pus has already been mentioned.

Water-soluble drugs are useful for extracellular

Some antibiotics do have more effect on anaerobic bac-

organisms and where intracellular organisms have a

teria than others under such conditions (see Table 61.4).

Table 61.3

Antibacterial drug activity in urine. Urinary infections are relatively uncommon in cattle but can lead to therapeutic problems.

Not affected by urine pH

Most active in alkaline urine

Most active in acid urine

Cephalexin

Colistin

Carbenicillin

Cephaloridine

Dihydrostreptomycin

Chlortetracycline

Cephalothin

Erythromycin

Doxycycline

Chloramphenicol

Framycetin

Methacycline

Nalidixic acid

Gentamicin

Nitrofurantoin

Sulphonamides

Kanamycin

Oxytetracycline

Trimethoprim and sulphonamides

Neomycin

Penicillin G

Paromomycin

Tetracycline

Polymyxin B

Streptomycin

Acidifiction

D-Methionine (oral)

Alkalinization

Ascorbic acid (oral)

Sodium bicarbonate (oral)

Table 61.4

Antibiotics effective in vitro against anaerobic bacteria.

High efficacy

Moderate efficacy

Low efficacy

Amoxycillin

Chlortetracycline

Dihydrostreptomycin

Ampicillin

Erythromycin

Framycetin

Carbenicillin

Oxytetracycline

Gentamicin

Chloramphenicol

Procaine penicillin G

Kanamycin

Clindamycin

Tetracycline

Neomycin

Metronidazole

Paromomycin

Streptomycin

Table 61.5

Penicillinase (b-lactamase) active antimicrobials.

Penicillins

Cloxacillin, methicillin

The advent of antimicrobial drugs has resulted in the

Cephalosporins

Cefoperazone, cephalexin,

emergence of resistance to these drugs (see Table 61.5).

cephalonium, cephaloridine,

The use of antibiotics in therapeutic concentration

cephalothin

results in an alteration of the microflora within the

Aminoglycosides

Amikacin, framycetin, gentamicin,

host. There is a tendency for a loss of the sensitive

kanamycin, neomycin, paramomycin

strains with the resistant ones remaining. This selection

Macrolides

Erythromycin, oleandomycin,

allows multiplication of resistant strains within the

spiramycin, tylosin

less competitive environment. The resistant organisms

Nitrofurans

Furazolidone, nitrofurantoin,

can remain in the animal and also contaminate

nitrofurazone

the environment, thereby allowing passage to other

Fluoroquinolones

Danofloxacin, enrofloxacin,

animals. The prevalence of the resistant organisms

marbofloxacin

Others

Bacitracin, chloramphenicol, florfenicol,

tends to reduce the longer the period since the drug was

lincomycin, novobiocin, sulphonamide

used.

and trimethoprim, vancomycin

Spontaneous mutation of organisms can occur but it

is probably only of limited importance in practice.

However, transferable drug resistance is of significance.

This resistance, as determined in the form of plasmids

or transposons, is transferred to susceptible strains.

levels that are effective against most susceptible organ-

Plasmids are extrachromosomal genetic material that *isms, with minimal side-effects. In most cases the rec-*

can replicate independently of the chromosome. These

ommended dose is the minimal dose. This is particularly

plasmids can be transferred by conjugation within or

so for farm animals where both the interval between

between bacterial species and they can also act as

therapy and the suggested dose level tend to be lower

vectors for transposons. This allows the transfer of

than for man or small animals due to cost.

single or multiple antibiotic resistance and has

Less susceptible organisms require higher levels to

produced many of the resistant bacteria found in en-

ensure success. Increasing the dose needs to be consid-

teric calf infections including both E. coli and S.

ered carefully, but it is of little danger if the drug has a

typhimurium as well as in Staphylococcus aureus and low toxicity. However, when the antimicrobial agent

some Pasteurella and Mannheimia spp. infections. In

is of high toxicity any increase in dosage should be

some countries the use of chloramphenicol in food

undertaken with caution. Different dosages may also *animals is restricted or banned because of the usage in*

influence the drug withdrawal time. It should be

humans and also due to potential human toxicity from

remembered that when different companies produce

handling it. Increasing concern has been expressed

the same antibiotic it may well contain different

about microbial resistance to antibacterials in human

amounts of the drug and the vehicle in which it is

beings caused by contact directly with, or indirectly

presented may vary.

from food produced from, farm animals. While the risks

appear to be minimal in creating human microbial

resistance compared with other causes, all veterinarians

Route of administration

should bear the problem in mind when treating or

prescribing for cattle.

The choice of administration route depends on the

Table 61.5 gives examples of antimicrobials which

speed with which infection has to be counteracted as

still have activity in the presence of penicillinase.

well as the volume to be given, ease of administration, *etc. The principal routes used are given in Table 61.6.*

Dosage

Duration of therapy

When an antimicrobial agent is selected it must be in a

high enough concentration and used for a long enough

In general terms, most injections are used for three to

period to result in contact with the organism and its

five days and for at least one day after normality is

consequent demise. Various factors influence this,

reached. However, there is a tendency not to treat for

including the dose, formulation and rate of administra-

long enough in chronic conditions such as some cases

tion. Doses are usually based on body weight. The rec-

of chronic joint or thoracic infections when therapy

ommended dose usually provides good blood and tissue

should be continued for at least 10–14 days. If it was a

Table 61.6

Routes of administration of antimicrobial drugs.

Intravenous (iv): always give slowly

Disadvantages

Advantages

May provoke marked fluid reaction

Rapid high blood and tissue levels, therefore useful for

Only slowly absorbed

septicaemias

Speed of absorption less than im

Always higher circulating levels than im or oral

Intra-articular

Increased levels at areas where levels usually low, e.g.

Increased level in joint

necrotic areas, chronic abscesses

Must be sterile technique

Useful for large volumes

Useful for painful injections

Intrapleural

Useful for irritant injections

Increased level in thorax

Only method of obtaining accurate blood and tissue

Must be non-irritant

levels

Must be a sterile technique

Disadvantages

Subconjunctival

Acute toxic reactions more common

Useful for ocular conditions

Specific formulations necessary

Must be non-irritant

Requires good technique

Must be sterile technique

Perivascular and intravascular thrombosis can occur

Oral (water or feed)

Intramuscular (im)

Advantages

Advantages

Easiest method of administration

Most common route

Can be undertaken by owner

Only 20 ml per injection site

Disadvantages

Peak blood and tissue levels within 2 hours

Blood and tissue levels less than for comparable parenteral dose Slightly less irritant injections than those given iv can be

Higher doses usually used

given by deep im injection

Absorption is variable (depends on gut motility, type of feed, Allows a reasonable level to be maintained over a period

volume of feed, drug binding, e.g. calcium, kaolin impair

of time

absorption of tetracycline, oxytetracycline, chlortetracycline, Disadvantages

methacycline, doxycycline, ampicillin, lincomycin)

Muscle damage

Blood levels do not peak for 12–18 hours

Try not to do within 3 weeks of slaughter

Antibiotics may influence normal ruminal flora

Severe reactions to some drugs

Some antibiotics not absorbed, e.g. streptomycin,

Some injections painful

dihydrostreptomycin, neomycin, framycetin,

Accurate blood and tissue levels not obtained

phthalylsulphathiazole

Some antibiotics destroyed, e.g. benzylpenicillin

Intraperitoneal (ip)

Topical

Advantages

Ointments, powders, aerosol sprays

Speed of absorption similar to im injection

Usually well absorbed

Ophthalmic preparations

Useful for peritonitis

Ointments and drops. Limited retention at site except some

Useful if very toxic

special preparations

Useful for irritant drugs

Aural preparations

Useful in severe respiratory distress (especially

Drops and ointments

tetracyclines)

Large volumes can be given

Intramammary (use aseptic technique)

Advantages

Disadvantages

Convenient

Possible sepsis

Good efficacy

Accurate blood and tissue levels not obtained

Disadvantages

Subcutaneous (sc)

Often diffusion reduced by blocked lactiferous ducts, etc.

Advantages

Used for clinical treatment

Little used for antimicrobials except sulphonamides

Dry-cow therapy used for subclinical mastitis and prophylaxis

Large volumes can be given

If intramammary tube used in one quarter all milk should be

Less irritant than im

withheld

human or small animal there would often be no dispute

activity against Mycoplasma, Rickettsia and Chlamydia.

about such a length of therapy. Many antibacterial

The antibacterial activity of drugs can also vary (see

preparations are now available that can be injected at

Table 61.7): some have a narrow spectrum, only inhibit-

extended intervals to provide adequate drug concen-

ing either Gram-negative or Gram-positive organisms;

trations for several days. However, in some cases the

others have most activity against Gram-positive

duration of effective therapy can be overestimated.

organisms but will inhibit some Gram-negative agents.

However, some have a broad spectrum inhibiting both

Gram-positive and Gram-negative bacteria.

Spectrum of drug activity

Antibacterial drugs vary in their degree of activity

Bacteriostatic or bactericidal activity

against various classes of organism. They are usually

considered narrow spectrum if they are only active

At times it is important to know the activity of a

against bacteria, but broad spectrum if they also have

drug. Some drugs are bactericidal, e.g. penicillin,

Table 61.7

Antibacterial activity other than for anaerobic bacteria.

Gram-positive

Gram-negative

Broad spectrum: Gram-positive

bacteria

bacteria

and Gram-negative bacteria

Penicillins

Penicillins

Penicillins

Cloxacillin

Carbenicillin

Amoxycillin

Methicillin

Ampicillin

Penicillin G

Polymyxins

Clavulanic acid and amoxycillin

Penicillin V

Colistin

Polymyxin B

Sulphonamides

Macrolides

Many forms

Erythromycin

Aminoglycosides

Oleandomycin

Amikacin

Tetracyclines

Spiramycin

Dihydrostreptomycin

Chlortetracycline

Tylosin

Framycetin

Doxycycline

Gentamicin

Methacycline

Others

Kanamycin

Oxytetracycline

Bacitracin

Neomycin

Tetracycline

Lincomycin

Paromomycin

Novobiocin

Streptomycin

Cephalosporins

Tiamulin

Cefquinone

Vancomycin

Others

Ceftiofur

Apramycin

Cephalexin

Spectinomycin

Cephaloridine

Cephalothin

Nitrofurans

Furazolidone

Nitrofurantoin

Nitrofurazone

Fluoroquinolones

Danofloxacin

Enrofloxacin

Marbofloxacin

Others

Chloramphenicol

Florfenicol

Halquinol

Sulphonamide and trimethoprim

Table 61.8

Bactericidal and bacteriostatic drugs.

Bactericidal

Bacteriostatic

Penicillins

Halquinol

Amoxycillin

Novobiocin (high concentration)

Ampicillin

Spectinomycin (occasionally)

Carbenicillin

Sulphonamide and trimethoprim

Cloxacillin

Vancomycin

Methicillin

Penicillin G (benzylpenicillin)

Macrolides

Penicillin V (phenoxypenicillin)

Carbomycin

Erythromycin (low concentration)

Macrolides

Oleandomycin

Erythromycin (high concentration)

Spiramycin

Tilmicosin

Nitrofurans

Tylosin

Furazolidone (high concentration)

Nitrofurantoin (high concentration)

Sulphonamides

Nitrofurazone (high concentration)

All types

Cephalosporins

Nitrofurans

Ceftiofur

Furazolidone (low concentration)

Cephalexin

Nitrofurantoin (low concentration)

Cephaloridine

Nitrofurazone (low concentration)

Cephalothin

Tetracyclines

Polymyxins

Chlortetracycline

Colistin

Doxycycline

Polymyxin B

Methacycline

Oxytetracycline

Aminoglycosides

Tetracycline, etc.

Amikacin

Dihydrostreptomycin

Others

Framycetin

Apramycin

Gentamicin

Chloramphenicol

Kanamycin

Clindamycin

Neomycin

Florfenicol

Paromomycin

Lincomycin

Streptomycin, etc.

Novobiocin (low concentration)

Fluoroquindones

Spectinomycin (usually)

Danofloxacin

Tiamulin

Enrofloxacin

Trimethoprim

Marbofloxacin

Others

Bacitracin

Panfloxacin

Whether a drug is bactericidal or bacteriostatic needs to be known as problems can occur with combinations.

aminoglycosides, while others are bacteriostatic and

Drug combinations

require the animal's own defence mechanism to help in *the organisms' removal (Table 61.8). These definitions*

These are frequently used in veterinary practice but are

are only relative and some agents are bactericidal in

often best avoided. They are of used where infection

high concentrations but only bacteriostatic at low levels.

is due to mixed organisms. They can be helpful where

synergism has been shown with the combination, e.g.

biotic testing. Where they have occurred they involved

penicillin and aminoglycosides, or trimethoprim and

usage of milk. Another possible hazard is drug resist-

sulphonamides. Although the bacteriostatic or bacteri-

ance in humans but adequate documented evidence for

cidal nature of many drugs is dependent on the

the occurrence of this following consumption of milk or

concentration used, it is still a good ploy to combine

meat is still required. The main effect of antibiotics in

antibiotics with a similar activity. This is of particu-

milk is a commercial one in that it can affect the starter

lar importance when treating immunocompromised

cultures for cheese or yoghurt.

animals. Besides the broader spectrum of activity Various factors influence the withdrawal time and attained with some combinations, cost may be less and these include the drug dose rate, age, disease, duration in some cases there may be a reduction in toxicity. and role of therapy. The injection site will obviously When using combinations it is best to give each contain higher levels than other sites. Depending on drug individually at the correct dose with an interval how the drug is metabolized, the kidney and liver between administrations. When two drugs are com- may have higher levels than other tissues. In all bined in commercial preparations then the dosage of cases it is the duty of the veterinary surgeon to ensure each is fixed regardless of the needs of the particular that any withdrawal time is observed and that the situation or the interval between doses. Care should be owner of the animal is made aware of this. It is always taken in the choice of antimicrobial agent when used in best to write the time down either on the drug vial if combination with corticosteroids.

doses are to be provided for administration by the

farmer, or on an invoice or note to the farmer. Where

a withdrawal time is not known then the manufacturer

Cost

or distributor of the drug should be contacted.

However, in general, when no withholding time is

This is a major drawback in that often the best therapy

stated then milk must be discarded for seven days

cannot be instituted because of the expense. Repeat

and cattle may not be slaughtered for human con-

doses also cause problems, especially as oral therapy is

sumption for 28 days. In the USA veterinarians can

not often advisable in ruminants. The problem can be

obtain information on withdrawal times and residues by

overcome by long-acting preparations or providing

contacting the Food Animal Residue Avoidance Data

combination injections for the farmer or stockworker

book (FARAD).

to administer. It must be remembered there is an indi-

rect cost, particularly to the dairy farmer, in the length

of time the milk has to be withheld after the end

Legal considerations

of treatment. The beef farmer encounters a similar

The availability of antimicrobial agents in most coun-

problem regarding meat withdrawal time but to a lesser

tries is first dependent on their being licensed for use

extent.

by a regulatory authority. This can be the Veterinary

Medicines Directorate, Food and Drug Administration

Toxicity

or another similar body. Some antibiotics are available

in certain countries but are banned in others, e.g. chlo-

ramphenicol, which is prohibited from use in North

Except where there is routine usage of antimicrobial

America and most of Europe.

drugs in adult animals, few problems of toxicity

arise. Some of the more common are give in Table

61.9.

Frequency of dosing

Drug withdrawal times

The frequency of administering therapeutic prepara-

tions varies. Some compounds are placed in slow-

Following use of an antimicrobial agent there is now

release boluses to facilitate this. The rate of absorption

usually a period between finishing therapy and the use

also varies between different preparations, dependent

of the milk or the slaughter of the animal for meat. Milk

on the particle size; thus those with micronized parti-

or meat containing antibiotics can present a public

cles are rapidly absorbed. The form of the antibiotic

health risk. There is the possibility of allergy to peni-

will also influence the level of activity. Thus with

cillins or other antibacterials following medical pre-

penicillin, benzylpenicillin is rapidly absorbed (in

scription. Documented cases are rare and are now

minutes) to reach peak levels but only persists for

almost non-existent in countries with adequate anti-

about 6 hours. However, procaine benzylpenicillin

Table 61.9

Toxicity of antimicrobial drugs.

Penicillins

Very low toxicity, hypersensitivity. Occasional severe adverse reactions

Sulphonamides

Toxicity rare, rapid intravenous injection causes collapse and respiratory distress, crystalluria Macrolides

Pain and reaction following sc or im injections. Crystalluria not a problem in large animals. Erythromycin and tylosin irritant following injection

Lincomycin

Diarrhoea, reduced milk production (oral)

Aminoglycosides

Ototoxicity (unlikely), cardiovascular damage, hypotension (for toxic and shocked animals), renal toxicity Tetracyclines

Acute collapse syndrome (iv). Alimentary tract dysfunction (if oral). Deposition in bone and teeth Chloramphenicol

Little toxicity. Superinfection (oral). Anaemia in humans

Polymyxyn B Colistin

Usually only used topically as toxic shock and death can occur following parenteral use Nitrofurans

Acute – nervous signs

Chronic – haemorrhagic syndrome

Table 61.10

Some possible antibacterial therapy for infections in cattle.

Calves

Diarrhoea (acute) bacterial

Amoxycillin, ampicillin, (chloramphenicol), chlortetracycline, clavulanic acid and amoxycillin, danofloxacin, enrofloxacin, framycetin, marbofloxacin, *neomycin, oxytetracycline, trimethoprim and sulphonamide*

Diarrhoea (subacute) bacterial

Neomycin, nitrofurazone, oxytetracycline, sulphonamides

Joint ill

Lincomycin, oxytetracycline

Meningitis

(Chloramphenicol), danofloxacin, enrofloxacin, marbofloxacin, trimethoprim and sulphonamide

Navel ill

Amoxycillin, ampicillin, clavulanic acid and amoxycillin, oxytetracycline, trimethoprim and sulphonamide

Pneumonia

Amoxycillin, ampicillin, cefquinone, ceftiofur, cephalexin, clavulanic acid and amoxycillin, danofloxacin, enrofloxacin, florfenicol, marbofloxacin, oxytetracycline, penicillin and streptomycin, tilmicosin, tylosin

Ringworm

Griseofulvin, natamycin

Salmonella spp.

Amoxycillin, ampicillin, apramycin, (chloramphenicol), clavulanic acid and amoxycillin, danofloxacin, enrofloxacin, marbofloxacin, neomycin, nitrofurazone, trimethoprim and sulphonamide

Septicaemia

Amoxycillin, ampicillin, (chloramphenicol), clavulanic acid and amoxycillin, danofloxacin, enrofloxacin, marbofloxacin, trimethoprim and sulphonamide

Older cattle – injections

Actinomycosis

Amoxycillin, cephalexin, oxytetracycline, penicillin, sulphonamides Anthrax

Amoxycillin, oxytetracycline, penicillin and streptomycin

Blackleg

Benzylpenicillin

Clostridial infections

Oxytetracycline, pencillin

Diarrhoea (acute)

Sulphonamide

Infectious bovine keratoconjunctivitis

(Chloramphenicol), oxytetracycline

Leptospirosis

Amoxycillin, oxytetracycline, streptomycin

Mastitis (peracute) (parenteral)

Amoxycillin, ampicillin, cefquinone, cephalexin, oxytetracycline, trimethoprim and sulphonamide

Metritis

Amoxycillin, ceftiofur, cephalexin, clavulanic acid and amoxycillin, oxytetracycline Peritonitis

Sulphonamides, trimethoprim and sulphonamides

Pneumonia (acute)

Amoxycillin, ceftiofur, danofloxacin, enrofloxacin, marbofloxacin, oxytetracycline, trimethoprim and sulphonamide

Pneumonia (subacute)

Amoxycillin, ampicillin, ceftiofur, oxytetracycline, penicillin and streptomycin, trimethoprim and sulphonamide

Pyelonephritis

Procaine penicillin

Salmonella spp.

Amoxycillin, ampicillin, (chloramphenicol), danofloxacin, enrofloxacin, marbofloxacin, neomycin, trimethoprim and sulphonamide

Tetanus

Benzyl and procaine penicillin

Wooden tongue

Amoxycillin, oxytetracycline, penicillin and streptomycin, sulphonamide Note: Not all these drugs are registered for the species or for the use suggested.

Box 61.1

Advantages and disadvantages of slow-release

reaches a maximum level in 2–4 hours and persists for

antibiotic preparations.

24 hours, benethamine benzylpenicillin has a slow

absorption (6–24 hours) and may be effective for three

Advantages

to four days, and benzathine benzylpenicillin is slowly

Often used in prophylaxis

Post-operatively

absorbed over 6–24 hours and is often effective for four

Post calving where there has been intervention

to seven days.

Dry cow therapy: most remain about 3–4 weeks in udder but

The advantages and disadvantages of slow-release

some persist six weeks or longer

antibiotic preparations are given in Box 61.1.

Less stress to animal

Reduced handling

Less pain to animal

Possible antibacterial therapy

Convenience

for cattle

Disadvantages

Animals may not be examined as regularly as when injected

A survey of some of the drugs used in the treatment of

often

cattle is given in Table 61.10. It is emphasized that this

Thus animal less monitored

list is not complete and some preparations are not per-

Usually tissue and blood levels lower than routine injections

mitted in all countries.

Increased withholding time for milk or injection-to-slaughter

time

Chapter 62

Inflammation and Pain

J.L. Fitzpatrick, A.M. Nolan, P. Lees and S.A. May

The nature of inflammation

1045

tially, local blood flow increases. Vascular endothelial

Mediators and modulators of inflammation

1046

cells change their shape, with the formation of inter-

Classification of anti-inflammatory drugs

1048

endothelial cell gaps through which plasma leaks. This

Non-steroidal anti-inflammatory drugs (NSAIDs)

1050

leads to the formation of protein-containing exudate

Classification and mechanism of action

1050

(oedema fluid) in the interstitial compartment. At this

Actions and interactions of NSAIDs and general uses

1051

stage blood flow slows and eventually becomes static.

Pharmacokinetics of NSAIDs

1052

The contents of the microcirculation include plasma

Side-effects and toxicity of NSAIDs

1055

Residues

1056

and the cellular elements of blood. The phagocytic leu-

Steroids

1056

cocytes (neutrophils and monocytes) emigrate from the

Classification and general properties

1056

circulation during the inflammatory process and engulf

Mechanism of action

1057

the tissue irritant, including micro-organisms, in the

Administration and pharmacokinetics of steroids

1058

inflammatory exudate. The initial step is margination

Side-effects of steroids

1059

and adherence of leucocytes to the vascular endothelial

General uses of steroids

1059

wall, followed by pavementing, the process whereby the

Therapy with anti-inflammatory drugs

1060

cells roll along the wall to the inter-endothelial cell gaps.

Respiratory diseases

1060

Passage through the wall and directional movement to

Mastitis and endotoxaemia

1061

the site of injury occurs by the process of diapedesis.

Metritis

1063

Neutrophils are the first cell type to enter the lesion, fol-

Calf scours

1063

Hypersensitivity reactions

1063

lowed after several hours by mononuclear phagocytes.

Arthritis and joint diseases

1063

Other circulating cells (platelets, eosinophils and

Foot-and-mouth disease

1063

basophils) may also migrate to the extravascular space.

Pain

1063

Inflammation, if associated with infection, may be

Conclusions

1064

accompanied by fever, as the result of resetting of the

'thermostat' in the hypothalamus. These changes at the

level of the tissue or organ comprise Celsius' four clas-

The nature of inflammation

sical signs of inflammation, rubor et calore cum tumor

et dolor (redness and heat with swelling and pain) . To Inflammation (from the Latin inflammare, to burn) is

these Virchow added a fifth sign, functio laesa (loss of common to many diseases involving injury to living

function), many centuries later. The essential features

tissues. Inflammation is, in fact, the basis of most pathol-

of the acute inflammatory process are outlined in Fig.

ogy. Acute or chronic inflammation occurs as a conse-

62.1.

quence of chemical, physical or microbiological damage

The suffix '-itis' is appended to the name of the

to tissues. Acute inflammation has been described

affected tissue to describe organ-based inflammation in

as the response of the living microcirculation and its

the conditions of mastitis, bursitis, colitis, cystitis, metri-contents to injury. A range of defence mechanisms

tis, arthritis, tendonitis, laminitis and many others.

including the immune system may be utilized. If the

Severe local inflammation or more widespread inflam-

inflammation is caused by micro-organisms, tissue *mation, particularly associated with infection, may be*

damage may proceed as far as host cell death. An avas-

accompanied by fever.

cular tissue like cartilage, as with dead tissue, cannot

The outcome of acute inflammation may be resolu-

respond to injury by mounting an acute inflammatory

tion and hence restoration of normal tissue architecture

response, although in some circumstances it may

and function. However, particularly if the stimulus per-

degrade.

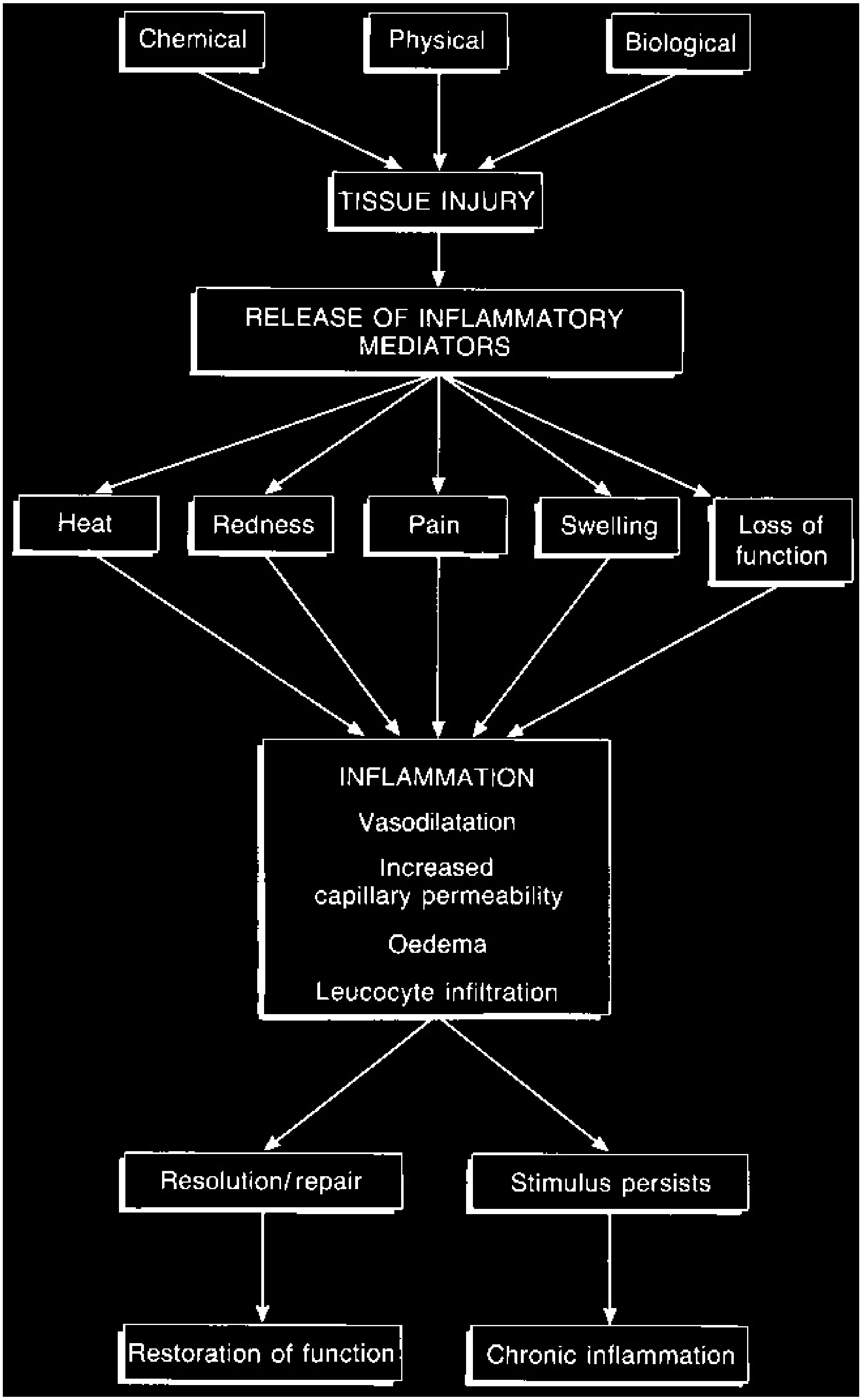
sists, tissue destruction may occur with fibrous tissue

The microcirculation therefore plays a crucial role in

formation and repair, potentially compromising normal

tissue response to injury. Blood vessels dilate and, ini-

function. In some cases, there may be delayed healing


Chemical
Physical
Biological
TISSUE INJURY
RELEASE OF INFLAMMATORY MEDIATORS
Heat
Redness
Pain
Swelling
Loss of function
INFLAMMATION
Vasodilatation
Increased capillary permeability
Oedema
Leucocyte infiltration
Resolution/repair
Stimulus persists
Restoration of function
Chronic inflammation

lesions, including sole ulceration, white line disease and acute digital tissue infection, leading to lameness. The pain component of inflammation arises from activation and sensitization of fine unmyelinated and some myelinated sensory fibres to the actions of chemicals released from a variety of sources during inflammation (Ferreira, 1983). Information from the periphery is conducted to the spinal cord and from there to the brain, where pain is perceived. Inflammation induces alterations in nociceptive information processing which may have serious consequences for the animal. Allodynia (perception of innocuous stimuli as noxious) and hyperalgesia (exaggerated responses to noxious stimuli) are common features of inflammatory pain (Coderre & Melzack, 1987; Nolan, 2000).

Mediators and modulators of inflammation

The characteristic pathophysiological changes of acute and chronic inflammation are produced by the action *of chemicals, either released from cells such as mast cells, macrophages and fibroblasts or formed by de novo synthesis. If there is an immune basis to the inflammatory response, lymphocytes are also involved. Compounds like histamine, that act directly to produce microvascular changes, or like bradykinin, to cause pain are called inflammatory mediators or, if their role has not been firmly established, they are termed putative mediators.*

The number of putative mediators identified is con-

Fig. 62.1

The inflammatory process.

siderable. Moreover, there are some species differences in mediators, so that, for example, 5-hydroxytryptamine (5-HT) is probably an acute inflammatory mediator in or even persistent chronic inflammation, with local pro-rodents only. Some mediators, such as complement liferation of connective tissue and mononuclear cell fragments C5a and C3a, not only act directly on the accumulation. The granulation tissue in chronic inflam-microcirculation but also cause mast cell degranulation, *mation comprises highly vascularized connective tissue.*

leading to histamine release and hence reinforcement

In some forms of chronic inflammation lymphocytes are

of the inflammatory response. In addition, there is a

present, suggesting an immune response superimposed

sequential release of mediators, such that histamine, 5-

on the inflammatory response.

HT and bradykinin are involved in the early part of the

Pain associated with inflammatory disease is proba-

acute phase, whereas lysosomal and other proteolytic

bly the major source of pain in ruminant species. The

enzymes are involved subsequently. Much is now

measurement of pain in animals is fraught with diffi-

known about acute inflammatory mediators; informa-

culties and, to date, pain research in animals has focused

tion on the mediators responsible for the transition to,

primarily on mechanisms of acute pain (e.g. Lascelles et

and the subsequent persistence of, chronic inflamma-

al., 1997; Dolan & Nolan, 2000). Pain is a complex expe-tion is more sparse. Examples of mediators inducing

rience, dependent not only on the severity of the insult

vascular leakage are bradykinin, histamine and platelet
to pain pathways and the degree of tissue or nerve
activating factor (PAF), which act directly, and
damage, but also on previous pain experiences and on
leukotriene B4 (LTB4) and complement fragment C5a,
social position within a herd. The most significant
which exert their effect through neutrophil-dependent
inflammatory diseases likely to be associated with pain
mechanisms (Williams, 1983). Mediators of cell migra-
in ruminants are mastitis and inflammatory limb
tion and accumulation include C5a, PAF, LTB4,

interleukin-1 (IL-1) and many other chemokines and
markedly both the pain produced by kinins such as
cytokines, whilst mediators responsible for producing
bradykinin and the increased vascular permeability
tissue damage include the neutral proteases and the
produced by simple amines, like histamine (Davies et
highly reactive oxygen (free) radicals, notably the
al. , 1984). Those compounds that amplify the actions of hydroxyl radical.
others are described as modulators of inflammation.

Mediator interactions are complex, and there are

The properties and sources of some important media-

compounds whose principal role is to interact synergis-

tors and modulators of inflammation and joint disease

tically with inflammatory mediators. For example, the

are described in Table 62.1. It should be noted that the

vasodilator prostanoid prostaglandin (PGE2) enhances

list is not comprehensive!

Table 62.1

Mediators and modulators of acute and chronic inflammation.

Putative mediator/modulator

Properties and source

Histamine

An amine produced from histidine by decarboxylation. Stored in mast cells, basophils and platelets. Mast cell degranulation leads to release into extracellular environment in immune and non-immune inflammation. Causes vasodilatation and increased permeability of small postcapillary venules. Local administration causes pain and itching 5-Hydroxytryptamine (serotonin) Another simple amine stored in platelets and mast cells. Increases permeability of small venules in rodents but probably at most a minor mediator in other species Bradykinin

A peptide containing nine amino acids that act on bradykinin receptors. Synthesized from plasma kinins de novo. Produces vasodilatation, increased vascular permeability and pain Neuropeptides

Main peptides involved are substance P, serokinin A (both tachykinins) and calcitonin gene related peptide. Induce mediator release, contract smooth *muscle and induce vasodilation Complement system*

Several complement components including C3a, C5a, C8, C9 exert proinflammatory actions, e.g. vasodilatation, increased vascular permeability, mast cell degranulation, leucocyte chemotaxis and cytolysis

Eicosanoids

PGE2

Derived from cell membrane phospholipid, following release of the precursor arachidonic acid.

Produces prolonged dilatation of small arterioles and potentiates the increased vascular permeability and pain produced by other mediators like histamine and bradykinin PGI2

A potent dilator of small arterioles. Possesses similar properties to PGE2 but with shorter duration of action

PGJ2

A derivative of PGD2. Believed to play a role as anti-inflammatory prostanoid in the resolution of acute inflammation

LTB4

Potent chemoattractant for polymorphonuclear leucocytes and mononuclear cells. Enhances vascular permeability produced by other mediators such as PGE2, PGI2 and bradykinin Lipoxin A

Produced from cell membrane phospholipid by polymorphonuclear leucoctyes. Stimulates leucocytes to generate superoxide radical and causes release of lysosomal enzymes. Lipoxins also possess anti-inflammatory properties and are probably involved in resolution of acute inflammation

Platelet activating factor (PAF)

An ether-linked analogue of phosphatidylcholine. Derived from cell membrane phospholipid.

Produces platelet and neutrophil aggregation, bronchoconstriction, vasodilatation, increased capillary permeability and chemotaxis

Interleukins and other

Produced by macrophages, chondrocytes and synovial cells.

cytokines, e.g. IL-1, TNF-a

Chemotactic for leucocytes and possess mitogenic and pyretic properties. Stimulate release of PGE2 and collagenase by chondrocytes, synovial cells and dermal fibroblasts. Possibly involved in cartilage breakdown. Other cytokines possess anti-inflammatory properties Enzymes

Lysosomal enzymes such as lysozyme and acid phosphatase concerned with lysis of foreign and host cells in acute and chronic inflammation. Non-lysosomal metalloproteinases such as stromelysin, concerned with proteoglycan breakdown in arthritis

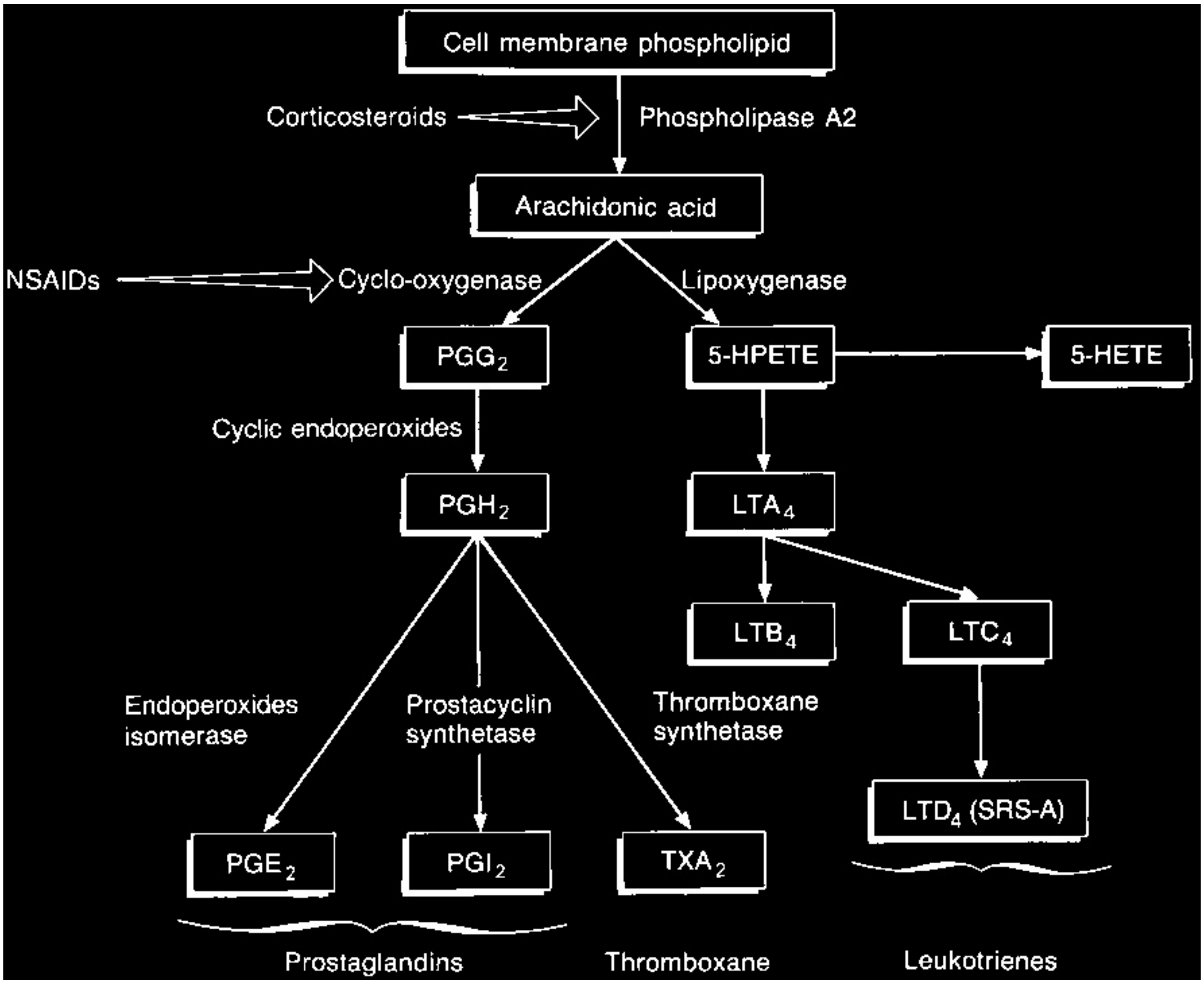


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Fig. 62.2

The arachidonic acid cascade

illustrating pathways of generation of

eicosanoids and proposed sites of action

of steroids and NSAIDs.

The eicosanoid group of mediators and modulators

Classification of

is particularly important to a consideration of the two

anti-inflammatory drugs

most important anti-inflammatory drug groups in cattle

medicine, steroids and non-steroidal anti-inflammatory

drugs (NSAIDs). Eicosanoids are formed from the 20-

In view of the complexity of the inflammatory process

carbon unsaturated fatty acid substrate arachidonic

and the involvement of many mediators and modula-

acid (Willoughby, 1968). Arachidonic acid is released

tors in determining the time course of inflammatory

from an esterified form in which it is bound as a natural

reactions, it is inevitable that those anti-inflammatory

component of the phospholipid of cell membranes. The

drugs with activity against a single mediator have only

release is catalysed by phospholipase A2, an acylhydro-

limited clinical effectiveness. With currently available

lase enzyme that is activated by tissue injury. Arachi-

drugs, it is easier to inhibit the pain, increased blood

donic acid may act as a substrate for two enzyme

flow and oedema associated with acute inflammation

groups, the cyclo-oxygenases (COX) and lipoxygenases

than it is to suppress chronic inflammation or the carti-
(LO). Cyclo-oxygenases catalyse the production of
lage breakdown that characterizes degenerative joint
prostanoids such as prostaglandin (PG)E2 and PGI2 and
disease. However, there have been some interesting
thromboxane A2 (TXA2) from the cyclic endoperoxides
recent advances in the latter field.
PGG2 and PGH2 (Fig. 62.2). Lipoxygenases, of which
Table 62.2 gives a general classification of drugs that
there are three groups, 5-LO, 12-LO and 15-LO, on the
either possess anti-inflammatory properties or that
other hand, are responsible for the synthesis of hydrox-
have been used to treat various joint diseases. Drugs
yeicosatetraenoic acids (HETEs), leukotrienes and
that inhibit COX are the classical aspirin-like drugs
lipoxins (Fig. 62.2). The importance of the arachidonic
collectively known as NSAIDs (Higgs et al., 1980, 1981).
acid pathway in inflammation in general, and in veteri-
The first compound of this class in clinical use was
nary therapeutics in particular, lies in the fact that the
salicylate, derived initially from the bark of willow and

steroids and NSAIDs act, at least partially, by inhibit-

poplar trees. Aspirin was the first synthetic NSAID; it

ing enzymes in the arachidonic acid pathway (Fig. 62.2)

is the acetyl derivative of salicylate and was introduced

(Higgs et al. , 1981). The NSAIDs act by inhibiting COX

into clinical medicine by Hoffman in 1898.

and thus they decrease the release of PGE2 and TXA2,

More recently introduced are the drugs that inhibit

since COX catalyses the conversion of arachidonic acid

both 5-LO and COX enzymes, so-called dual inhibitors.

released from cell membranes when they are damaged

By inhibiting the synthesis of leukotrienes such as LTB4

(Vane, 1971).

as well as prostanoids like PGE2, these novel com-

Table 62.2

Classification of anti-inflammatory drugs and drugs used in the treatment of joint disease.

Drug class

Examples

General properties

Antihistamines

Tripelenamine, mepyramine,

Classical histamine (H)1-receptor antagonists. Produce some

diphenhydramine

suppression of acute inflammation but limited to early phase of acute inflammation

COX inhibitors

Aspirin, phenylbutazone, flunixin,

Provide analgesia in inflammatory pain and some suppression of carprofen, meloxicam, tolfenamic

vascular changes in inflammation. Little or no effect on leucocyte acid, vedaprofen, ketoprofen

migration. Gastrointestinal ulceration may occur and blood

dyscrasias; hepatotoxicity and renotoxicity may arise

occasionally

Dual inhibitors of

Tepoxalin

Inhibit most changes in acute inflammation, possess fewer side-COX/5-LO

effects than pure COX inhibitors

Corticosteroids

Hydrocortisone, cortisone,

Suppress all components of acute and chronic inflammation but *dexamethasone, betamethasone,*

side-effects associated with medium- to long-term use (adrenal prednisolone, prednisone,

atrophy, immune suppression, decreased bone strength,

triamcinolone

Cushinoid symptoms, delayed wound healing, muscle wastage,

etc.)

Disease modifying agents

Penicillamine, gold salts

Retard the degenerative changes in immune-based arthritides.

Very slow onset of effects (several weeks). Potentially severe side-effects, little veterinary use

Cytotoxic agents

Cyclophosphamide,

Used in rheumatoid arthritis in the dog. Immune suppression

chlorambucil

and other toxic effects to rapidly dividing cells limit clinical value Free radical scavengers

Orgotein, copper-containing

Possess superoxide dismutase activity. Scavenge toxic free

compounds, DMSO, some

radicals, e.g. superoxide, hydroxyl

NSAIDs

Miscellaneous

Hyaluronic acid, polysulphated

Inhibit prostaglandin synthesis and proteolytic enzymes, e.g.

glycosaminoglycan, pentosan

stromelysin. Administration by intra-articular injection may be sulphate

required for some drugs

pounds may provide the basis for the introduction of

inhibit induction of one isoform of COX, described as

agents with a broader spectrum of activity than

COX-2 (see below).

inhibitors of COX enzymes alone. They may be of use

Of other drug classes listed in Table 62.2 several,

in immune-based diseases such as asthma, chronic

including immune stimulants, disease modifying agents

obstructive pulmonary disease and insect bite allergies.

and cytotoxic agents, have been used extensively to

However, only one compound of this class, tepoxalin, is

treat rheumatoid arthritis in man. They slow the pro-

currently in veterinary use in the dog. An interesting

gressive degenerative changes in cartilage and soft *feature of dual inhibitors is their excellent gastroin-*

tissue inflammation in this disease. Some have also

testinal tolerance.

been used for similar therapy in veterinary medicine,

Corticosteroids are the anti-inflammatory agents that

notably in the dog, but their use has been limited by

provide a greater control of all elements of both acute

several factors such as slow onset of action and poten-

and chronic inflammation than any other class of drug.

tially severe side-effects have prevented extensive vet-

They exert membrane-stabilizing properties on lysoso-

erinary use. They are not used in bovine medicine.

mal and cell membranes. Through this and other

Other drugs which have been used in the therapy of

actions, they suppress the release of inflammatory

joint disease, especially in the horse, are the free radical

mediators and act to preserve cell integrity. Their mode

scavengers orgotein and dimethyl sulphoxide (DMSO)

of action is multifactorial. It is attributable partly to

and drugs with uncertain mechanisms of action,

their action on the cell nucleus to promote, by protein *hyaluronic acid and chondroprotective agents. Again,*

transcription, the synthesis of a group of endogenous

the use of these compounds in bovine medicine has

polypeptides with antiphospholipase activity, the

been very restricted to date, mostly due to lack of

lipocortins or annexins (Fig. 62.2). However, they also

licensed products for use in food producing species.

Non-steroidal

produce hyperalgesia, inflammation, pyrexia and

anti-inflammatory drugs (NSAIDs)

platelet coagulation (Fig. 62.2). Differences in relative

potency between drugs for these activities are probably

Classification and mechanism of action

due to tissue differences in enzyme structure, i.e. the

existence of isoenzymes. Two forms of COX have been

The organic acid drugs in this important group of com-

identified, COX-1, a constitutive enzyme, and COX-2,

pounds can be divided into two subclasses, carboxylic

which is expressed constitutively in some tissues, but is

acids (R—COOH) and enolic acids (R—COH).

also inducible. The existence of COX isoenzymes may

Further subdivisions can be made on the basis of chem-

also explain species differences in plasma concentra-

ical structure. For example, the main enolic acid groups

tions required for efficacy. Therapeutic concentrations

are pyrazolone derivatives, such as phenylbutazone and

of phenylbutazone in the horse are of the order of

oxicams, like piroxicam; the carboxylic acid groups

10–30 mg/ml (Gerring et al., 1981), however, in cattle include the propionic acid drugs such as ketoprofen.

even higher concentrations produce only limited COX

Most non-steroidal anti-inflammatory drugs (NSAIDs)

inhibition (Arifah & Lees, 2002).

possess three principal types of pharmacological activ-

All NSAIDs can have antithrombotic effects by

ity: peripheral analgesic and anti-inflammatory actions

blocking platelet COX-1, and thus inhibiting produc-

and central antipyretic, anti-inflammatory and analgesic

tion of the proaggregatory eicosanoid, TXA2. However,

actions (Table 62.3). Some differences between drugs

at therapeutic doses most NSAIDs do not impair clot-

have been reported for the three types of activity.

ting mechanisms or prolong bleeding time. Aspirin is

Paracetamol possesses weak peripheral actions and

unique in this respect since it irreversibly binds to COX

does not produce significant gastrointestinal irritation.

so that production of TXA2 is inhibited for the life-span

However, it is a relatively weak anti-inflammatory drug

of the platelet. Consequently, aspirin is a potent anti-

and is principally a centrally-acting analgesic (Lees et

thrombotic drug.

al., 1991; McKellar et al., 1991).

COX-1 may also contribute to the inflammatory

An important action of NSAIDs, underlying their

process and in particular to the pain component and,

therapeutic uses, is inhibition of COX and consequent

consequently, COX-2 selective inhibitors may not be

inhibition of production of the eicosanoids, which

as efficacious as mixed inhibitors in their anti-

Table 62.3

Principal therapeutic and toxic effects of NSAIDs.

Site of action

Pharmacological or toxicological action/therapeutic use

Therapeutic effects

CNS

Antipyretic. Lowering of body temperature in patients with fever but not in normothermic subjects. Action on temperature regulating centre in hypothalamus

Analgesic and anti-inflammatory. Mechanisms poorly understood

Peripheral

Anti-inflammatory in acute inflammation and analgesic against inflammatory, but not against non-inflammatory pain

Antithrombotic through inhibition of platelet COX. Aspirin, irreversible inhibitor of COX

Anti-endotoxic. Some effects on endotoxin due to release of eicosanoid synthesis being inhibited by NSAIDs

Toxic effects

Gastrointestinal tract

Ulcerogenic following parenteral as well as oral administration. Blood or plasma loss. Melaena. Emesis in simple-stomached animals only

Kidney

Nephropathies such as renal papillary necrosis

Liver

Both cholestatic and parenchymal cell toxicity

Blood cells and

Various dyscrasias including aplastic and haemolytic anaemias and *agranulocytosis described.*

cardiovascular

Methaemoglobinaemia, hypoprothrombinaemia and prolongation of bleeding time. Small vein phlebopathy.

system

Alteration of acid-base and electrolyte balance

Skin

Urticaria, erythema

Fetus

Teratogenic and embryopathic effects with some drugs. Delayed gestation at term

inflammatory actions.

COX-2 is constitutively

inflammatory agents and this suggests that the princi-

expressed in kidney, and mice which have the COX-2

pal mechanism of action, of at least some drugs, is due

gene deleted suffer from renal failure and are poorly

to some other effect. Carprofen, for example, has been

viable, while displaying inflammatory responses similar

shown to inhibit secretion of interleukin 6 (IL-6)

to normal mice. Both COX-1 and COX-2 are constitu-

(Armstrong & Lees, 2002).

tively expressed in the central nervous system (CNS)

In general, NSAIDs do not, at clinical dose rates,

and their relative expression varies depending on

affect all components of the inflammatory response.

species. More work is required to elucidate the role of

They do not affect cellular events or minimize tissue

these enzymes in CNS function. COX-2 generated PGs

damage, although high doses of some drugs do possess

are also involved in ovulation, parturition and may be

free radical scavenging properties, suggesting tissue

involved in the resolution phase of acute inflammation

healing mechanisms may be impaired, but more

and wound repair.

research in this field is required.

Until recently, it was considered that the PGs that

Other actions of NSAIDs have been described.

mediate inflammation, fever and pain were produced

Recent evidence suggests that some NSAIDs can act by

by COX-2, while the PGs that are important in gas-

mechanisms other than COX inhibition; for example, *trointestinal and renal function are produced via COX-*

aspirin inhibits the transcription factor NF-kB pathway

1. This led to the belief that the NSAIDs exerted their

(Kopp & Ghosh, 1994), and recently the R(-)- and

therapeutically beneficial effects primarily by inhibiting

S(+)-enantiomers of ibuprofen were reported to inhibit

COX-2, while inhibition of COX-1 was considered to

activation of NF-kB (Scheuren et al., 1998), an effect be responsible for some of the toxic side-effects associ-independent of specific COX inhibition. By preventing

ated with these drugs, e.g. gastric ulceration and renal

the translocation of NF-kB into the nucleus, NSAIDs

papillary necrosis.

modify the expression of genes such as the COX-2 gene,

Recent work has indicated that the distinction

which is involved in the cellular response to acute

between the two roles of COX-1 and COX-2 is not as

inflammation. Furthermore, activation of the glutamate

clear as was once considered (for review see Wallace,

receptor, N-methyl d-aspartate (NMDA), a key step in

1999). Most commercially available NSAIDs at present

both the induction and maintenance of inflammatory *licensed for use in animals inhibit both enzymes. There*

hyperalgesia, activates NF-kB (Guerrini et al., 1995).

is much controversy over the selectivity of these com-

An action on prostanoid receptors has been described

pounds, with conflicting data being obtained depending

for meclofenamic acid (see above), while some drugs

on the test systems used for assessing COX-1 and COX-

inhibit glucuronidase release from neutrophils. Recent

2 selectivity and whether these assays were carried out

work in humans has indicated a role for COX-2 inhibi-

in vitro, ex vivo or in vivo. In addition, drugs may tion in the therapy of colonic cancer. This may repre-appear selective for one enzyme over the other, while

sent a new role for NSAID use in the future.

not being highly potent. Currently, there are no truly

selective/specific COX-2 inhibitor drugs licensed for

Actions and interactions of NSAIDs and

use in veterinary medicine. The balance of evidence

general uses

currently available suggests that phenylbutazone, flu-

nixin and ketoprofen are non-selective, whereas car-

The analgesic action of most NSAIDs on the CNS is *profen, meloxicam and tolfenamic acid are COX-2*

weaker than that provided by narcotic analgesic drugs

preferring, depending on the test systems used. There

of the morphine type. To what extent the central anal-

is, however, evidence of specific differences on COX1 :

gesic effect accounts for the clinical efficacy of NSAIDs

COX2 selectivity in ruminant species.

is unclear, but there is increasing recognition of its

While most NSAIDs inhibit COX very effectively,

importance for some drugs. The peripheral analgesic

other actions, both on the arachidonic acid pathway and

effect is thought to be due to blockade of synthesis

on other unrelated enzymes, may contribute to their

of PGs, which exert hyperalgesic actions through syner-

effects. For example, some fenamate derivatives inhibit

gism with pain-inducing mediators like bradykinin

some (but not all) actions of PGs by blocking activity

(Ferreira, 1983). Suppression of pain produced by tis-

at PG receptors in addition to blocking their synthesis.

sue damage is a major use of NSAIDs, together with

High doses of most NSAIDs also block 5-LO, and thus

suppression of the acute inflammation associated with
suppress leukotriene synthesis. However, it is doubtful
tissue trauma. Post surgical use of NSAIDs to provide
whether this action contributes significantly to the clin-
analgesia and to reduce oedematous swelling that can
ical efficacy of most NSAIDs, although tepoxalin is
lead to wound breakdown is now widespread. These
exceptional in this respect. Finally, some NSAIDs
drugs are clearly of value in the former circumstance,
(carprofen is one example), although relatively weak
but the doses required for anti-oedematous actions may
COX inhibitors, are nevertheless effective anti-
be higher and are less well established in veterinary

medicine. NSAIDs have been used increasingly alone to
per cent per day. Longer inhibition can occur if signifi-
treat acute inflammatory conditions caused by micro-
cant amounts of aspirin penetrate to the developing
bial diseases but, more usually, they are combined with
megakaryocytes in bone marrow.
antibacterial agents. Endotoxic shock may result from a

This action of aspirin explains its use in preventing
number of disease states when endotoxin derived from
clot formation in humans who may be prone to throm-
Gram-negative bacterial cell walls is released into the
boembolic diseases. It is of interest that low doses
circulatory system. This may occur, for example, in cases
of aspirin are preferred in these subjects, because in-
of equine colic, acute and peracute mastitis, metritis
hibition of synthesis of PGI2, an endogenous anti-
and in septic peritonitis. Some of the ensuing effects on
aggregatory agent released from endothelial cells, by
cardiovascular function and the respiratory system,
high aspirin doses could offset blockade of synthesis
together with metabolic and gastrointestinal changes,
of TXA2 by platelets. Low aspirin doses, administered
are produced by the release of eicosanoids such as PGI2
once daily or every second day, very effectively inhibit
and TXA2. Hence, the pathophysiological changes asso-
platelet COX, without seriously impairing COX in
ciated with endotoxaemia are generally suppressed,
endothelial cells. The full potential for the antithrom-

though rarely abolished, by NSAIDs such as flunixin.

botic action of aspirin in veterinary medicine has not

This is particularly so when, in experimental circum-

yet been fully explored, although it is recommended for

stances, the drugs are administered prior to the onset of

use in prevention of aortic embolism in cats and may

endotoxaemia. However, the effectiveness of these

be of value in conditions such as laminitis, navicular

drugs once shock is established is likely to be less than

disease and disseminated intravascular coagulation.

when pre-treatment is possible. The clinical value of

The use of two, or more, NSAIDs in combination

NSAIDs therefore remains to be established; however,

generally has no clear advantages over the administra-

anti-endotoxaemic effects have been demonstrated for

tion of a single drug at a higher dose rate. Most NSAIDs

flunixin meglumine at doses considerably less than

probably act by the same mechanisms and they are

those required for anti-inflammatory or analgesic activ-

likely to be additive in their toxic as well as their ther-

ity (approximately ¥0.25).

apeutic effects. Non-steroidal anti-inflammatory drugs

Prostaglandin E2 is a pyretic agent released as a result

have been licensed for the treatment of inflammation

of the action of endogenous pyrogens such as IL-1. The

in animal species and, more recently, their potent anti-

local release of PGE2 in the anterior hypothalamus

hyperalgesic activity has been recognized (Welsh &

leads to resetting of the thermoregulatory centre.

Nolan, 1994; Cheng et al., 1998). Although the meas-

NSAID inhibition of PGE2 synthesis accounts for their

urement of pain in ruminants has not been described

antipyretic action when infections are accompanied by

frequently, workers have described the occurrence of

fever. The reduction in body temperature gives symp-

hyperalgesia in animals suffering from lameness (Ley et

tomatic relief in such patients. However, NSAIDs may

al., 1995; Whay et al., 1998; Dolan & Nolan, 2000) and theoretically influence adversely viral diseases, since the

mastitis (Fitzpatrick et al., 1998). While the magnitude production and release of interferons are increased in

of hyperalgesia does not appear to be related to the

pyrexia. In spite of this, NSAIDs have been used in the *stimulus intensity, the duration of hyperalgesia does*

treatment of respiratory disease produced by parain-

appear to be correlated significantly to the intensity of

fluenza type 3 (PI3) virus in calves and in the therapy

the inflammatory stimulus (Nolan, pers. obs. supported

of acute interstitial pneumonia caused by Ascaris suum

by Fitzpatrick et al., 1998; Dolan & Nolan, 1999; Dolan in pigs (Selman et al., 1984; Selman, 1988). Both the

& Nolan, 2000). Inflammatory conditions that induce

anti-inflammatory action in the lungs and the central

hyperalgesia therefore probably induce spontaneous

antipyretic action may underlie the therapeutic

pain in the first instance, and contribute to adverse

response in these diseases.

welfare over a longer duration (Dolan & Nolan, 2000).

Aspirin differs from other NSAIDs in that its

Thus, measurement of hyperalgesia is potentially a

inhibitory action on COX is irreversible (Lees et al., useful tool in validating disease severity and since it is

1987). It covalently acetylates the enzyme, which is,

a consequence of altered pain processing, it provides a

in consequence, permanently inhibited. In most body pathophysiological link between disease and pain.

cells new COX enzyme can be synthesized in the cell

nucleus. As aspirin concentration falls the cell's ability

Pharmacokinetics of NSAIDs

to form the products of COX metabolism is restored.

However, the platelet cannot do this. The platelet is

The pH of fluids within the gastrointestinal tract varies

anuclear and the enzyme is thus inactivated perma-

but at all sites it is usually more acidic than plasma.

nently, i.e. for the lifespan of the platelet. Partial inhi-

In the stomach of monogastric species, fluid pH can be

bition may persist for several days since platelet

as low as 1.0. This marked difference from plasma

numbers are replaced at the rate of approximately 10

increases, by the mechanism of ionic trapping, the rate

at which NSAIDs are absorbed. Being weak organic

Thus many NSAIDs are retained at the site of inflam-

acids they are relatively less ionized in gastrointestinal

mation for periods long in excess of those predicted by

tract liquor than in plasma and this facilitates absorp-

the plasma half-lives. In consequence, there are signifi-

tion. A similar mechanism, enhancing NSAID absorp-

cant differences in dosing schedules between species.

tion, will operate in ruminants in the reticulum and

As well as species differences in pharmacokinetics, the

rumen, where liquor pH is also acid relative to plasma.

possibility of breed differences should be noted, as has

However, the normal pH, approximately 4–5, is less acid

been described for naproxen in dogs. Whether similar

than the gastric juice of monogastric species. Moreover,

differences occur for any NSAIDs in other species,

other factors are involved in determining rates of

including cattle, is not known, but such information is

absorption. Low drug solubility in acidic conditions for

clearly important to the rational setting of efficacious

some NSAIDs, such as aspirin, can lead to precipitation

and safe dosage schedules.

in the stomach and this prolongs and slows absorption

A further factor relevant to the activity of some

and may also increase local irritation. Diet can also be

NSAIDs is the formation in vivo of active metabolites.

an important factor in horses and ruminants, since some

The conversion of aspirin to salicylate is one example.

NSAIDs may be adsorbed on to hay. Such binding to

Another is the hydroxylation of phenylbutazone in

feed, with subsequent release of the drug by fermenta-

several positions. One such metabolite, oxyphenbuta-

tive digestion within the large intestine of the horse, has

zone, is of similar potency to phenylbutazone and is

been suggested as a cause of the ulcerogenic action of

formed in the liver in quantities that are sufficient to

phenylbutazone in the distal parts of the gastrointesti-

contribute about one-fifth of the overall activity in the

nal tract (Lees & Higgins, 1985; Maitho et al., 1986). In horse. Plasma concentrations achieved in the goat may

spite of these factors, absorption of most NSAIDs is

also be significant, but in both young and adult cattle,

generally good after oral dosing in all species and

concentrations are low or undetectable and no contri-

bioavailability generally exceeds 50 per cent.

bution of oxyphenbutazone to efficacy can therefore be

Another factor that may potentially markedly influ-

assumed in cattle.

ence NSAID absorption following oral dosing in rumi-

Age may also affect NSAID pharmacokinetics. In

nants is operation of the oesophageal groove reflex.

general, both urinary excretion and hepatic biotrans-

Closure of the groove can direct orally administered

formation of drugs are less efficient in very young

substances directly to the abomasum and this will gen-

animals, aged less than two to six weeks depending on

erally speed absorption into plasma, since dilution

species. Aged animals may also metabolize and excrete

within the vast fluid volume in the rumen inevitably

NSAIDs less readily than young adults. There is some

extends the time course of absorption. Double peaks in

evidence in support of this for phenylbutazone in the

the plasma concentration–time curve of the NSAID

horse (Lees et al. , 1985). Reduced capacity to metabo-meclofenamate after oral dosing in sheep have been

lize drugs in the liver is likely to be of greater signifi-

attributed to an initial rapid absorption phase from the

cance than any decreased renal excretory capacity in *abomasum and slower subsequent absorption from the*

the case of NSAIDs, since virtually all are highly bound

rumen-reticulum of that fraction of the administered

(usually greater than 98 per cent) to plasma protein.

dose which enters the rumen (Marriner & Bogan,

Consequently, less than 2 per cent of the drug in plasma

1979). A similar mechanism of oesophageal closure

is available for excretion in urine by glomerular filtra-

does not seem to operate for oral phenylbutazone in

tion. This small fraction is readily excreted in the urine

adult cattle (Lees et al. , 1988). Further studies are of herbivores, since it is 'trapped' in ionized form in the

required to determine to what extent species, drug sub-

alkaline urine, i.e. tubular reabsorption is limited or

stance, drug formulation and age determine operation

absent. Nevertheless, only a very small proportion of

of the oesophageal groove reflex. NSAIDs are usually

the administered dose will be removed from the body

administered parenterally. Some NSAIDs are irritant

by urinary excretion of parent drug. Reduced dosage or

to tissues when injected perivascularly but flunixin, *longer intervals between doses is probably required in*

meloxicam and carprofen can be given intramuscularly

both young and old animals.

or subcutaneously when absorption is rapid and tissue

Limited and indirect evidence indicates that at least

irritation is minimal. Species differences in pharmaco-

some NSAIDs are excreted by active secretion in bile

kinetic parameters, particularly clearance and elimina-

in cattle, possibly with subsequent reabsorption to

tion half-life, have been described for many NSAIDs

create an entero-hepatic shunt. This is suggested, for

and within the bovine species elimination half-lives

example, by the 'kink' in the plasma concentration–time

vary between drugs and with different studies. How-

curve that occurs consistently following the administra-

ever, it should be noted that plasma half-lives of the

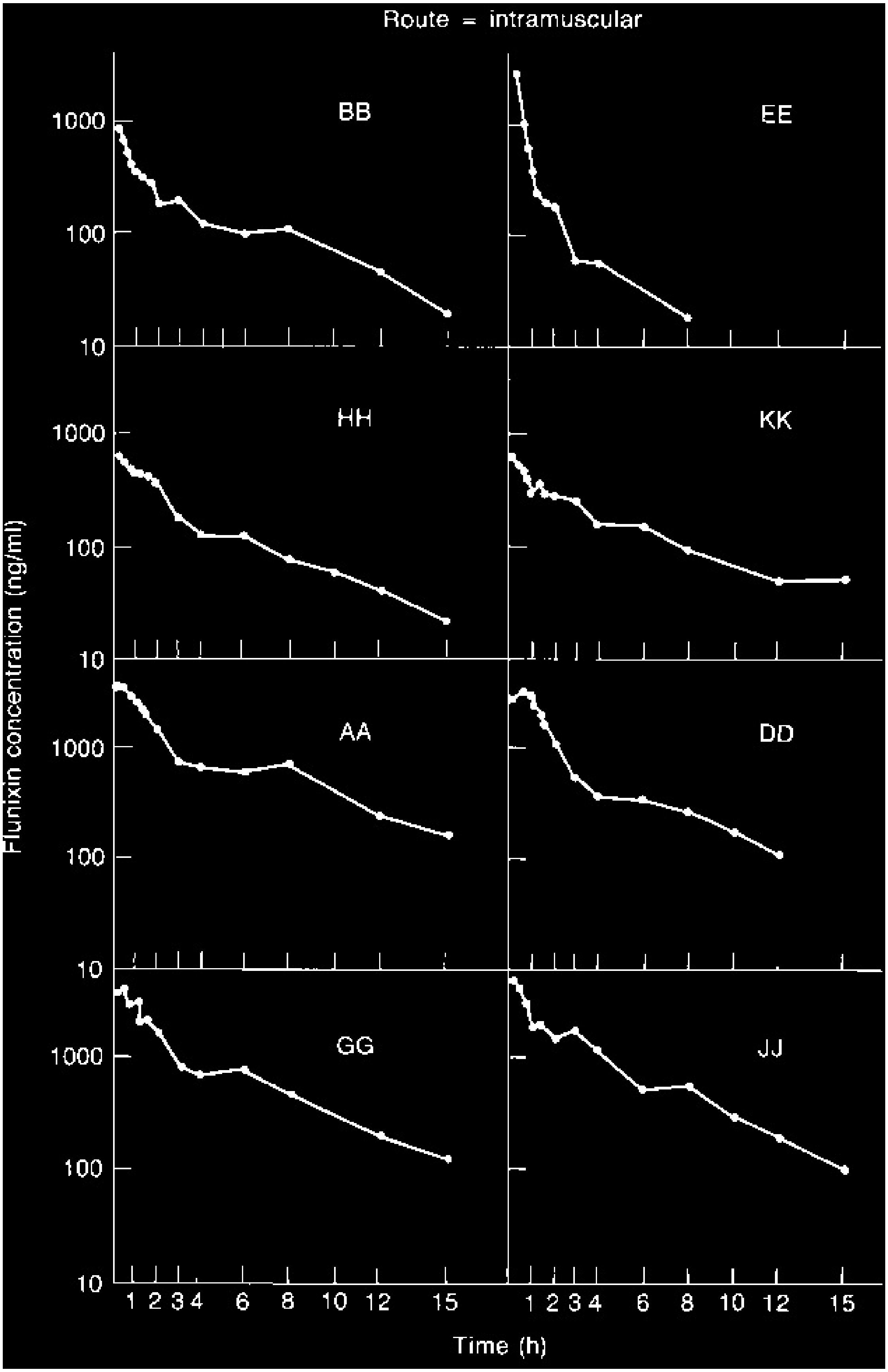
tion of flunixin intravenously and intramuscularly to

NSAIDs do not always relate to the tissue half-lives

calves (Fig. 62.3). Studies of bile : plasma concentration

because of the tissue binding properties of the drugs.

ratio are required to investigate this possibility further.



Route = intramuscular
BB
EE
HH
KK
AA
DD
GG
JJ
1000
100
10
Flunixin concentration (ng/ml)
1 2 3 4 6 8 10 12 15
Time (h)

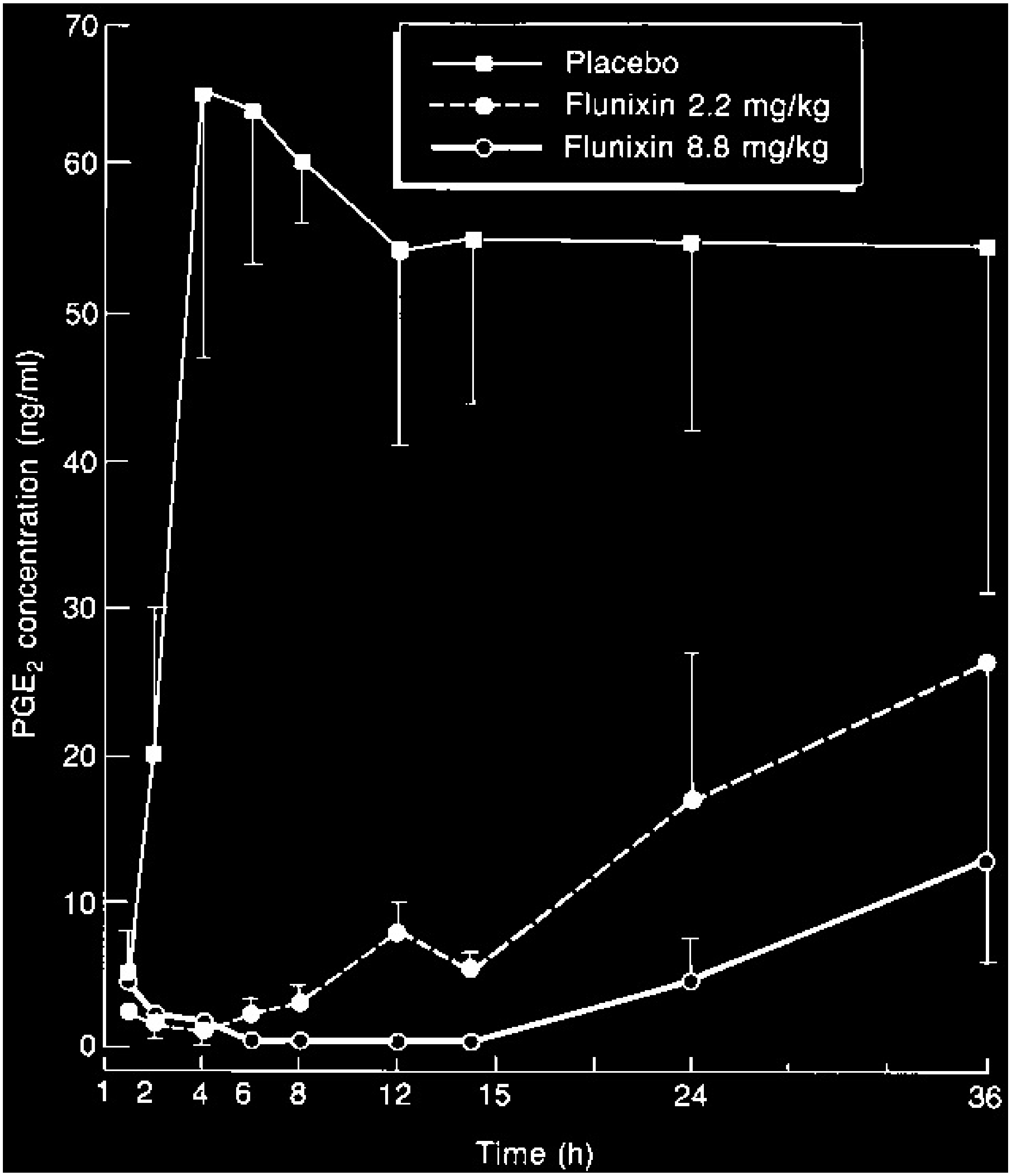


Fig. 62.4

Influence of two dose rates of fluxinin (2.2 and 8.8 *mg/kg body weight) administered intramuscularly to calves on*

the generation of the pro-inflammatory mediator, PGE2, in

carageenan-induced inflammatory exudates. Each point is the

mean ± SEM for six animals.

Fig. 62.3

Plasma concentration–time curves for eight calves

clearance of carprofen was slower in animals aged 8

receiving fluxinin meglumine by intramuscular injection at two weeks than in 16 week old animals (Lees et al. , 1986; dose rates: 2.2 mg/kg body weight (BB, EE, HH, KK) and 8.8

Delatour et al. , 1996). Profound differences in ketopro-mg/kg body weight (AA, DD, GG, JJ).

fen pharmacokinetics were demonstrated in young

goats compared to adult animals (Eltom et al. , 1993).

Second, the pharmacological actions may be longer for

Knowledge of the pharmacokinetics of particular

NSAIDs than might be predicted from plasma clear-

NSAIDs cannot be transposed between species since

ance data. Studies have shown that relatively prolonged

interspecies differences are marked. Pharmacokinetic

inhibition of production of the inflammatory and hyper-

data in cattle are available for flunixin, tolfenamic acid, *algesic mediator, PGE2, is produced by therapeutic*

ketoprofen, carprofen and meloxicam and these drugs

doses of flunixin, tolfenamic acid and ketoprofen,

have licensed products in the UK for use in food-

administered to calves (Landoni et al. , 1995a, 1996; Lees producing species (NOAH Compendium of Data Sheets

et al. , 1998) (Fig. 62.4) and, moreover, there are likely for Veterinary Products 2000–2001). Pharmacokinetic

to be species differences in IC50 values for inhibition of

data are available for other drugs including aspirin and

COX isoenzymes. This has been shown for example in

phenylbutazone, neither of which are licensed currently

studies comparing COX isoenzymes from the horse and

for use in food producing animals. Phenylbutazone has

the dog (Brideau et al. , 2001; Armstrong & Lees, 2002).

a long half life (40–60 hours) in both calves and adult

In cattle, tolfenamic acid was shown to significantly

cattle (Arifah & Lees, 2002). Even when basic pharma-

inhibit serum TXA2 and inflammatory exudate PGE2,

cokinetic data are available, it is not possible to define

measured as indicators of blockade of the isoforms

dosage schedules with such data alone for two reasons.

COX-1 and COX-2, respectively (Lees et al. , 1998).

First, different plasma and tissue concentrations of

Whilst penetration of these drugs into tissue cage fluid

NSAIDs are likely to be required for the various

was poor, passage into acute inflammatory exudate

therapeutic effects of analgesic, anti-inflammatory,

was good and clearance from the latter fluid was slow,

antipyretic and antithrombotic actions. In calves,

i.e. there was a strong tendency for them to accumulate.

It is likely that three distribution compartments

melaena. For example, high doses of phenylbutazone

relating to the different sites of action of the NSAIDs

administered to the horse can quickly lead to significant

exist: a central compartment and shallow and deep

plasma loss, haemoconcentration and death from hypo-

peripheral compartments (Landoni et al. , 1995b, 1996).

volaemic shock only a few days after the commence-

The very high degree of binding to plasma protein

ment of therapy. The horse may be particularly

probably explains both the relatively high concentra-

susceptible to this effect of phenylbutazone (Lees &

tion in inflammatory exudate, into which plasma

Higgins, 1985).

protein passes readily, and the low concentration in

Until recently,

it was considered that the

interstitial fluid into which it does not. Similar con-

prostaglandins that mediate inflammation, fever and

siderations apply to most NSAIDs, since almost all

pain were produced by COX-2,

while the

are highly bound to plasma protein (Galbraith &

prostaglandins that are important in gastrointestinal

McKellar, 1996).

and renal function are produced via COX-1. This led to

the belief that the NSAIDs exerted their therapeuti-

cally beneficial effects primarily by inhibiting COX-2,

Side-effects and toxicity of NSAIDs

while inhibition of COX-1was considered to be respon-

At high dose rates NSAIDs may affect a number of bio-

sible for most or all of the toxic side-effects associated *chemical pathways. However, with clinical doses the*

with these drugs, e.g. gastric ulceration and renal papil-

toxic effects of most drugs, like the therapeutic effects,

lary necrosis. Recent work has indicated that the dis-

are probably caused primarily by inhibition of COX.

tinction between these two roles is not as clear as was

There are exceptions, however. Carprofen is a relatively

once considered (for review see Wallace, 1999). Thus,

weak inhibitor of COX, except in sheep where it pro-

highly COX-2 selective drugs (still in development) are

duced marked inhibition (Cheng et al. , 2002), but it is, gastro-protective and do not induce gastric ulceration.

nonetheless, an effective anti-inflammatory agent.

However, COX-2, while expressed in low amounts in a

The NSAID side-effect reported most commonly is

healthy stomach, appears to play an important role in

irritation leading potentially to ulceration of the gas-

promoting ulcer healing in the stomach. Consequently

trointestinal mucosa. All NSAIDs produce this effect at

where gastric ulceration is present, COX-2 inhibitors

high dose rates and with most drugs some gastric irri-

may delay healing as, indeed, may non-selective COX tation is associated with oral dosing with therapeutic inhibitors.

dose levels. The mechanism of action may involve Useful data on the ulcerogenic actions of particular back-diffusion of acid, although ulceration is not NSAIDs in cattle and any relationship to age, dose restricted to the stomach; it may occur throughout the administered and route of administration are generally gastrointestinal tract and it may accompany intra- lacking. However, there is no reason to suppose that venous as well as oral dosing. The vasodilator ruminant species are not susceptible to the ulcerogenic eicosanoid PGI2, generated in the COX pathway, may action of these drugs. Attempts have been made to be a local hormone controlling blood flow to the gas- reduce the degree of gastrointestinal tract irritation by trointestinal mucosa. By inhibiting the synthesis of the use of slow-release formulations, enteric coating PGI2, NSAIDs may produce ischaemia and hence and water-soluble salts. The use of such approaches in *hypoxia of the mucosal surface. This may be the*

cattle does not seem to have been described in the lit-

mechanism that causes erosion and hence ulceration

erature. In ruminants, in general, NSAIDs are adminis-

of the gastrointestinal tract mucosa.

tered parenterally.

The ratio of doses of NSAIDs producing ulcero-

Non-steroidal anti-inflammatory drugs may be

genicity relative to anti-inflammatory and analgesic

nephrotoxic. At high dose rates they may produce

activities seems to be low for some drugs, e.g. aspirin,

tubular nephritis. Renal papillary necrosis has also been

intermediate for others such as phenylbutazone and

reported in man. In horses papillary necrosis has been

high for some selective agents, e.g. COX 2 inhibitors. It

described in animals that received clinical doses of

is, however, not possible to draw general conclusions

NSAIDs. However, this occurred only when horses on

concerning particular NSAIDs since many factors

NSAID therapy also had restricted access to water.

have been claimed to influence their ulcerogenicity

Retention of fluid leading to oedema is a commonly

(Rainsford, 1977); these include species, age, sex and the

reported side-effect of NSAIDs in humans. Oedema

animal's nutritional status. Moreover, high drug con-

seems to be uncommon and transient in animals, but

centrations in bile for some NSAIDs may explain

has been described in horses receiving phenylbutazone

lesions occurring in distal regions of the gut. When

(Lees et al. , 1983). Cholestatic and parenchymal hepa-severe, the gastrointestinal ulceration induced by

totoxicity have also been reported in animals. Since

NSAIDs can lead to plasma protein-losing enteropathy

most NSAIDs are metabolized in the liver, any toxicity

or to blood losses into the gastrointestinal tract and

to parenchymal cells might, potentially, lead to a cycle

of drug cumulation and toxicity. Again, evidence for

in lactating dairy cattle, including flunixin, ketoprofen,

drug-induced hepatotoxicity has been described for

tolfenamic acid and meloxicam.

horses receiving a high dose rate of phenylbutazone, *but whether similar effects occur in cattle has not been*

Steroids

reported.

A number of blood dyscrasias have been reported in

Classification and general properties

human subjects treated with NSAIDs, generally over

long periods. Similar blood cell effects in dogs, cats and

Three classes of steroid hormone are secreted by the

horses have been described. However, the data avail-

adrenal cortex into the peripheral circulation: sex

able are limited and it has not been established whether

steroids (generally in small quantities only), mineralo-

particular drugs or certain species are especially impli-

corticoids and glucocorticoids. The latter two groups

cated. With the use of clinical dose rates of NSAIDs,

together comprise the corticosteroid hormones. The

the incidence of blood dyscrasias in animals seems to

mineralocorticoids, secreted by the zona glomerulosa

be low.

and zona fasciculata, include aldosterone; their princi-

At high dose rates some NSAIDs, notably aspirin and *pal endocrinological actions are exerted on electrolyte particularly when administered for long periods, impair and water balance. They promote sodium and chloride platelet aggregation and thereby affect blood clotting. retention and potassium loss by their actions on the Potentially, this may lead to internal or external bleed- renal distal tubule and on parts of the gastrointestinal ing. Another problem of impaired clotting, through an tract, notably the large intestine. Sodium retention is indirect mechanism, may occur when NSAIDs are used accompanied by osmotically obliged water. When together with anticlotting drugs of the coumarin group. administered as drugs or secreted in excessive amounts For example, the combination of phenylbutazone and in some disease states, aldosterone and related com- warfarin has been used in the therapy of navicular pounds cause oedema. Glucocorticoids influence lipid, disease in the horse. Phenylbutazone-induced suppres- carbohydrate and protein metabolism and some exert sion of warfarin metabolism may lead to warfarin tox- weak mineralocorticoid effects also. The principal glu-*

icity. Both cardiovascular and respiratory effects result

cocorticoid hormone secreted by the zona fasciculata

when very high doses of NSAIDs are administered, but

and zona reticularis in most species is cortisol

acute cardiovascular/respiratory effects do not gener-

(hydrocortisone).

ally occur with normal dose rates.

The main veterinary use of glucocorticoids derives

from the fact that they are potent anti-inflammatory

agents. Cortisol itself is used as an anti-inflammatory

Residues

agent, being administered systemically or applied

Published data on NSAIDs and their metabolite

locally. In addition, a number of synthetic steroids with

residues in cattle are sparse. Tissue concentrations of

much greater glucocorticoid potency than cortisol and

meclofenamate and phenylbutazone are lower than

with the advantage of reduced mineralocorticoid

corresponding concentrations in plasma and, for the

potency are available for clinical use. For example,

latter, drug plasma and tissue concentrations decrease *prednisone and prednisolone are some four to five*

in parallel (Toutain et al. , 1982). Pharmaceutical manu-times more potent than cortisol as glucocorticoids, but

facturers have submitted residue data to registration

they possess slightly weaker mineralocorticoid activ-

authorities to establish meat withholding times for

ities. Unwanted side-effects on water and electrolyte

flunixin, carprofen, ketoprofen, tolfenamic acid and

balance are therefore less likely when prednisone and

meloxicam in cattle. Theoretically, the passage of

prednisolone are used at equi-effective dose rates to

NSAIDs into milk in healthy cattle will be severely

hydrocortisone. The relative potencies of a number of

limited by the more acid pH relative to plasma and by

corticosteroids in producing glucocorticoid and miner-

the high degree of drug binding to plasma protein. In

alocorticoid effects (in arbitrary units, cortisol = 1) have

practice, this has been found to be the case for one drug,

been reported by Keen (1987) and are presented in

phenylbutazone (milk concentration about 1 per cent

Table 62.4. It will be seen that methylprednisolone and

of plasma concentration), and will almost certainly

triamcinolone are about five times as potent as cortisol

apply to others. In mastitis, however, the pH of milk

as glucocorticoids and both have little or no mineralo-

is less acid and the 'blood–milk' barrier is much more

corticoid activity. For dexamethasone and betametha-

permeable, so that higher NSAID concentrations in

sone, effects on electrolyte balance are also slight, but

milk may occur and it is necessary therefore that milk

these drugs are 25–30 times as potent as cortisol as glu-

withdrawal times following therapy with NSAIDs are

cocorticoids. In contrast, the synthetic corticosteroid

adhered to by farmers and veterinary practitioners.

deoxycorticosterone acetate (DOCA) is a potent min-

Only some of the available NSAIDs are licensed for use

eralocorticoid with negligible glucocorticoid activity.

Table 62.4

Relative potencies and biological half-lives of some corticosteroids used in veterinary practice (from Keen, 1987).

Relative potency (hydrocortisone = 1.0)

Biological half-life (h)

Glucocorticoida

Sodium retaining

Hydrocortisone (cortisol)

1

1

8–12

Cortisoneb

0.8

0.8

Prednisolone

5

0.8

12–36

Prednisoneb

4

0.8

Methylprednisolone

5

Minimal

Triamcinolone

5

None

24–48

Dexamethasone

30

Minimal

36–54

Betamethasone

25

Negligible

Flumethasone

100

Negligible

a Closely paralleled by anti-inflammatory and HPA-suppressant activity.

b Inactive until converted to active drug in the body.

Anti-inflammatory potency of corticosteroids closely

tissue. For example, in some species (rabbit, mouse)

parallels glucocorticoid activity. Clinically, this is most

high doses reduce thymus weight and reduction in the

important since it means that whilst mineralocorticoid

size of the spleen and lymph nodes occurs. Immuno-

activity has been divorced from anti-inflammatory
suppression by glucocorticoids is reflected in a number
activity, glucocorticoid effects have not and this dictates
of ways, principally by a reduction in cell-mediated
the side-effects associated with clinical usage. An
immunity and, usually at higher dose rates, by suppres-
appreciation of the general actions of glucocorticoids
sion of antibody production. The secretion of miner-
will therefore assist an understanding of these potential
alocorticoid hormones is regulated in a number of ways,
side-effects, which are described in a subsequent section
but the principal mechanism involves the renal release
of this chapter. Glucocorticoids are gluconeogenic, pro-
of renin from the juxtaglomerular apparatus and sub-
moting the release of amino acids from skin, muscle and
sequent conversion of angiotensin I to angiotensin II,
connective tissue, and they subsequently increase the
which acts on the adrenal cortex zona glomerulosa cells.
conversion of amino acids to glucose. Glucocorticoids
Glucocorticoid secretion from the zona fasciculata, on
produce hyperglycaemia in many species, especially in

*the other hand, is increased in response to stress, but
ruminants, and they promote the storage of glucose as
there is also a basal level of secretion that is subject to
liver glycogen, although both uptake and utilization of
a diurnal rhythm. In the dog, cortisol secretion peaks
glucose by other tissues are reduced. In general, rates
during the day, usually late morning, whilst in nocturnal
of lipolysis are increased, leading to fatty acid and glyc-
species, like the cat, peak levels occur at night. The
erol release from adipose tissue. Subsequently, the glyc-
regulatory control involves secretion of adrenocorti-
erol may be converted to glucose. Calcium metabolism
cotrophic hormone (ACTH) from the anterior pitu-
is altered by glucocorticoids in several ways. First,
itary, which in turn is regulated by the release of
calcium absorption from the intestines is decreased and
corticotrophin releasing factor from the hypothalamus
renal excretion is increased. Second, there is increased
(Fig. 62.5). There is a negative feedback of cortisol on
parathormone secretion and a resulting osteoclast
this system and high levels of glucocorticoid drugs*

stimulation whilst osteoblast activity is inhibited. These

in the circulation similarly suppress ACTH secretion.

actions together promote calcium mobilization from

Long-term suppression induced by steroid drugs leads

bone, and bone strength is reduced. Glucocorticoids

not only to inhibition of cortisol secretion, but also to

cause diuresis by dilating glomerular afferent arterioles

reduced cell function to the point of adrenal atrophy.

and thus increasing glomerular filtration rate and also

by depressing tubular water reabsorption in the distal

Mechanism of action

nephron.

The main action of glucocorticoids on blood is to

The mode of action of steroids is multifactorial. Unlike

promote leucophilia, principally reflecting an increased

NSAIDs, they generally suppress all components of

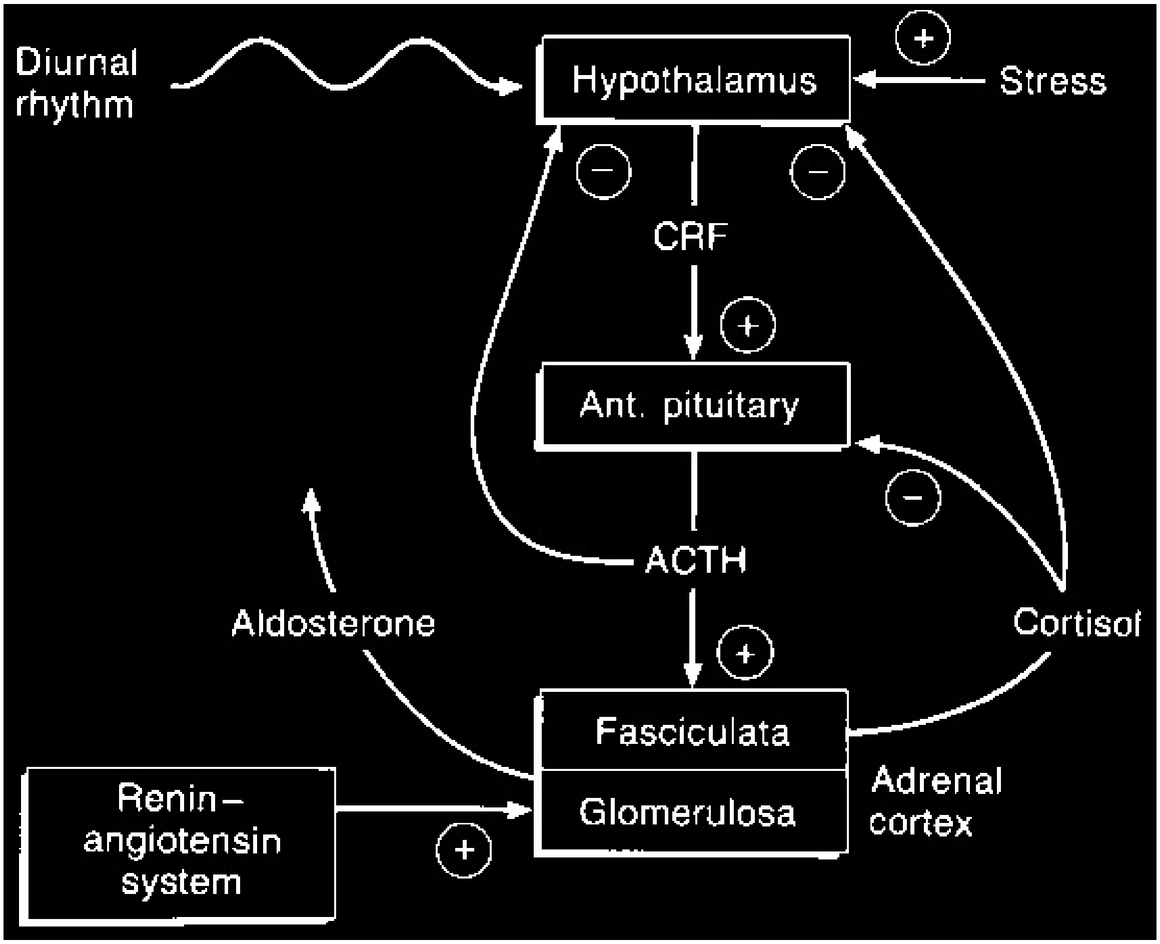
number of circulating neutrophils. However, circulating

acute and chronic inflammation. Indeed, steroids are

lymphocyte and eosinophil numbers are reduced. In

the anti-inflammatory drugs 'par excellence'. Steroids

addition, glucocorticoids are depressant to lymphoid inhibit the vascular dilatation in the microcirculation



response. Because of this delay, it follows that any relationship between effect achieved and plasma or tissue drug concentration will be complex. Drug effects will generally outlast the period for which they can be detected in biological fluids. This may explain why dexamethasone, which has an elimination half-life of approximately 1 hour in horses and 2.5 hours in cattle

(Toutain et al. , 1982), possesses a 'biological' half-life of 36–54 hours (Table 62.4).

As discussed earlier, arachidonic acid may act as a substrate for two groups of enzymes, COX and LO. Through the production of lipocortins and consequential blockade of phospholipase A2 steroids can be expected to block the synthesis of COX-derived inflammatory mediators, including PGE2 and PGI2, and LO-derived HETE and leukotriene compounds. One of

Fig. 62.5

Pathways of mechanisms of control of secretion of adrenal steroids.

these, LTB4, is a potent chemotactic agent for neutrophils and the peptidoleukotrienes LTC4 and LTD4 are believed to be important mediators of allergic and the increased capillary and small vein permeability airway diseases. They may be involved in such condi- and they thereby lessen oedema. Steroids also inhibit tions as fog fever in cattle and chronic obstructive hyperalgesia and fibrin deposition. The extravascular pulmonary disease in horses. The evidence that anti-

migration of polymorphonuclear leucocytes initially

inflammatory steroids act through the production of

and subsequent movement of monocytes are reduced.

lipocortins and blockade of eicosanoid synthetic path-

In addition, phagocytic activity of leucocytes is

ways is, however, controversial (Lane et al. , 1990). High depressed. In the repair stage of the inflammatory

doses certainly do affect eicosanoid synthesis, but

response and in chronic inflammation, proliferation and

whether doses used in veterinary therapy effectively do

the deposition of collagen are suppressed. In conse-

so is far less certain. Another important action of

quence, wound healing and cicatrization are delayed.

steroids at the molecular level is inhibition of induction

Glucocorticoids also decrease the production of inflam-

of COX-2 in response to inflammatory stimuli.

matory complement components, reduce lymphocyte

accumulation and decrease production of interleukin-2

Administration and pharmacokinetics

(IL–2) and other lymphokines from lymphocytes.

of steroids

*Glucocorticoids exert a stabilizing action on all bio-
logical membranes. Cell, mitochondrial and lysosomal
The application of steroids topically to skin and mucous
membranes are affected and this suppresses the syn-
membranes, e.g. the eye, is commonly used in veterinary
thesis or release of acute inflammatory mediators such
practice. It provides high drug concentrations at
as PGE2 and histamine, and subsequently the tissue
required sites of action and at the same time minimizes
breakdown arising from the effects of released lysoso-
the risks of inducing systemic side-effects, although
mal and non-lysosomal enzymes is suppressed.
some systemic absorption is likely. In addition, most
However, these actions, although relevant to the anti-
steroids are readily absorbed from the gastrointestinal
inflammatory effects of steroids, do not explain how
tract, so that licking sites of drug application can lead
they act at the molecular level.
to significant absorption from the gut. In some topical
Many studies have shown that one biochemical
products local activity is high, but systemic absorption*

pathway inhibited by glucocorticoids is the arachidonic

from the site of application is low and systemic side-

acid cascade. Arachidonic acid is released from its

effects are thus unlikely. Betamethasone-l7-valerate

esterified form from the phospholipid component of

and beclomethasone dipropionate are examples of

cell membranes by the action of phospholipase A2 (Fig.

esters with activity restricted to local sites.

62.2). Anti-inflammatory steroids inhibit this enzyme

Oral corticosteroid administration is a frequently

indirectly by promoting the synthesis of a family of

used route for medium or long-term therapy. There are

endogenous polypeptides, the lipocortins, which possess

unavoidable potential risks of significant suppression of

antiphospholipase activity. This indirect mechanism of

the hypothalamic–pituitary–adrenal axis (HPA) (see

action may account for the lag period of 1–5 hours

Chapter 67) when long-term treatment is employed and

between steroid administration and the biological

ways of reducing this to a minimum have been sought.

A short-acting preparation administered at twice the

achieve benefits without the undesirable side-effects of

recommended dose rate on alternate days instead of

high doses.

normal dosing once per day has been proposed on

Some steroids are prodrugs, requiring metabolic con-

the assumption that HPA suppression will decline on

version in the body. This is true of cortisone and pred-

the non-treatment days. The therapeutic effects, on the

nisone which are converted, respectively, to cortisol and

other hand, may persist since steroid biological half-life

prednisolone. Such drugs may be used for systemic

is generally much longer than the pharmacokinetic half-

therapy, but they are not applied locally.

life (Table 62.4). Another approach has been to recom-

mend drug dosing in the morning in the dog and in the

Side-effects of steroids

evening in the cat. Then, maximum circulating concen-

trations of drug can be expected to coincide with peak

The side-effects of those steroids with mineralocorti-

circulating concentrations of endogenous cortisol. This, *coid activity, e.g. prednisolone and prednisone, include*

in theory, will produce HPA suppression for the

sodium and water retention and resulting oedema, and

minimum time over each period of 24 hours.

hydrogen and potassium loss leading to hypokalaemia

Corticosteroids are frequently administered pa-

and metabolic alkalosis. Effects arising from glucocor-

renterally and generally this will give less variable

ticoid action on the kidney include a transient polyuria

plasma concentrations than oral dosing for short- or

and a compensatory polydipsia. Hyperglycaemia, pos-

medium-term therapy. Water-soluble formulations

sibly leading to glucosuria, also occurs. Protein catabo-

include succinates, phosphates and m-sulphobenzoates.

lism with long-term therapy causes muscle wasting and

They may be administered intravenously or intramus-

in the short term may delay wound healing. The lipoly-

cularly. Pharmacokinetic properties have been reported

tic action of glucocorticoids is associated with redistri-

for commonly used corticosteroids. Thus, with intra-

bution of body fat with the characteristic ‘moonface’ *venous dosing the half-life of dexamethasone ranges*

appearance in man and pendulous abdomen in animals.

from 290 to 335 minutes in the cow, 53 minutes in the

With prolonged treatment, changes in calcium metabo-

horse to 110 to 130 minutes in the dog (Toutain et al. , lism can lead to osteoporosis and bone fractures.

1982).

Gastrointestinal side-effects include reduced motility,

The water-soluble short-acting esters are rapidly

thinning of the gastric mucosa and reduced mucus pro-

absorbed from intramuscular injection sites to give an

duction. However, unlike NSAIDs, glucocorticoids are

onset and duration of action almost as quick as and of

not normally regarded as ulcerogenic. Nevertheless,

fairly similar duration to intravenous administration. In

colonic perforation in corticosteroid treated dogs has

addition, water-insoluble esters providing longer dura-

been described (Toombs et al. , 1986). The immunosup-

tion of action, from 2 to 14 days, are available. These

pressant actions involve a reduction in cell-mediated

suspensions, providing a depot at the injection site,

immunity, suppression of lymphoid tissue and lympho-
include acetate, undecanoate, pivalate and phenyl-
cyte movement and activity and, possibly, reduced anti-
propionate esters. Some very insoluble esters, e.g.
body production.
acetonide and adamantoate, provide effective concen-
When long- or medium-term steroid therapy is ter-
trations over several weeks, and the use of these esters
minated, the HPA axis suppression present during
involves undesirable, but unavoidable, HPA axis sup-
therapy is restored only over several weeks and animals
pression.
are susceptible to stress during this period. Stepwise
Intra-articular injection, for the treatment of joint
reduction in steroid dose rate and increasing the inter-
diseases, is another route employed. Intra-articular
dose interval may be helpful in assisting restoration of
dosing reduces but does not prevent the risks of sys-
HPA axis function.
temic side-effects, since some formulations are rapidly
absorbed. Long-acting formulations maintaining local

General uses of steroids

concentrations for several days are sometimes used.

A careful aseptic technique is required with all intra-

Anti-inflammatory steroids are widely used for the

articular injections. Steroids are used in this way to sup-

therapy of immune and non-immune inflammatory con-

press soft tissue inflammation, reduce stiffness and pain

ditions. Allergic and non-allergic eczemas respond to

and allow more joint movement. Disadvantages are

steroid therapy and steroids are used in the treatment

that they may suppress natural repair processes and

of inflammatory conditions of the eye and the ear. In

they may induce osteoporosis and osseus metaplasia.

dogs and cats, steroids have been used to terminate the

Steroids are chondrodepressant and can lead to 'steroid

itch–scratch cycle in non-specific dermatoses. Steroids

arthropathy'. However, in recent years it has been

have been used extensively in the therapy of anaphy-

increasingly recognized that low dose steroids can

lactic, endotoxic and haemorrhagic shock, but there are *several disadvantages. The slow onset of action of*

mended and a number of contraindications may be

steroids has been discussed earlier and very large doses

stated.

are required, making therapy in cattle and other large

animal subjects impractical and/or prohibitively expen-

sive. Administration to patients in shock should be by

Guidelines

intravenous injection since absorption from intramus-

(1)

As animals vary in their response, depending on

cular and subcutaneous sites in shocked patients would

disease severity, dosing schedules should be estab-

be slow.

lished for individual subjects.

In inflammatory conditions associated with bacterial

(2)

Single large doses of steroids or short-

infections, steroids are commonly administered with

term therapy are unlikely to produce serious

appropriate antibacterial agents. However, the im-

side-effects.

munosuppressant actions are undesirable and some

(3)

The incidence and severity of side-effects gener-

authorities believe that such combinations are not jus-

ally increase with the duration of treatment.

tified. Where antimicrobial cover cannot be provided,

(4)

Corticosteroid treatment is usually symptomatic

as in some viral infections, corticosteroid therapy is gen-

rather than curative.

erally totally contraindicated.

(5)

Cessation of therapy abruptly after a pro-

Corticosteriods have been used successfully in treat-

longed course of treatment may reveal adrenal

ment of bovine iritis, or ‘silage eye’, a condition that is

insufficiency.

thought to be associated with infection with Listeria

monocytogenes (see p. 923) and involves the patho-

physiological change iridocyclitis. Corticosteriods are

Contraindications

most frequently administered by subconjunctival

(1)

Glucocorticoids are insulin antagonists and may

administration, either alone or in conjunction with

therefore exacerbate or precipitate diabetes mel-

antibiotic injections.

litus (see p. 930). They should not generally be

There are a number of musculoskeletal conditions for

used in diabetic animals.

which steroids may be indicated, including traumatic

(2)

Steroids should be used with extreme caution in

arthritis, osteoarthritis (see p. 453), myositis (see p. 451), acute infections because of their immunosuppres-eosinophilic myositis, tendonitis (see p. 452) and bursi-

sant actions and, if used, this should be in combi-

tis (see p. 461). In joint diseases steroids provide relief

nation with bactericidal antibiotics.

through their analgesic and anti-inflammatory actions.

(3)

Steroids are generally contraindicated in viral

However, they may suppress natural repair mechanisms

infections, in late pregnancy due to the risk that

and repeated injections or long-acting formulations

they may induce parturition and in subjects with

may produce degenerative changes in cartilage (steroid

corneal ulcers.

arthropathy). For this reason, glucocorticoid use in all

(4)

Administration by intra-articular injection should

forms of arthritis is increasingly controversial, and they

be avoided when there is sepsis in or close to the

are definitely contraindicated in septic arthritis. Simi-

joint, in the presence of intra-articular fracture,

larly, in patients with laminitis steroids have fewer and

when the articular cartilage is damaged, when

fewer advocates. If they are used, treatment should be

extensive degenerative bony lesions are present, if

limited to the initial 24-hour period after the appear-

previous injections were ineffective and when

ance of signs. Otherwise steroids may exacerbate the

there is any likelihood that the treated joint will *condition.*

be over-exercised.

A number of respiratory conditions (see Chapters 17,

20, 49), both allergic and non-allergic, have been treated

with systemic steroids. They include acute respiratory

Therapy with anti-inflammatory drugs

distress syndrome in cattle and chronic obstructive pul-

monary disease in horses. In these conditions steroids

***Respiratory diseases** (see Chapters 17, 20, 49)*

are most useful when disease signs are severe; high

doses of water-soluble formulations are administered

Acute and sometimes overwhelming life-threatening

intravenously. Depot preparations of steroids have

inflammatory conditions occur in cattle and it is possi-

been used in severe cases of the equine allergic skin

ble that the use of anti-inflammatory drugs, especially

disease 'sweet itch'. Other indications for steroid

non-immunosuppressant agents, will reduce morbidity

therapy are ulcerative colitis, cerebral oedema and

and mortality in such cases. Acute calf pneumonias of

autoimmune haemolytic anaemia.

viral or bacterial origin and those of mixed aetiology,

In view of the potentially serious side-effects of

for example, have been shown to respond to NSAID

steroids, guidelines for their use have been recom-

treatment. Although such treatment is symptomatic it

can be effective in life-threatening pneumonias. Selman

A study comparing the effectiveness of carprofen to

and coworkers showed that flunixin reduced signi-

flunixin for respiratory disease showed that a single

ficantly lung consolidation scores in calves infected

dose of the former drug had similar beneficial clinical

experimentally with PI3 virus (Selman et al. , 1984).

effects to three doses of the latter drug when used as an

Flunixin also reduced lung lesions, post-mortem lung

adjunctive therapy to antimicrobial treatment (Balmer

weights (reflecting an anti-oedematous action) and

et al. , 1997). Meloxicam has been licensed for use in clinical signs of the disease in an experimental bovine

dogs for medium to long term therapy of muscu-

pasteurellosis model based upon challenge with *loskeletal pain and inflammation and is available as a*

Mannheimia haemolytica A1. However, the benefits of

suspension and in injectable form. It is available as

flunixin therapy were not apparent when the drug was

an anti-inflammatory drug for use in the therapy of calf

used alone but when used in combination with oxytet-

pneumonia. Further evaluation of NSAIDs in acute

racycline (Selman, 1988). The additional benefits pro-

life-threatening respiratory infections is needed, since

vided by the combination over oxytetracycline by itself

some of the reports have reached conflicting conclu-

comprised a lower body temperature, decreased respi-

sions. Nevertheless, carprofen, flunixin, ketoprofen,

ratory rate and improved food intake.

tolfenamic acid and meloxicam all possess marketing

Anderson (1989) confirmed the benefits of a flu-

authorizations for use in pneumonia in calves.

nixin/oxytetracycline product in comparison with

oxytetracycline alone in field cases of pneumonia, with

***Mastitis and endotoxaemia** (see Chapters*

treatment daily for three days. Reduction in coughing, *22, 23, 24, 30)*

return to normal food intake and weight gain were

improved more with the combination product and there

Mastitis in cattle also benefits from NSAID treatment.

were fewer relapses. Since these early studies, other

The main indication is in acute and peracute cases

NSAIDs have been used in combination with antibi-

in which Escherichia coli or other endotoxin-releasing otics in calf pneumonia; they include ketoprofen,

bacteria are involved. Thus, within the udder, the endo-

meloxicam, carprofen and tolfenamic acid (Delaforge

toxin-induced increases in PGE2 and TXA2 concentra-

et al. , 1994). The precise way in which NSAIDs act in tions were significantly reduced by systemic flunixin

these subjects is unclear, but it seems likely that the

therapy (1.1 mg/kg at 8-hour intervals for seven doses)

anti-inflammatory action (reduced pulmonary oedema)

(Anderson et al. , 1986a) and clinical signs of both udder improves pulmonary function and respiratory gas

inflammation and depression as well as pyrexia were

exchange, while the antipyretic action may improve

suppressed (Anderson et al. , 1986b). The enhanced *the clinical status to the point where animals wish to eat*

phagocytosis of Staphylococcus spp., which occurs in

and drink. In this way nutritional and fluid require-

milk neutrophils harvested from endotoxin-inoculated

ments will be maintained. Species such as cattle, which

quarters, was not affected by flunixin treatment.

rely principally on respiration for temperature regula-

However, flunixin did suppress significantly the

tion, may be under particular stress from infections

increased whey IgGI and IgM concentrations produced

causing pyrexia, thus the antipyretic actions of NSAIDs

by endotoxin inoculation (Anderson et al. , 1986c). The may be particularly useful in such species. NSAIDs are

local effects of systemically administered flunixin may

also potent analgesics (against inflammatory pain) and

seem surprising when the high degree of binding to

when pain is a significant element in cattle pneumonias,

plasma protein and its acidic nature are considered;

this analgesic action of flunixin is likely to contribute to

these properties should severely limit penetration

the improved clinical status.

across the blood–milk barrier. However, in the acutely

Ingestion of 3-methylindole (3MI) in cattle produces

inflamed udder blood flow is increased and milk pH will

a chemical toxicosis characterized by respiratory signs

be much closer to plasma pH than in non-mastitic milk

and pulmonary lesions (congestion, oedema, interstitial

and the permeability of the blood–milk barrier will be

emphysema) that are indistinguishable from naturally

increased. Probably of even greater significance in per-

occurring acute bovine pulmonary emphysema (fog

acute cases will be antagonism of the acute systemic

fever). Intoxication with 3MI is accepted as a valid

effects of endotoxin by NSAIDs, since these are medi-

model of the natural disease. Selman and co-workers

ated in part through activation of the arachidonic acid

have shown that parenteral flunixin (2.2 mg/kg)

cascade with release of PGE2 and TXA2. Clinically,

markedly reduces respiratory rate and the extent of

Anderson et al. (1986b) also demonstrated improve-

lung lesions assessed by lung weights and both patho-

ment, including reduction in rectal temperature, in mas-

logical and histopathological examinations. Flunixin

titic cows with coliform mastitis.

resulted in a prompt return to normal demeanour and

Flunixin in combination with oxytetracycline has also

respiratory rate and it reduced the degree and severity

been evaluated in cases of peracute mastitis in com-

of alveolar epithelial hyperplasia.

parison with the antibiotic alone and clinical appraisal

suggested that the combination product gave better

provide analgesia in inflammatory conditions in cattle,

results (Christie, 1988). Similarly, ketoprofen was

although further work is required to establish optimal

shown to significantly improve recovery in naturally-

and economical treatment regimens.

occurring clinical mastitis in dairy cows when used in

There have been few attempts to administer NSAIDs

combination with sulphadiazine and trimethoprim

locally by intramammary infusion to establish whether

(Shpigel et al. , 1994). Carprofen has also been evaluated their analgesic and anti-inflammatory effects are of

in cows with endotoxin-induced mastitis, at a dose rate

value in providing symptomatic relief in any form of

of 0.7 mg/kg. Clearance of the drug was slower, elimi-

mastitis. No doubt such use has been precluded by

nation half-life longer and penetration into milk greater

the irritant properties of many NSAIDs. One NSAID,

in endotoxaemic compared with normal cows. In the

ibuprofen, has been administered locally into udders of

mastitic animals carprofen reduced heart rate, rectal

cows with induced endotoxin mastitis. The drug atten-

temperature and quarter swelling significantly (Lohuis

uated reduction in milk yield when compared both with

et al. , 1991), although at the time of writing no licensed control cows and steroid-treated cows (DeGraves &

product containing carprofen is available for use in

Anderson 1991), but no licensed product is currently

lactating cows in the UK. Similarly, flunixin showed

available in the UK. A specially prepared, non-

antipyretic, anti-inflammatory effects and reduced clin-

commercial preparation of flunixin was administered

ical depression following experimental intramammary *via the intramammary route in the study by Fitzpatrick*

infusion with endotoxin.

et al. (1998), described above. As expected, the somatic Mastitis is an inflammatory disease associated with

cell count increased on infusion of the compound, but

pain (Chapter 23). Indeed bradykinin, a hyperalgesic

there was no evidence of an excessive induced inflam-

mediator, has been detected in milk from cases of clin-

matory response from observation of clinical signs or

ical and subclinical mastitis in cows (Eshraghi et al., from milk yield subsequent to the clinical episode.

1999). Kinin peptides are released during inflammation

Interestingly, abrogation of the allodynia resulting from

and are among the most potent mediators of vasodila-

the use of intravenous flunixin was not seen when the

tion, oedema and pain. Bradykinin was detected in milk

intramammary route was employed, indicating the pos-

from cows with clinical and subclinical disease and the

sibility that the drug had a central effect on pain pro-

concentrations of bradykinin were shown to correlate

cessing, probably at the level of the spinal cord.

with the severity of the disease. Bradykinin concentra-

*Steroids with anti-inflammatory actions, such as pred-
tions were significantly higher in quarters with high
nisolone, have been used extensively for the therapy of
somatic cell counts and from which Staphylococcus
clinical bovine mastitis. Corticosteroids are incorpo-
aureus was isolated compared to high cell count quar-
rated in a number of products containing also one or
ters from which no pathogen was isolated. Whether
more antibiotics and used to treat clinical cases during
systemically administered NSAIDs are beneficial in
lactation. The popularity of such products is indicated
clinical cases of mastitis that are not so severe as to
by volume usage; in the UK at the present time the
be classified as acute or peracute has received little
three most widely used lactating-cow intramammary
attention to date. However, Pyorala and co-workers
products all contain an anti-inflammatory steroid. The
(1988) examined the influence of phenylbutazone
value of steroids in such products is unclear and in view
(10 mg/kg) and flunixin (2.2 mg/kg) administered
of their potential immunosuppressant actions such*

intravenously in cases of chronic subclinical mastitis.

usage has been questioned. One suggestion has been

Neither drug influenced bacterial growth, somatic cell

that the main value of steroids is not to influence the

count or the levels of inflammatory markers (N-acetyl-

disease, but merely to suppress the irritancy that

b-d-glucosaminidase activity and trypsin-inhibitory

inevitably accompanies intramammary infusions and

capacity). Eckersall et al. (2001) showed that dairy cows which varies in degree with the product formulation/

with naturally-occuring clinical mastitis of mild or mod-

excipients. However, studies have been undertaken

erate grades, assessed by farmer observation, had sig-

comparing intramammary antibiotic products with and

nificantly different concentrations of the acute phase

without steroids in bovine models of mastitis induced

proteins serum amyloid A and haptoglobin in serum

by E. coli endotoxin, Streptococcus uberis and Staphy-and in milk compared to normal cows. The cows in this

lococcus aureus (Bywater et al. , 1988). Signs of inflam-study showed evidence of allodynia for approximately

mation (swelling, milk consistency) were reduced, but

5 days and 40 days in the case of mild and moderate
leucocyte infiltration was not impaired. Further studies
cases of mastitis, repectively (Fitzpatrick et al., 1998).
in this field, for example to establish that the phagocytic
The allodynia was shown to be abrogated by a single
capacity of infiltrating neutrophils and immune protec-
intravenous dose of flunixin (2.2 mg/kg), an effect that
tive mechanisms are not impaired, would provide con-
lasted for 24 hours, after which the allodynic state
firmation of the value of steroids in some forms of
resumed. This indicates the potential use of NSAIDs to
mastitis. In acute and peracute mastitis the slow onset

of action of steroids is likely to limit their value, but in
aspirin and the actions of these drugs in acute intersti-
the Streptococcus uberis model mentioned above,
tial pneumonia has been described above.
benefit was obtained when treatment was administered
16–18 hours after challenge (Bywater, pers. comm.).

Arthritis and joint diseases (p. 453)

In summary, it seems at least possible that the anti-

endotoxaemic effects of systemically administered
In contrast to the horse and dog, long-term therapy of
NSAIDs may be of value (together with other sup-
joint diseases in cattle is not commonly undertaken.
portive therapy, including fluids and systemic antibiotic
This in part relates to economic factors, in part to drug
administration) in cases of acute and peracute mastitis,
and drug metabolite residue problems in milk and
whereas reduced swelling and pain provided by intra-
edible tissues and in part to the lack of knowledge of
mammary infusion of steroid/antibiotic products may
drug pharmacokinetics linked to dosage regimens that
assist recovery in less severe clinical mastitis. The latter
are known to be effective and safe. However, some joint
proposal is compatible with the suggestion of Sandholm
diseases of cattle have been treated with phenylbuta-
and co-workers (1990) that inflammatory changes in the
zone, corticosteroids or NSAIDs but there is, as stated,
mastitic gland seem to improve bacterial nutrition and
an urgent need to establish rational dosage schedules.
growth, with potential adverse effects on the host.

Whether the chondroprotective class of agents, which

However, further studies are needed to examine these

includes polysulphatedglycosaminoglycans and pen-

proposals concerning both steroids and NSAIDs.

tosan sulphate, is likely to be used in the future is not

Steroids have also been used, usually systemically, to

clear. Some increase in therapy in this field can be antic-

counteract the life-threatening symptoms of endotoxic

ipated, should the economic situation in the farming

shock in cattle, commonly together with large volumes

industry improve, as joint disease is relatively common

of fluids. In addition to their anti-endotoxaemic effects,

and can affect individual valuable animals, where treat-

steroids promote gluconeogenesis and this may con-

ment may be justified.

tribute to the therapeutic response. The disadvantages

of steroids are the large doses required and conse-

***Foot-and-mouth disease** (Chapter 43(c))*

quential high cost of treatment and the latent period

prior to onset of action. This can be minimized by the

This contagious viral disease is characterized by fever *use of water-soluble steroids.*

and vesicular eruptions in the mouth and in the inter-

digital area of the feet. The clinical presentation varies

but a proportion of animals suffer severe ulceration

***Metritis** (pp. 520, 521)*

with loss of large areas of oral epithelial tissue and

While some studies showed no beneficial effect of

under-running of hoof structures. The use of NSAIDs

NSAIDs in the treatment of reproductive disorders

might be of value as adjunctive therapy and one agent,

such as retained placenta and post-partal endometritis

flunixin, has been studied. Artificially infected cattle

(Konigsson et al. , 2001), flunixin was shown to reduce treated with flunixin showed clinical improvement, indi-the incidence of pyrexia in cows with either acute and

cated by lowered body temperature and increased

subacute metritis compared to non-treated controls

weight gain, whilst antibody titres were not affected. In

(Amiridis et al. , 2001). Uterine involution and onset light of the recent epidemic of foot-and-mouth disease

of oestrus occurred earlier in cows that received

(FMD) in the UK (2001) and the considerable concerns

flunixin.

for the welfare of affected animals prior to slaughter,

the role of NSAIDs in palliative therapy could be

evaluated and implemented, to allow improved pain

***Calf scours** (Chapter 14)*

management, should future outbreaks of FMD occur.

Early studies by Jones et al. (1977) indicated a possible benefit of flunixin in suppressing inflammation, reduc-

Pain

ing fluid losses in faeces and suppressing morbidity and

mortality in calf scours. Until recently, no drugs were

Calves that received ketoprofen before and after

available with licensed indications for such use.

dehorning following a sedative and a local anaesthetic

However, meloxicam is now licensed for use in calf

showed reduced behavioural signs thought to be asso-

scours in combination with anti-microbial drugs.

ciated with pain, such as head shaking and ear flicking,

compared to untreated controls (Faulkner & Weary,

2000). Different methods of castration such as use of

***Hypersensitivity reactions** (p. 927)* *rubber rings, bloodless castrators or surgical methods*

Anaphylaxis can be inhibited both in vivo and in vitro were shown to result in different levels of pain

in cattle by the NSAIDs sodium meclofenamate and

response, demonstrated by altered behaviour (Robert-

son et al. , 1994). This indicates that there may be the with amoxycillin and clavulanic acid. In Proceedings of the potential to use NSAIDs either pre- or post-procedure

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to reduce or abrogate pain caused by castration.

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Conclusions

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It seems likely that both steroids and, in particular,

tory effects of carprofen, carprofen enantiomers and Ng-

NSAIDs, judiciously used, may be of value in a number

nitro-L-arginine methyl ester in vivo using sheep as a

of cattle diseases in which inflammation, endotoxaemia

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and/or pain are major components. Further work is

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inflammatory agent: flunixin meglumine. British Veterinary cially if licensed pharmacological products that will

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improve animal health and welfare are to result from

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Chapter 63

Growth Promoters in Cattle

K. Lawrence

Introduction

1067

use in human medicine, nor do they share a mode

In-feed additives

1067

of action with any compound in human medicine.

Rumen

1067

Interestingly, in addition, the ionophores do not have

Intestine

1069

antibiotic resistance encoded by transferable genes.

Hormonal implants

1071

Monensin acts on bacteria by facilitating the carriage of

Growth hormone (BST)

1073

sodium ions in to the cell. This causes the cell to speed

Repartitioning agents

1073

up the sodium/potassium pump in the cell membrane

to redress the ion balance. As the transport mechanism

requires energy in the form of ATP, continuous expo-

Introduction

sure to monensin could lead the cell to exhaust energy

supplies, resulting in death by osmotic disruption of

Bovine growth promoters are divided into four groups:

the cell, but more usually it prevents the bacteria from

• In-feed additives

competing in a mixed population and numbers decline

• Hormonal implants

(Pinkerton & Steinrauf, 1970; Pressman, 1976).

• Growth hormone (somatotropins)

The mode of action of monensin in the rumen has

• Repartitioning agents (b-agonists)

been elucidated and it can act as model for other pro-

ducts in this class, such as lasalocid (Bovatec, Alpharma

In the European Union (EU) the use of hormonal

Animal Health Division) and laidlomycin (Cattlyst,

implants and b-agonists has been banned since 1988,

Alpharma Animal Health Division).

followed in 1990 with a moratorium on bovine soma-

The rumen is a fermentation vat that converts

totropin (BST) that became a ban in 2000. Meanwhile

carbohydrates into volatile fatty acids (VFAs) such

the use of in-feed additives is under close scrutiny with

as acetic, butyric and propionic acids that drive the

a proposed 'phase out' by 2006. The EU position on

animal's metabolism (see Fig. 63.1). While all three

growth promoters has been taken in spite of the

VFAs can be used in the nutrition of the bovine, the

increased production costs to farmers and the enor-

production of propionic acid is the most efficient

mous knock-on costs of increased feed usage and slurry

leading to an improved efficiency of usage of both com-

production leading to environmental pollution (Verbeke

pounded feed and roughage. The key to the efficiency

& Viaene, 1996). The other major cattle-producing

of production of the VFAs is the preservation of the six

countries of the world continue to use a variety of

carbons from the final fermentation substrate, usually a

growth promoters, as they have done for over 30 years.

hexose sugar such as glucose. With acetic acid only four

of the carbon atoms are retained in the rumen, with two

being lost as the gases carbon dioxide and methane;

In-feed additives

butyric acid is similar although only carbon dioxide is

produced. Only with propionic acid is there a complete

In-feed additives are divided into two types by the site

retention of all six carbon molecules in the fermenta-

of primary activity: rumen and intestine.

tion products.

Richardson et al. (1976) provided the first evidence of the effects of monensin on VFA production using anaer-

Rumen

obic batch fermentation. In this study the propionic acid

The most widely researched of the rumen active growth

levels rose from 7.4 mM/ml to 12.5 mM/ml as the concen-

promoters is monensin sodium (Romensin, Elanco

tration of monensin was increased (Table 63.1).

Animal Health). Monensin is an 'ionophore', a group

Similar results were found in vivo by Van Maanen et of antibiotics that are used only in agriculture – there

al. (1978) in steers being fed both roughage and grain are no equivalent products used or in development for

based rations – there was a significant increase in the

GLUCOSE

Table 63.2

The effect of monensin on rumen propionate pool

size and production rate in steers consuming roughage or grain based diets.

Treatment

Propionate Propionate

pool size (g)

production rate

ACETATE

PROPIONATE

BUTYRATE

(g/day)

Roughage

32.0 ± 1.3

441 ± 24

CO2

CO2

Roughage + monensin

56.5 ± 2.1

659 ± 22

Grain

36.5 ± 2.0

510 ± 10

CO

Grain + monensin

66.3 ± 4.1

899 ± 45

2

CH3

Fig. 63.1

Rumen fermentation pattern for a simple carbohy-

drate, showing the preservation of carbon molecules.

Table 63.3

The sensitivity of rumen bacteria to monensin and

their related products of fermentation. (After Chen & Russell ***Table 63.1***

The shift of VFA production ratios with increasing

(1989); Chow & Russell (1990); Dawson & Boling (1983); Dennis levels of monensin, during anaerobic batch fermentation.

et al. (1981).)

Monensin

Acetic

Propionic

Butyric

Products of fermentation

(mcg/ml)

(mM/ml)

(mM/ml)

(mM/ml)

Monensin-sensitive organisms

0.0

19.6

7.4

7.1

Ruminococcus

Acetic acid

0.10

20.8

8.6

7.2

Methanobacterium

Acetic acid, methane

0.25

20.2

9.4

6.9

Lactobacillus

Lactic acid

0.50

19.6

10.6

6.5

Butyrivibrio

Acetic acid, butyric acid

1.00

19.1

11.1

6.3

Streptococcus

Lactic acid

5.00

17.5

11.2

5.8

Methanosarcina

Methane

25.00

16.7

12.5

5.6

Monensin-insensitive organisms

Selenomonas

Propionic acid

Bacteroides

Acetic acid, propionic acid

size of the propionate pool and the production rate. The

Veillonella

Propionic acid

results are summarized in Table 63.2.

The effect of monensin seems to be mediated by

changes in the balance of the bacterial population in the

Table 63.4

The effect of monensin on rumen protozoa and pro-

rumen. The sensitivity of a range of rumen bacteria to

pionic acid production in fistulated sheep.

monensin is reviewed in Table 63.3, along with their

fermentation output. Monensin clearly inhibits the

Monensin feed

Total protozoa

Molar % propionic

major acetate- and butyrate-producing bacteria, allow-

inclusion (mg/kg)

(¥105/ml)

acid concentration

ing a proliferation of the primary propionate producers.

Monensin has also been observed to reduce the con-

0

10.1

20.2

centration of rumen protozoa in many experiments.

11

9.0

23.6

This has also been associated with an increase in the

22

6.2

24.4

proportion of propionic acid production, as is shown in

33

7.1

25.8

the sheep study presented in Table 63.4.

44

5.4

28.7

Goodrich et al. (1984) and Potter et al. (1986) have reviewed the expected performance benefits from the use of monensin and highlighted the different nature

but the ADF is markedly reduced. This contrasts with

of the response in grain-based and roughage-based

the roughage diets where the ADG is increased while

systems. In all performance trials two measurements

the ADF is unchanged. In balanced rations composing

are made to derive a third. The feed intake (ADF,

both grain and forage the effects on ADF and ADG are

average daily feed in kg) and the growth rate (ADG,

less clear, but there is still an 8 to 10 per cent improve-

average daily gain in kg) are measured and the feed

ment in FCR.

conversion ratio (FCR) is calculated by dividing

There are additional benefits from the rumen active

ADF/ADG. While the FCR is improved in all the trials,

growth promoters in the control of acidosis (Nagaraja

in grain-based diets the ADG often remains unchanged

et al. 1985, 1987), bloat control (Sakauchi & Hoshino,

1981; Bartley et al., 1983; Lowe et al., 1991) and the pre-animals matched that of the germ-free group; there *vention of coccidiosis (Watkins et al., 1986).*

was no effect of the antibiotic on the germ-free group.

Antibiotics within the digestive tract of animals inhibit

the growth and modify the metabolism of susceptible

Intestine

populations of bacterial flora. Since most of the anti-

The growth promoters with a more pronounced effect

biotics used for growth promotion have a Gram-

in the intestine are the bambermycins (Flavomycin,

positive spectrum of activity, such bacteria as Clostridia, Intervet) and virginiamycin (Stafac, Phibro Animal

Enterococci and Bacilli seem likely candidates. The Health). This does not imply that these products have

inclusion of growth promoters in cattle feeds serves to

no effect in the rumen and indeed with virginiamycin

allow a conventionally raised animal to grow at the

there have been reports of significant effects on VFA

same rate as a germ-free animal.

production and the control of acidosis (Hedde et al.,

Studies on the physiological, nutritional, metabolic

1980).

and immunological effects associated with the use of

Likewise monensin is described as a rumen active

antibiotic feed additives demonstrate the complexity of

growth promoter, but this does not imply it has no effect

their mode of action (Visek, 1979; Hays, 1979; Coates,

in the intestine. Indeed, as monensin has been shown to

1980; Anderson et al., 2000). The reported effects

be an effective growth promoter in pigs it must also

include:

have a more conventional mode of action in this species

• Inhibition of the growth or modifying the metabo-

(Mackinnon, 1987).

lism of harmful gut bacteria;

The mode of action of in-feed growth promoters in

• Decreased elaboration of toxic substances, includ-

monogastric animals and in the intestine of a ruminant

ing bacterial toxins;

is complex and still open to debate. The comparison of

• Reduced bacterial destruction of essential nutrients;

healthy animals with a normal digestive tract bacterial

• Increased synthesis of vitamins and other growth

flora to germ-free animals has produced an insight into *factors;*

the role of the gut flora in inhibiting nutrient absorp-

• Improved efficiency of nutrient absorption by

tion. This has been built upon by comparing the

modification of the gut wall;

response of each group to antibiotic incorporated into

• Reduced intestinal mucosal epithelial cell turnover;

their diet (Visek, 1979). Conventional animals grow

• Reduced intestinal motility.

more slowly and use their feed less efficiently than gno-

tobiotic or 'germ-free' animals because of the presence

The net effect of the changes in the intestine listed in

of the intestinal flora. When antibiotic was adminis-

Table 63.5 is an increased availability and absorption of

tered, the growth response of the conventionally grown

nutrients and a reduced cost/kg gain.

Table 63.5

Some physiological, nutritional and metabolic effects ascribed to in-feed growth promoters (after Ewing & Cole, 1994).

Physiological effectsa

Nutritional effects

Metabolic effects

Gut food transit time

Ènergy retention

–

Ammonia production

`

Gut wall diameter

`

Gut energy loss

`

Toxic amine production

`

Gut wall length

`

Nitrogen retention

–

Alpha-toxin production

`

Gut wall weight

`

Limiting amino acid supply

–

Fatty acid oxidation

`

Gut absorptive capacity

–

Vitamin absorption

–

Faecal fat excretion

`

Faecal moisturè

Vitamin synthesis

`

Liver protein synthesis

–

Mucosal cell turnover

`

Trace element absorption

–

Gut alkaline phosphatase

–

Stress

`

Fatty acid absorption

–

Gut ureasè

Feed intake

_, `, 6

Glucose absorption

–

Calcium absorption

–

Plasma nutrients

–

à denotes a reduction; _ denotes an increase; 6 denotes no change.

In spite of the different emphasis of the mode of

(1)

Selection of antibiotic resistance in the gut flora. In action of the rumen and gut-active in-feed growth pro-any population of bacteria, there is a range of antibiotic

moters, their effects on the efficiency of performance is

susceptibility from fully sensitive to solidly resistant –

very similar with a 6 to 8 percent improvement in FCR.

even in the absence of antibiotics (Linton, 1982).

Consumer concerns have been raised about the use

Usually, the bulk of the bacteria remain sensitive to

of in-feed growth promoters in all species. The spectrum

an antibiotic, unless a therapeutic dose is administered

of data on this aspect of these products submitted for

which kills the sensitive and allows the few resistant

registration was summarized by Lawrence (1998).

bacteria to proliferate; thus a resistant population

As with therapeutic veterinary medicines, stringent

develops (Evangelisti et al., 1975).

safety studies are necessary for growth promoters. The

It is a truism that the use of a therapeutic dose of an

safety data requirements for registration in the EU are

antibiotic selects for the survival of the few resistant

listed below (source: Official Journal of European Com-

organisms in the population; it does not cause indi-

munites L208-21 T025):

vidual sensitive bacteria to become resistant. As the

growth promoters are included at levels approximately

1.

Studies on target species

10 to 100 times lower than therapeutic doses (Corpet,

1.1

Safety studies

– Biological

1996), there is little, if any, selection pressure on the gut

– Toxicological

flora. A selection of studies on growth promoters that

– Macroscopic

have demonstrated their low resistance selection capac-

– Histological effects

ity at authorised use levels are listed below:

1.2

Microbiological studies of the additive

• Flavomycin

(Dealy & Moeller, 1977; Devriese,

1.2.1

Antibacterial spectrum of activity

1980; Mee, 1982; Corpet, 1984; Dutta & Devriese,

1.2.2

Cross-resistance to therapeutic

1984)

antibiotics

• Monensin

(Dutta & Devriese, 1984; Newbold

1.2.3

Tests to find out whether the additive is

et al., 1993)

capable of selecting resistance factors

• Virginiamycin (Gaines et al., 1980; Devriese, 1980;

1.2.4

Tests to determine the effect of the

Mee, 1982; Dutta & Devriese, 1984)

additive:

–

on the microflora of the digestive

It is usual for the antibiotic growth promoters to have

tract

a Gram-positive spectrum of activity; therefore they

–

on the colonisation of the digestive

cannot have a selection pressure on the Enterobacteri-

tract

aceae and do not contribute to antibiotic resistance in

–

on the shedding or excretion of

Salmonella spp. or E. coli.

pathogenic micro-organisms

1.2.5

Field studies to monitor bacterial

(2)

Effect on the excretion of enteric pathogens by

resistance

animals. An increased number of organisms or an

1.3

Studies of the metabolism and residues

extended shedding time in the faeces could lead to an

2.

Studies on excreted residues – 'ecotoxicity'

increased risk of contamination of human food. All

3.

Studies on laboratory animals

current growth promoters have been examined for their

3.1

Acute toxicity

effect on Salmonella and, in many cases, other bacteria 3.2

Chronic toxicity

including E. coli. All modern studies, undertaken with 3.3

Mutagenicity

authorized inclusion levels, have given satisfactory

3.4

Carcinogenicity

results (Nurmi & Rantala, 1974; Hinton, 1988).

3.5

Reproductive toxicity

Ungemach (1996) considered that the use of growth

3.6

Toxicity of metabolites

promoters in animal feeds posed no risk to the indige-

nous gut flora of human consumers.

Microbiological safety of the use of growth promot-

(3)

Residues in the meat and the effect on human gut

ers has been included in the registration dossiers from *flora. Growth promoters administered in animal feed*

the earliest legislation. All the potential hazards of their

do not leave detectable residues in the meat. Indeed,

use have been well recognized from the very beginning.

they can be used from birth to slaughter, i.e. they have

The microbiological safety is assessed in three areas:

a zero withdrawal. As there is no detectable residue in

the meat, there is unlikely to be a selection pressure on

(1)

Selection of antibiotic resistance in the gut flora.

human gut flora (Ungemach, 1996).

(2)

Effect on the excretion of enteric pathogens by

animals.

The public health implications of the use of antibi-

(3)

Residues in the meat and the effect on human gut

otics in animal feeds have been examined on many

flora.

occasions:

Netherthorpe Committee

1962

The mode of action of the hormone implants has not

Swann Committee

1969

been fully elucidated although some work has indicated

FDA Task Force

1972

that changes in serum concentrations of IGF-1 occur in

Kennedy Report

1977

implanted steers, while serum IGF-1 concentration

Office of Technology Assessment (OTA) Report 1979

in the control steers remains or changed or, indeed,

AVI Conference – "Ten Years after Swann"

1979

decreases across time. This suggests that IGF-1, the

National Academy of Sciences Review (NAS)

1980

essential growth hormone, is related to the additional

Council for Agricultural Science & Technology *gain of the implanted steers. However, the reason for*

Report

1981

this linear decrease in serum IGF-1 concentration

American Society of Animal Science

1986

sometimes reported in control cattle is unclear. For

Office of Technology Assessment (OTA) Report 1995

example, it does not appear that the effect can be attri-

Scientific Conference on Growth Promotion in

buted to the control animals approaching their physio-

Meat Production

1995

logical maturity, because the control and implant

Antimicrobial Feed Additives

1997

animals usually exhibited similar degrees of fatness. The

Office International des Epizooties. The Use of

net effect could be an increase in protein synthesis and

Antibiotics in Animals. Ensuring the

protein gain, which translates into greater, more effi-

Protection of Public Health

1999

cient liveweight gain and profit for the cattle producer

Advisory Committee on the Microbiological

(Simpkins et al., 2000).

Safety of Food Report on Antimicrobial

The usual explanation is more mundane as bulls grow

Antibiotic Resistance in Relation to

faster and produce a leaner carcass than steers; steers

Food Safety

1999

grow faster and produce less fatty meat than heifers

All have discussed the hazards but none have proved

and cows. The differences in growth rate are usually

any risk to human health.

ascribed to hormonal status and the levels of androgen

in particular. The hormone implants are used to replace

or adjust the circulating hormone levels to achieve

Hormonal implants

optimal growth.

The efficacy of hormonal implants is well accepted, *Hormonal implants are not currently licensed for use in*

both alone and in combination with in-feed growth pro-

the European Union. Those listed in Table 63.6 are in

moters (see Table 63.7 for a typical trial). There is some

use in the rest of the world.

Table 63.6

Hormonal implants licensed for use as growth promoters in non-EU countries (modified from table in the report of the fifty-second meeting of Joint FAO/WHO Expert Committee on Food Additives (JECFA, 1999) ***Product namesa***

Comparison of the composition (mg/implant) of hormonal implants used for growth promotion Oestradiol

Testosterone

Testosterone

Progesterone

Trenbolone

Target

propionate

acetate

cattle

Compudose 200

24

Cattle

Compudose 400

45

Cattle

Synovex S

20

200

Steers

Synovex H

20

200

Heifers

Synovex C

10

100

Calves

Steeroid

20

200

Steers

Heiferoid

20

200

Heifers

Implix BM

20

200

Steers

Implix BF

20

200

Heifers

Torelor

40

200

Steers

Revalor

20

140

Calves

Revalor G

8

40

Steers

Revalor S

24

120

Steers

Revalor H

14

140

Heifers

Finaplix-S

140

Steers

Ralgro

Active ingredient is Zeranol 3 ¥ 12 mg pellets/dose

Cattle

a Product names are registered trade marks®.

Table 63.7

The efficacy of an implant in grazing steers used either alone or in combination with supplementary feed and the in-feed growth promoter monensin. (Source: Elanco Animal Health in-house data.) ***Treatment***

ADG (kg)

Increased ADG (kg)

Total gain in 150 days (kg)

Control

Compudose®

No supplement

0.554

0.631

0.077

11.55

Compound feed (1 kg)

0.613

0.709

0.096

14.4

Compound feed (1 kg) + monensin

0.659

0.782

0.123

18.45

®, registered trade mark (oestradiol 17b).

evidence that the response to an implant varies with

1.00

40

the start weight, with the greatest response in finishing

0.90

0.84

0.87

35

0.76

cattle being reported from the heaviest cattle (see Fig.

0.80

0.71

30

e

0.70

0.60

0.65

g

63.2).

25

0.60

Some carcass traits can be changed by the use of

0.50

20

implants, with lower dressing percentages (Kuhl et al., ADG (kg) 0.40

Percenta

15

1989), reduced marbling (Eversole et al., 1989) and a

0.30

10

reduction in top grade carcasses (Foutz et al., 1989)

0.20

5

0.10

being reported. These changes vary between implants,

0.00

0

but have not been associated with any significant

<300

300 to 400

>400

changes in the eating quality of the meat.

Initial weight (kg)

While the efficacy of hormonal implants is accepted,

Control

Implant

Percentage increase over control

the consumer safety of implanted meat has been a focus

of conflict between the USA and the EU, leading to

Fig. 63.2

The effect of the initial weight on the percentage

a complaint to the World Trade Organization (WTO).

response from an implant in finishing cattle.

The USA consider the hormone ban in the EU to be

an unjustified barrier to trade and have effectively won

as well as the recent assessment of the SCVPH report

this case at arbitration through the WTO Appellate

by a subgroup of the Veterinary Products Committee

Body. The findings of the case centred round the lack

(VPC) of the Veterinary Medicines Directorate

of a proper risk assessment prior to the imposition of

(VMD) in the UK on the potential risks to human

the ban on imports of meat from animals treated with

health from hormone residues in bovine meat and *hormones.*

meat products

This whole debate is best followed by reading the full

(http://www.vmd.gov.uk/) see under Publications.

Joint FAO/WHO Expert Committee on Food Additives

(JECFA) assessments:

The main areas of concern have been best summarized

in the VPC subgroup report and they are reviewed

Natural hormones (WHO Feed Additive Series 43–52nd

below:

Meeting JECFA)

(http://www.inchem.org/documents/jecfa/jecmono/

(1)

Direct consumer exposure to hormone residues in

v43jec05.htm)

meat. The residues are all very low compared with

Zeranol (WHO Feed Additive Series 44–53rd Meeting

the acceptable daily intakes (ADIs) identified by

JECFA)

JECFA. Therefore consumer exposure to oestra-

(http://www.inchem.org/documents/jecfa/jecmono/

diol, progesterone and testosterone will be very

v44jec14.htm)

low compared with those naturally produced in

Trenbolone (26th meeting JECFA)

the body (see Fig. 63.3). The ADI is an amount of

(http://www.inchem.org/documents/jecfa/jecmono/

medicine/hormone that can be eaten every day

v23je03.htm)

over a lifetime in the practical certainty that, based

and the Opinion of the Standing Committee on

on current knowledge, no harm will result.

Veterinary Measures related to Public Health

(2)

Hormonal residues can adversely affect the

(SCVPH) dated 30 April 1999

immune system. References used to support this

(http://europa.eu.int/comm/food/fs/sc/scv/out21_en.

argument in the SCVPH report did not reflect

html)

modern physiological understanding of the

3.3

duction. This does not mean that the effects of BST on

3.5

3

the growth performance and carcass characteristics in

ADI

2.5

beef animals have been neglected. The earliest trial in

2

1.7

1959 (Brumby, 1959) and those in the late 1980s pro-

1.5

duced consistent effects leading to increased growth

1

Percent of

0.6

rates, improved feed conversion and carcass lean, while

0.5

0.01

0.06

0.05

decreasing carcass fat. The effects on eating quality of

0

the meat associated with reduced carcass fat were a

Oestradiol

Progesterone

Testosterone

reduced acceptability because of lower scores on ten-

derness. The available data in cattle on growth per-

Maximum exposure

formance were summarized by Enright (1989) and on

Minimum exposure

meat quality by Allen and Enright (1989). As nearly all

Fig. 63.3

The maximum and minimum consumer exposure to

the data summarized were from trials involving the

natural hormone residues from implanted meat as a percentage

daily injection of BST, and even sustained-release

of the JECFA ADI. (JECFA Joint FAO/WHO Expert Committee

injectable formulations only last 14 days, there does not

on Food Additives. ADI (acceptable daily intake) in the amount currently seem to be a place for its use in the beef indus-of a medicine or hormore that can be taken every day during a *try as a growth promoter.*

lifetime in the practical certainty no harm will result.)

A direct comparison has been made between ana-

bolic steroids and BST. Untreated controls (UC) were

compared with steroid implants (STI) and 160 mg BST

immune system. With reference back to the first

injected weekly (Preston et al., 1995). Daily gain was area of concern, the residues are such a small frac-increased by both treatments (UC 1.30 kg/day; STI

tion of daily endogenous hormone production as

1.66 kg/day; BST 1.51 kg/day) and feed conversion was

to be without effect.

improved (UC 5.92; STI 4.88; BST 5.13). The anabolic

(3)

Hormonal residues can lead to an increase in

effects of STI and BST were considered to be poten-

certain common cancers. However, epidemiologi-

tially additive.

cal evidence only shows a direct link between

meat and fat consumption; to relate that to

hormone residues is a leap in logic. The leap is

Repartitioning agents

difficult to support as these tumours are found

equally widely in both men and women in coun-

b-Adrenergic receptor agonists (b-agonists) increase

tries where hormonal growth promoters are not

muscle mass and decrease fat mass when fed to cattle.

permitted.

A wide range of compounds has been investigated

(4)

Hormone residues in meat could affect many

including cimaterol, clenbuterol, fenoterol, isopre-

aspects of human development and reproduction.

naline, mabuterol, ractopamine, salbutamol, terbutaline

The only evidence of such an effect comes from

and zilpaterol (see Fig. 63.4). The most extensive review

high levels of hormones injected into experimen-

of the use of b-agonists in meat animals was published

tal animals. No current data show any ground for

by Anderson et al. (1991), in which nearly 400 papers

these suspicions in respect of residues, even with

were reviewed. There are currently no b-agonists regis-

the intensive research in this area.

tered in the EU for use in cattle as growth promoters,

The 'hormone' debate is about politics and the role

indeed in the EU this class of compound is specifically

of science to support obviously conflicting views. Even

prohibited under EU Directive 96/22/EU. There is one

if the science supporting the safety of hormones wins

product registered as a growth promoter in cattle in

the politicians can still ensure that there will be no con-

South Africa and Mexico – zilpaterol (Zilmax, Hoechst

sumer acceptance for this technology in the EU. It is

Roussel Vet) – and one in pigs in the USA, Mexico,

not anticipated that there will be a return of the implant

Brazil, Philippines and Korea – ractopamine (Paylean,

in beef production in the EU, but this should not

Elanco Animal Health).

jeopardize its use in other countries with less political

The mode of action is complex, with direct effects on

interference in product registration.

skeletal muscle cells, leading to hypertrophy, and on

adipocytes, causing lipolysis, as well as secondary mech-

anisms mediated by other hormones and changes in

Growth hormone (BST)

blood flow (Mersmann, 1998). Studies attempting to

relate the relative density of b2-adrenoreceptors on

The use of bovine somatotropin (BST) in cattle has

muscle and the local response to b-agonists have failed

primarily been concentrated on increasing milk pro-

to find a useful tool to predict efficacy of compounds

OH

Table 63.8

The effect of ractopamine on growth performance

H

in finishing cattle. A summary of six trials.

N

Dose (ppm)

ADG (kg)

ADF (kg)

FCR

H2N

0

1.26a

9.40a

7.46a

10

1.34b

9.31a

6.95b

Cimaterol

20

1.39b

9.40a

6.76b

N

30

1.48c

9.31a

6.29c

ppm, parts per million; ADG, average daily gain; ADF, average daily OH feed; FCR, feed conversion ratio; kg, kilogram. Means with different H superscripts are significantly different.

Cl

N

Table 63.9

The effect of ractopamine on carcass yield in

H2N

finishing cattle. A summary of six trials.

Cl

Clenbuterol

Dose (ppm)

Dressing (%)

Protein (%)

Fat (%)

OH

0

60.71a

15.16a

30.31

OH

H

10

60.76a

15.16a

30.24

N

20

61.02b

15.36a

29.70

30

61.03b

15.54b

28.81

HO

ppm, parts per million. Means with different superscripts are significantly different.

Ractopamine

and a 'rebound' when the product is removed, leading

OH

to an increase in fat deposition and a reduction in

H

muscle mass (Elliot et al., 1993). The most effective use N

of a repartitioning agent is therefore in the finishing

period in the one to two months prior to slaughter. The

results from the use of b-agonists in cattle are very con-

HO

sistent and are summarized in Table 63.8, which shows

Salbutamol

HO

significant increases in growth rates and feed utiliza-

tion, and Table 63.9, which shows significant increases

in dressing percentage, increased carcass lean.

OH

b-agonists are usually divided into two classes (Smith,

H

1998):

N

(1)

Halogenated aromatic ring. This class tends to

have a long serum half-life and when coupled with high

oral absorption and potency of action in humans there

HN

N

can be a real safety concern from residues in meat. An

Zilpaterol

example of such a compound is clenbuterol (pharma-

O

codynamic dose in man 10 mg/day – Meyer & Rinker,

1991); levels found in contaminated meat in the EU

Fig. 63.4

Structural details of a range of b-agonists that have

affected humans who consumed as little as 100 g of the

been proposed as growth promoters in cattle

product (Kuiper et al., 1998). See Table 63.10 for a

summary of some poisoning incidents.

(Hoey et al., 1995). Moody et al. (2000) have undertaken (2)

Hydroxylated aromatic ring. The metabolism is

a detailed review of the mode of action of the b-agonists

much simpler with the hydroxylated b-agonists and

in all species. When b-agonists are used as growth

they tend to have relatively short plasma half-lives and

promoters, two major problems arise during chronic

when coupled with a low potency in humans they may

exposure. Firstly, receptor downregulation leads to a

pose little risk from residues. An example of this type

fall off in effect over time (Peters, 1989; Re et al., 1994) of compound would be ractopamine, where the phar-

Table 63.10

A summary of some documented cases of b-agonist poisoning in Europe (after Witkamp, 1995).

Year	***Source***	***Compound***	***No. of people***	***Symptoms***	***Country***
1990	*Bovine liver*	*Clenbuterol*	*135*	*Tremor, palpitations, tachycardia,*	*Spain*
	(0.16–0.30 mg/kg)			*nervousness*	
1990	*Calf liver*	*Clenbuterol*			

22

Tremor, headaches, dizziness,

France

(0.38–0.50 mg/kg

palpitations, malaise

1994

Calf liver

Clenbuterol (?)

127

Not specified

Spain

1995

Fillet, rump steak

Clenbuterol

16

Tachycardia, tremors, nervousness

Italy

(>0.5 mg/kg)

Class 1 – Halogenated aromatic ring

References and further reading

OH

Slow

H

Advisory Committee on the Microbiological Safety of Food

Cl

metabolic

N

(1999) Report on Antimicrobial Antibiotic Resistance in

inactivation

Relation to Food Safety. The Stationery Office, London.

H2N

Clenbuterol

Allen, P. & Enright, W.J. (1989) Effects of administration of Cl

somatotropin on meat quality in ruminants: a review. In Use Half life in man T1/ = 30 hr

2

of Somatotropin in Livestock Production (ed. by K. Sejrsen, Pharmacodynamic dose

M. Vestergaard & A. Neimann-Sorensen), pp. 201–9.

in man 10 mg/day

Elsevier Applied Science, London and New York.

American Society of Animal Science (1986) Public health

implications of the use of antibiotics in agriculture. 77th

Class 2 – Hydroxylated aromatic ring

*Annual Meeting, Suppl. 3. Journal of Animal Science, **62**, OH*

OH

Rapid

H

1–106.

metabolic

N

Anderson, D.B., McCracken, V.J., Aminov, R.I., Simpson, J.M.,

inactivation

Mackie, R.I., Verstegen, M.W.A. & Gaskins, H.R. (2000)

HO

Gut microbiology and growth-promoting antibiotics in

Ractopamine

swine. Nutrition Abstracts and Reviews. Series B, Livestock Half life in man T1/ = 4 hr

2

*Feeds and Feeding, **70**, 101–8.*

Pharmacodynamic dose

Anderson, D.B., Veehuisen, E.L., Schroeder, A.L., Jones, D.J.

in man 25 000 mg/day

& Hancock, D.L. (1991) The use of phenethanolamines

to reduce fat and increase leanness in meat animals. In

Fig. 63.5

A comparison with the metabolic deactivation rate

Proceedings of Symposium on Fat and Cholesterol Reduced

and plasma half-life of halogenated and hydroxylated aromatic

Foods – Advances in Applied Biotechnology Series (ed. by ring b-agonists.

C. Haberstroh & C.E. Morris), pp. 43–73. Portfolio

Publishing, New Orleans.

Anderson, D.B., Veehuisen, E.L., Smith, C.K., Dalidowicz, J.E., macodynamic dose in man exceeds 25 000 mg/day

Donoho, A.L., Williams, G.D., Jones, D., Schroeder, A.L.,

(Paylean Freedom of Information Summary).

Turbert, M.P. & Guneratne, R.J. (1993) Ractopamine

hydrochloride: a unique PLE (phenethanolamine lean

Effective doses of ractopamine and zilpaterol are

enhancer) for swine. In Proceedings of the 11th World

reported to have negligible to undetectable residue

Association of Veterinary Food Hygienists (WAVFH) Sym-

levels in the target species (Anderson et al., 1993;

posium (ed. by P. Ingkaninum & P. Poomvises). pp. 96–102.

Zilmax Technical Manual, 1998). These products have

The Thai Veterinary Medical Association, Bangkok.

only been cleared for use in food animals after exten-

Anon (1996) Working Group II – Assessment of health risk.

sive reviews of the safety of residues and it is perhaps

Scientific Conference on Growth Promotion in Meat

unreasonable for a class ban to have been introduced

Production, pp. 19–25. EU Commission DG VI Agriculture.

in the EU based on the misuse of clenbuterol when safe

Association of Veterinarians in Industry (1979) In Proceedings of the Conference 'Ten Years after Swann'. AVI, London.

alternatives were in development.

Bartley, E.E., Nagaraja, T.G., Pressman, E.S., Dayton, A.D.,

The classes of b-agonist are contrasted in Fig. 63.5.

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Chapter 64

Injection Damage

J.H. Pratt

Introduction

1078

would constitute a major contribution to future meat

Damage produced by injection

1078

quality standards and may now prove possible through-

out Western Europe where individual cattle identifica-

Methods of introducing contamination

1079

tion is obligatory under European Community law.

Where the farm of origin can be determined, advice

on proper injection techniques can be given thereby

Introduction

improving the welfare interests of the animal and

enhancing the future profitability of the producer.

The faulty administration of veterinary medicines by

Losses incurred by the abattoir through the downg-

injection can give rise to complaints from meat whole-

rading of affected cuts of beef from incorrect injection

salers and retailers and on occasions from consumers.

procedures would also be reduced.

The lesion resulting from the injection of a drug may

It is to be regretted that in Britain the use of data

be aesthetically repugnant to the consumer and com-

collected in the abattoir has not been exploited to its *mercially unacceptable in the case of abscessation or*

full potential. Such information can play a significant

fibrosis in muscle tissue to the wholesaler, the retailing

role in future preventive veterinary medicine strategies

butcher and the supermarket outlet.

and in the depiction of regional and national animal

disease patterns.

The losses incurred by the meat industry through

Damage produced by injection

poor injection technique are spasmodic but never-

theless can be substantial. There are, unfortunately, no

Abscesses deep in the gluteal region of cattle are

reliable figures in UK meat inspection records for

reported since the site is frequently used for intramus-

condemnation of meat for abscessation due to faulty

cular injection of drugs. Damage in this area reduces

injection procedures alone. However, on occasions a

the value of a relatively expensive part of the carcass.

number of animals within one consignment of cattle

Abscessation may render the entire limb unsuitable for

exhibit deep muscle fibrosis consistent with damage

*human consumption. Intravenous injections can result
from injected material, necessitating the rejection of
in haematoma formation and abscess production. In
1.5–2 kg of a high-priced cut of meat. These lesions are
some cases this is due to irritant substances invading the
formed in the same anatomical area in a number of
perivascular tissue rather than being delivered properly
animals within a group from the same unit. The simi-
into the bloodstream. In addition, the deep injection of
larity in age, character and distribution of these lesions
an irritant substance causing a localized reaction within
suggests a common cause, the introduction of foreign
muscle tissue may elude detection at meat inspection
material by injection. Both injectable nemicides and
and even later in the cutting premises. The damage may
substances used in the regulation of bovine reproduc-
not be revealed until further butchering procedures are
tion, e.g. some prostaglandins, may have been responsi-
performed on the beef in the processing plant or retail
ble for such damage encountered in recent years in this
shop by which time it may prove difficult to trace the*

country.

animal back to the farm of origin. Indeed, in countries

The leather industry also suffers financial loss, as

where complex marketing arrangements exist, the

injection damage due to scarring and abscessation can

tracing of animals back through marketing chains may

reduce the value of the hide, particularly if the lesion is

prove impossible until unique individual identification

in a position that prevents the optimal use of the com-

of the live animal and the resultant carcass and cuts

plete hide for large leather or suede items of clothing

becomes feasible in all stock. Such an achievement

and upholstery.

Intramuscular injection sites

Alternative siting of injections to that of the gluteal region is therefore desirable. The middle third of the neck, about one-third of the way down from the top, is *recommended (see Figs 64.1 and 64.2); this in itself does not reduce the incidence of abscessation or muscle scarring following the injection of drugs but trimming of this less expensive area reduces blemishing of the carcass. This area also tends to be cleaner than the hindquarters and so it is less likely that infection will be introduced with injection.*

The factors contributing to muscle damage and abscess formation must therefore be identified to allow the formulation of advice for veterinarians and animal owners to reduce such damage.

The efficiency of the host animal's inflammatory response in removing the foreign protein and devitalized tissue together with the persistence of the stimulus determine the size and progression of the abscess formation. In mild cases no abscess may form, but scar

Fig. 64.1

A growing calf being injected into the neck muscle.

tissue will mark the tissue damage. When an abscess has been formed and the inflammatory stimulus removed the abscess may persist for a prolonged period before *resolving to scar tissue.*

Methods of introducing

contamination

The introduction of foreign protein may occur in a

variety of ways.

Contamination of injected drugs: This is most likely to occur prior to administration as a result of poor

hygienic procedures employed. To obviate contamina-

tion of the contents of a bottle or vial a separate sterile

needle to that used for injection must remain attached

to the container and used only to refill the syringe.

In multiple dosing an automatic injection mechanism

avoids this requirement and results in a smoother

and more efficient operation. The manufacturer's

storage instructions should be followed; unused vaccine

should be discarded. When therapeutic agents such as

antibiotics are used they should be used up as quickly

Fig. 64.2

A bull adequately restrained before introducing an

as possible after opening.

injection into the neck muscles.

Contamination of needle or syringe: Ideally, a sterile needle should be used for every injection but in practi-10–15 cattle, when groups of animals are injected and

cal situations this is often not feasible; however, in

in any event when contamination of the equipment

special circumstances this approach may be applicable

occurs or is suspected or the needle is in any way

on veterinary advice in certain herds to avoid transfer

damaged.

of specific viral and other infections such as enzootic

bovine leukosis (EBL). It is good practice, however, to

Punching a fragment of host skin: The introduction of

change needles and syringes regularly, i.e. after every

host tissue along with the injection material is most

likely to occur when damaged needles are used. The

equipment and uncontaminated injectable materials.

regular changing of needles will reduce the chances of

Preparation of the injection site is an integral part of

this occurring. When needle damage has obviously

this hygienic approach; the avoidance of contaminated

occurred a replacement is necessary in order to avoid *sites of injection is essential. A clean site should be*

possible injury to the animal and to maintain good meat

chosen. If not available an area should be cleaned, or if

hygiene and quality standards.

necessary clipped and cleaned.

There are now available multidose syringes with

special sterilization caps to reduce the possibility of

Irritant injections: The introduction of an irritant

infections. Caps can also be placed on the tops of

substance that devitalizes tissue locally can be respon-

therapeutic agents.

sible for direct or indirect damage to muscle tissue.

The recommended route of administration and the

Examples used in veterinary medicine are: basic and

injection technique outlined in the manufacturer's

acidic compounds, such as the sulphonamide drugs

instructions must be followed. The incorrect route can

and spectinomycin; hypertoxic preparations, e.g. long-

lead to tissue damage, e.g. drugs recommended for

acting oxytetracycline; and adjuvants, e.g. aluminium

subcutaneous administration must not be given by the *hydroxide, saponin.*

intramuscular route or intraperitoneally unless specifi-

Vasoactive substances, e.g. local anaesthetic prepara-

cally indicated.

tions containing adrenaline and some synthetic

Proper restraint of the animal will lessen the likeli-

prostaglandins, lead to ischaemic necrosis.

hood of tissue damage and allow hygienic procedures

to be followed. The injection of a fractious or nervous

Contaminated skin: Pathogenic bacteria may be intro-

animal can lead to unnecessary suffering and damage

duced not only when injecting cattle with a contami-

to the animal, not to say injury to the operator also.

nated drug or when the needle or syringe is dirty but

Furthermore, struggling while injecting an animal may

when the skin surface is not clean; the introduction of

preclude the proper administration of the medicine

pathogens from the site of injection will occur in a

with less than the prescribed dose deposited at the

proportion of cattle treated. It is therefore incumbent

recommended site, the remainder forming a depot with *upon the veterinarian and the stock owner to employ*

ensuing damage. Thus all animals should be adequately

hygienic injection procedures at all times using sterile

restrained (see Figs 64.1 and 64.2).

Chapter 65

Alternative Medicine

C.E.I. Day

Introduction

1081

observer, but they are united in several respects, in that

Homoeopathy

1082

they are:

Principles

1082

How to cure

1082

• Natural, relying on no man-made chemicals for

Conversion to veterinary application

1084

their effect;

Application

1085

• Able to work with and through the body's own

The challenge of herd treatment

1088

mechanisms, stimulating the 'vital force' or 'life

Materia medica

1088

Prescribing guide

1090

energy' in order to achieve health;

Acupuncture

1091

• Holistic, embracing the concept of mind and body

Theory

1092

as a whole in harmony with the environment, and

Diagnosis

1096

recognizing the interaction of the whole body with

Treatment

1098

each part, and the interaction of the parts with the

Technique of needling and treatment

1101

whole body and with each other; and

Homoeopathy and acupuncture combined

1102

• Environmentally and dietarily appropriate, since

Herbal medicine

1102

they give rise to no tissue residues in animals so

Essential oils

1102

treated.

Other therapies

1103

Conclusion

1103

Exceptions to this last point are herbal medicine and aromatherapy, in that they can give rise to residues and taints, thus making the selection and use of herbs

Introduction

and oils, as medicines for food-producing animals, a

matter for great caution (see below).

Alternative medicine, in all its many modalities, was the

Owing to practical considerations, there are two main

object of a great resurgence of interest in the latter part

systems of alternative medicine that have been devel-

of the twentieth century. This phenomenon is consistent

oped and refined in the field of bovine medicine and

with the trend towards environmental consciousness

that have become partially accepted by the conven-

(the so-called 'green' movement), which embraces an

tional 'scientific' community. These are homoeopathy

awareness of the importance and of the mechanisms of

and acupuncture. Of these, the one used to the greater health. A large body of consumers now recognizes the

extent is homoeopathy, since it lends itself more easily

vital role played by diet in the maintenance of health.

to rapid, less specialized treatments and is applicable to

They have an awareness of the effect of additives and

herd medicine. Acupuncture is more demanding of pro-

of residues upon the value of food items and an under-

fessional time and is not appropriate to herd applica-
standing of the potential impact of livestock medication
tions. Both are very well suited to use on organic farm
upon the health of food animals and upon the whole-
units, since neither gives rise to any medicinal residues
someness of the products of animal husbandry.
in tissues or in milk.
As is suggested by the epithet, alternative medicine
The title ‘alternative’ is more appropriate for these
is relevant to this trend, in that it provides an ‘alterna-
therapies than ‘complementary’, in that each is a com-
tive’ to what has become the accepted system of medi-
plete system of medicine in its own right, demanding a
cine, modern conventional drug medicine. There are
full understanding of its principles and practice for its
many so-called systems of alternative medicine (some-
true value to be manifested. This should embody no
times now described as ‘complementary medicine’ in
contentious sentiments. The following is a brief intro-
an attempt to attenuate the overtones of conflict em-
duction to the concepts of each of these two, followed

bodied in the word alternative). The wide range of

by more medical detail. Other therapies, being less

such systems can present a baffling array to the casual

appropriate in the context of cattle medicine, are

described in very brief format, in order to act as an

(i.e. diluted 1/100, 30 times over) giving rise to a dilu-

introduction only.

tion of 10-60 (at 10-23 Avogadro's hypothesis suggests

that it is unlikely that a molecule could be carried over

to the next stage). What Hahnemann found, with his

Homoeopathy

serial dilution and succussion method (succussion is the

violent shaking of the solution at each stage of dilu-

Founded by a German physician, Hahnemann, in the

tion), were two phenomena. Not only was the toxic

latter part of the eighteenth century (1790), homoeopa-

power of the substance reduced at each stage (easily

thy is a system of medicine embodying the principle

understandable) but also the curative power was

‘ similia similibus curentur’ meaning ‘let like be cured by increased (not so readily acceptable). It is a fact of life

like’. This classical slogan is often enough in itself to

that this latter phenomenon exists and that science has

deter the casual student, since it constitutes an entirely

not yet found the way to explain it. It therefore remains,

opposite stratagem to that of conventional ‘school

unexplained, to puzzle the reader and sadly, in so many

medicine’. It is hoped that the reader will keep an

cases, to act as a complete blockade to further enquiry.

open mind, forming opinions only after searching and

The big advantage of Hahnemann’s discovery of the

objective study into the relative merits of each strategy

effects of extreme dilutions, made prior to any under-

and the part each system may play in the overall

standing of molecules and atoms, is that there can be no

fight against disease. The provision of an objective

drug residues in meat or milk. This makes homoeopa-

study requires some comparisons with the ‘known’ to

thy a front-runner in the choice of medicine for organic

be made, so as to shed light on the ‘unknown’ which *cattle units. Whereas herbal medicine, using the primary homoeopathy represents. effects of material doses of pharmacologically active The principle of like curing like is elevated from the plant material, relies on achieving significant tissue con- status of an amusing idea or the product of a fertile centrations of medicine, homoeopathy exploits the sec- imagination by the fact that it exploits a natural law ondary effects (the body's reaction) for the mediation (The Law of Similars). It was not an invention, there- of its medicinal benefit. It depends not upon material fore, that occurred in 1790 but a discovery. Hahnemann doses but upon energy interactions. The result of this is hit on his discovery as a result of objective testing of that, as there has been a rapid growth in conversions of the effects of Cinchona bark (the parent material of farms to organic status, so there has been an increasing quinine and an accepted cure for malaria even today). demand for skills in farm homoeopathy, stimulating a He dosed a healthy person (namely himself) in order to burgeoning interest among cattle veterinarians for* *try to discover the mode of action of Cinchona bark, as*

proper training. With the holistic discipline this study

he could not accept the current eighteenth-century

brings, cattle welfare can only be a beneficiary.

explanation for its activity. What happened must have

In more modern times, and in a veterinary context,

been a great shock to him, for he developed symptoms

clinical trials have revealed good results in many fields.

quite indistinguishable from malaria. Cause and effect

Examples are Caulophyllum and its use in controlling

he objectively established, by alternately withholding

porcine stillbirths (Day, 1984a), bovine mastitis preven-

and restarting the administration of the substance. This

tion studies (Day, 1986), bovine dystokia prevention

led him to formulate his hypothesis: ‘ To cure mildly,

(Day, 1985), reduction of calf rearing losses (Mahé,

rapidly, certainly and permanently, choose in every case

1987) and control of canine kennel cough (Day, 1987a).

of disease, a medicine which can itself produce an affec-

tion similar to that sought to be cured’ (quotation from

Principles

Organon der Heilkunst by Hahnemann 1790, translation by Boericke & Dudgeon).

A more detailed approach to veterinary homoeopathy

Having carried out tests (Prüfungen in German,

is provided by Day (1984b, 1987b).

which became translated as 'provings') on healthy

volunteers, with many substances, he started to use

How to cure

this system of medicine on his patients. He soon found

that his crude substances evoked quite serious 'aggra-

Hahnemann's four steps to cure (a word he used very

vations' in his patients, so he proceeded to dilute the

objectively, to indicate a removal of symptoms/signs

remedies. This led to the second great stumbling block

with no further need for therapy to maintain that

for the modern, conventionally-trained observer in that

healthy state) were: (i) know the remedies, (ii) know the

his commonly used dilutions exceeded those that could

disease, (iii) match the remedy to the disease and (iv)

reasonably be expected to contain even a single mole-

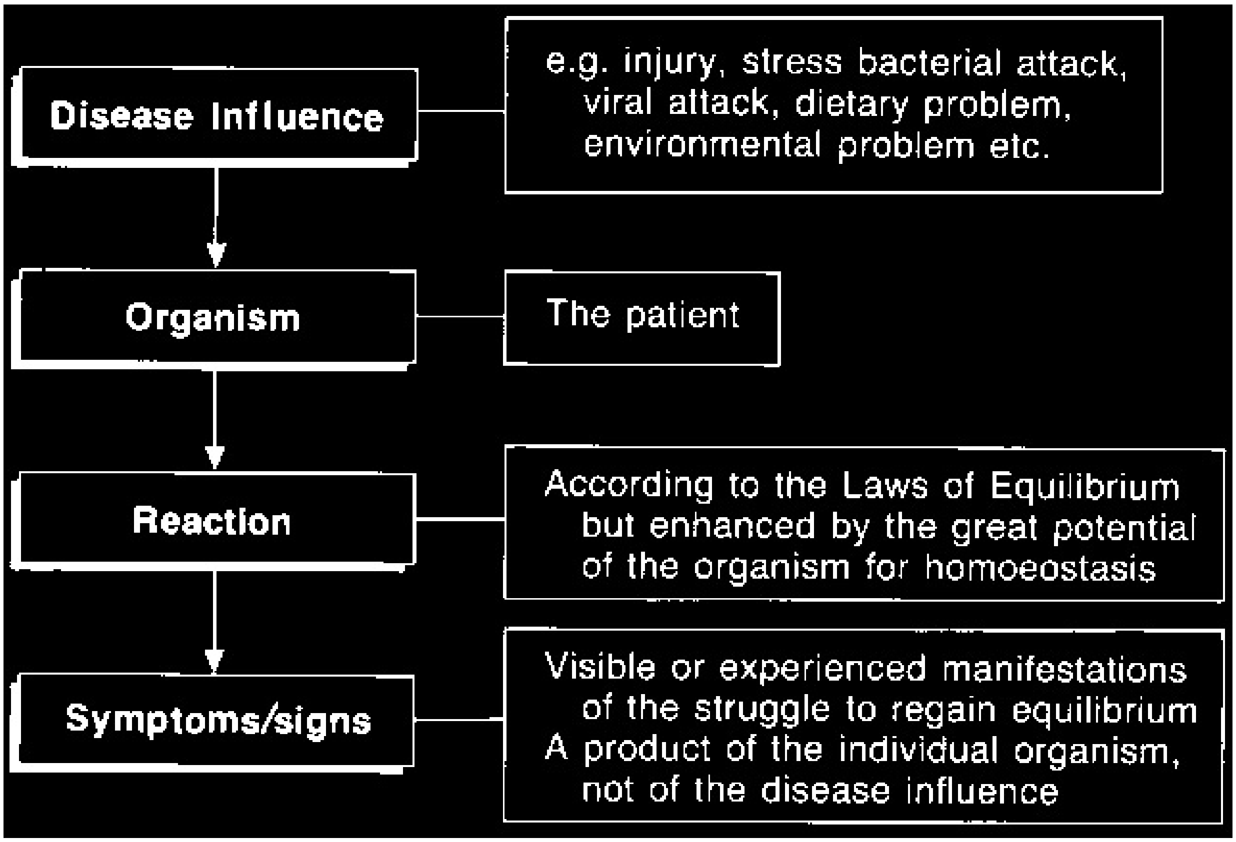
remove the obstacles to recovery. Our objective in vet-

cule of the original substance. His dilutions, called

erinary medicine is to cure disease wherever possible,

'potencies', were often to the extent of 30c and beyond

and it is difficult to argue with the logic of Hahnemann's



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four steps. The fourth is, in particular, a little surprising

in a positive way, in view of our modern culture's

opinion of the soundness of eighteenth century medical

beliefs and practices.

Know the remedies

A working knowledge of the 'provings' and actions of each individual 'remedy' or medicine is the basis of this stage. Obtaining this knowledge requires dedication. The remedies are written up in books of Materia Medica (e.g. Boericke, 1972; Clarke, 1982; Macleod, 1983; Vermeulen, 1997), which may run into several volumes. These books give an account of the properties of the remedies, in terms of source, general properties,

Fig. 65.1

A disease event in an animal.

'provings' and clinical findings with applications. This represents a huge body of knowledge on each remedy's known ('proven' by Hahnemannian tests) capabilities.

(1)

Aetiological or historical influences.

The information is recorded in very fine detail and

(2)

Generals:

symptoms/signs/properties of the

for each part of the body and mind, with its assumed

whole body, e.g. build, disposition, response *capabilities (from clinical data).*

to environment, response to food, response to

It is fair to say that, despite our pharmacological

climate, etc.

knowledge of modern manufactured drugs, there is not

(3)

Mentals: symptoms/signs relating to the mind,

the equivalent amount of knowledge of their actions in

e.g. demeanour, behaviour, character, responses

the body and, for the most part, very little is known of

to various mental stimuli.

a drug's possible actions apart from the major primary

(4)

Particulars: the symptoms/signs displayed in each

and local effects. It may also be fair to say that not

part of the body, in fine detail (the gleanings of a

enough pharmacodynamic studies have been made of

very thorough clinical examination and enquiry).

homoeopathic remedy actions but, if research is never

Also any 'modalities' shown by these signs, e.g.

directed this way, that information will never accrue.

'worse when cold and wet', 'worse after food',

Not even the most learned veterinary homoeopath

'better after exercise', etc.

has a full knowledge of even the major remedies (let

alone of the full range of several thousand available),

Match the remedy to the disease

since there is so much detail to be learnt. A basic knowl-

edge of major remedies is nonetheless essential to good

The findings of a detailed history-taking plus clinical

practice, as well as a superficial knowledge of minor

examination and the body of knowledge contained in

remedies. The hard work and dedication required, to

Materia Medica each constitute a picture that can be

obtain the necessary working knowledge, discourages

cross-matched, but this is often a daunting task. As each

many would-be practitioners.

disease incident is considered to be a unique event and

several thousand possible remedies exist, the task may

appear impossible. Once a basic knowledge of a good

Know the disease

number of remedies is obtained, however, then the

Since each set of symptoms and signs, displayed by

ability of the human brain to ‘compute’ at high speed

each individual patient suffering disease, is a product

makes the task achievable, in an acceptable number of

of the individual’s own reaction to a disease influence,

cases, for the conscientious student, after several years

then each disease occurrence encountered is a unique

of practice and study. There are also books to aid the

incident (Fig. 65.1).

process, which are basically computers in print. These

Knowledge of each disease incident must depend,

are called Repertories (Boericke, 1972; Kent, 1986;

therefore, upon one’s ability to discern as much as

Schroyens, 1993) and are basically dictionaries of symp-

possible of its aetiology in broad terms and upon

toms (in human terms) listed under ‘generals’, ‘mentals’

one’s ability to read the symptoms/signs shown by the

and ‘particulars’ (for each part of the body). A dedi-

organism, i.e. its reaction to the disease influence. A

cated veterinary version of the latter is in preparation.

detailed effort must therefore be made in history-taking

Several remedies are then suggested (with scoring or

and in clinical examination. The findings can be grouped

weighting) that are able to cause the precise symptoms

as follows:

sought and which may therefore be applicable in the

particular patient. If one lists enough symptoms and

Conversion to veterinary application

looks up each in a Repertory, the highest scoring

Homoeopathic medicine was developed in humans for

remedy (in theoretical terms at least) is the ideal choice.

humans and therefore presents some difficulties in

Resort to the Materia Medica will then help to confirm

conversion to veterinary practice. The difficulties can be

or negate this choice. Obviously, this is a fairly long-

summarized as:

winded process and, although helpful in difficult cases,

it is not applicable to rapid, on-farm selection of

• Lack of speech in animal patients;

remedies. Thus, for practical clinical application, a basic

• Interspecies differences in reaction to remedies;

knowledge of the remedies is required, together with a

• Lack of family history; and

practised ability to think rapidly in ‘picture’ format. No

• Intensivism in farm management.

equivalent veterinary Repertory yet exists although,

in slightly differing form, help can be found in books

Hahnemann (1814) did, however, advocate its use in

by MacLeod (1981, 1983), Brock and Nielsen (1986)

animals and so veterinary homoeopathy has a long

and Day (1984b, 1987b). Each of these works gives an

tradition.

easily assimilated guide to remedy choices under given

conditions, but (therefore?) is less accurate. Computer

programs are being developed for this type of work

Lack of speech

but, again, are not applicable to practical, on-farm use,

The lack of speech in animal patients leads to the loss

with the presently available technology.

of a large range of symptoms which would be of value

to the prescriber in human medicine. The ability to

Remove the obstacles to recovery

detail mental symptoms and feelings is lost, but much of what is needed in that respect can be discerned by

Even in the early stages of the twenty-first century,

extrapolation from the demeanour and behaviour of

the insight of Hahnemann in the eighteenth century

the patient. However, the finer details of how the mind

is remarkable. The single most exceptional example of

is affected by the disease influence, or why it responds

futuristic perspicacity is in the concept of ‘removal of

in the way it does, cannot be determined. Only the end

obstacles to recovery’. In trying to observe this fourth

result of behaviour is seen rather than the mental

provision for cure, very modern ideas must be

processes behind that behaviour. Since the mental

embraced. Not only must there be obvious remedial

symptoms of disease are a sure guide to the unique indi-

efforts, such as splinting or fixation of fractures, dietary

vidual response to disease, by each patient, a large pro-

investigation and correction, removal of an obstructive

portion of diagnostic (remedy-selecting) parameters is

foreign body from the bowel, etc. but also, in the herd *therefore lost to the veterinary prescriber. However,*

context, the myriad parameters (environmental, man-

deductions about mental symptoms, extrapolated from

agement, dietary, etc.) affecting herd health must be

the external behavioural signs, can provide an invalu-

considered. The idea that herd factors are important has

able guide to the sensitive observer. Lack of speech also

been practised by forward-thinking veterinarians for

deprives us of the enormous field of subjective symp-

only the last 40 or so years. However, Hahnemann made

toms. The adjectives used by human patients to describe

clear provision for it 200 years ago. Sadly, however, the

pain symptoms are legion. They are again an expression

most stringent efforts to improve the husbandry of

of the individuality of each disease incident and are

modern cattle farms will never provide truly ideal

therefore invaluable. Descriptions of pain such as

environmental and nutritional conditions for the

'tearing', 'cutting', 'burning ', 'aching', etc. are all lost in animals, although meticulous attention to detail can

veterinary medicine. Also hidden, among these symp-

approach the ideal. Thus, however much effort is

toms, is the headache in its many forms. We can rarely

applied, one is presented, in modern dairy cattle prac-

even diagnose headache in animals, let alone describe

tice, with an imperfectly fulfilled provision for real

it. Approximately 100 pages of Kent's Repertory (1986)

cure (Hahnemann's definition). This explains the need,

are devoted to headache, showing its importance to the

sometimes experienced on intensive farms, for repeated

prescribing physician.

medication (or possibly even continuous, in some of the

worst examples), but this must not be an excuse for

lack of effort. The unattainability of perfection must

Interspecies difference

not be an excuse for failure to achieve the best

conditions possible for the cattle nor for failure of

It is not unreasonable to suppose that different species

removal, to a maximum possible extent, of the obstacles

of animals will react differently to the medicines, when

to recovery.

compared with human reactions. There will also be dif-

ferences between the individual domestic species. To

Pathological

reconstruct the painstaking 'provings' of Hahnemann

To prescribe at the pathological level, one needs to be

and his followers, for each remedy for each species,

satisfied that the disease influence has evoked an acute

would involve several laboratories for many genera-

and easily identifiable disease process, that could be

tions, then only with an enormous usage of laboratory

easily matched to the actions of a particular remedy.

animals. This exercise would ethically be unjustifiable.

The effects of traumatic injury, for instance, are very Despite the obvious existence of such a problem, as

well covered by the properties of arnica. The adminis-

shown by the varying toxicology and pharmacology,

tration of arnica, as rapidly as possible after the trau-

known in different species, for many poisons (Garner,

matic insult, will swiftly and effectively initiate a healing

1967), drugs (Daykin, 1960) and foods, homoeopathy is

process that will reduce the pain, shock, haemorrhage, *largely transferable en bloc. This is a fortunate fact but tissue fluid accumulation and resultant tissue damage*

one that should never be taken for granted. Thus the

that normally follows trauma. The net result is a happier

astute practitioner of the art will need to be aware of

patient, less distortion at the site of injury and, more

the possibility of failure due to species difference and

importantly, less disturbance to the circulation in the

will use pharmacological and toxicological knowledge

area. Therefore there is more effective and rapid

to advantage.

restoration of normal tissue integrity and structure.

There is also a powerful and often underestimated

Lack of family history

antiseptic effect of this remedy.

The fact that one remedy covers this process is very

Although not strictly applicable to units where pedigree

convenient for the prescriber and very helpful to the

breeding and recording has gone on down the years, the

patient. It removes the need to apply the full rigours of

lack of family history of bovine patients, particularly in *the homoeopathic method, in times of emergency.*

terms of disease, will lead to loss of some accuracy in

Furthermore, this pathological level of prescribing

prescribing. Known line susceptibilities are an impor-

provides a simple proving ground for homoeopathy to

tant factor in choosing remedies in such conditions as

the sceptic and a useful starting point for learning

cancer, mastitis, lameness, etc., but the loss of some of

the first steps of the homoeopathic method. Other

this material is not likely to be as deleterious, to effec-

commonly used remedy/pathological indication pairings

tive veterinary prescribing, as the lack of speech and the

are:

potential interspecies differences.

Hypericum:

injury to areas rich in nerve endings (e.g.

in digit, tail, etc.), injury to nerves, painful

Intensive farming

grazes, photosensitization

This factor has been discussed previously (see. p. 955).

Ledum:

puncture wounds

Aconitum:

sudden shock to the mind or body,

sudden disturbances of the body's equi-

Application

librium (e.g. sudden-onset fever, sudden

haemorrhage)

Disease can affect an animal to a greater or lesser depth

Calendula:

open wounds – antiseptic and promotes

and, therefore, so can the so-called remedies of

healing

homoeopathy, since they are also 'disease-producing

agents' when administered to a healthy body. These

different levels of prescribing can be classified as:

Local

(1)

Pathological

One would apply this level of prescribing when the

(2)

Local

nature of the disease is acute and fairly superficial, to

(3)

Organ-specific

an otherwise healthy animal with a robust constitution.

(4)

Constitutional

Examples of this application are: acute-onset mastitis

(5)

Facilitative /regulatory

(see p. 326) resulting from a chill, where aconitum is

(6)

Detoxifying

useful, New Forest eye infection (see p. 919), where

(7)

Historical

mercurius corrosivus may be effective, and foul-in-the-

(8)

Specific and

foot infection (see p. 426), where hepar sulphuris could

(9)

Preventive

be the correct remedy. To prescribe effectively for these

conditions, one only needs to take note of the local pre-

These terms require explanation, since their usage in

senting signs and match these to a remedy. One does

this context is peculiar to homoeopathy alone.

not need, again, to delve into the deeper homoeopathic

method, discussed in previous pages, in order to achieve

Aurum

Corresponding to a great

a good result. However, it is vital to ensure that the

Pulsatilla

many cows that suffer

disease is not chronic in nature or an acute exacerba-

Sepia

typically female or hormonal

tion of an underlying chronic disorder. If this should

problems as a rule

prove to be the case, satisfactory results will not follow

Antimonium crudum

Fitting those cattle that suffer

from employment of this simplified technique and one

Nux vomica

digestive or liver problems

would need to apply the constitutional approach (see

Lycopodium

below).

Calcarea carbonica

Matching those cows suffer-

Calcarea phosphorica

ing from lactation-induced

Organ-specific

Phosphorus

disorders

Organ-specific remedies may be used when one organ

These generalizations are too sweeping to be strictly

is particularly embarrassed in an illness, when it is

followed but the pictures of the remedies listed above

considered important to support that organ. Some

are suitable to be grouped in the way shown. These are

remedies have a particular affinity for specific organs or

'big' remedies (Hahnemann's so-called polycrests) and

tissues and the most important are:

have wide-ranging effects on all parts of the body. They

Rhus toxicodendron:

muscles

cannot, therefore, be type-cast purely in the roles shown

Ruta graveolens:

tendons,

ligaments,

joint

above, but the groupings are useful nonetheless. The

capsules,

aponeuroses,

groupings represent trends in the relevant animal’s

periosteum

disease response patterns and are very useful for short-

Hypericum:

nerve fibres

listing of remedies. These and other useful remedies will

Symphytum:

bone

be discussed later (see pp. 1088–1090), in fuller detail.

Nux vomica:

liver

In the case of a patient affected by chronic disease,

Flor de piedra:

liver

no real cure can follow treatment unless this method of

Lycopodium:

liver

prescribing is followed. The organism has learnt, in the

Berberis:

liver, kidney

case of chronic disease, to live in a state of uneasy

Kali chloratum:

kidney

harmony with the disease. The animal is therefore

Digitalis:

heart

unable to regain health, often lost a long time previ-

ously, unless the deep, powerful and most appropriate

stimulus of true holistic constitutional homoeopathy is

Constitutional

prescribed.

The concept of a 'constitution' embodies everything

that is unique to an individual organism. It embraces

Facilitative/regulatory

the idea of the 'programmed' nature of each body's

The facilitative level of prescribing exploits the ability

response to a disease influence. Another way to con-

of certain 'potentized' substances to facilitate metabo-

sider this is to think of predetermined tendencies in

lism with respect to those substances. Examples are the

each individual. Response to disease is determined by

use of 'potencies' of calcium phosphoricum to facilitate

a number of factors: genetic make-up inherited from

metabolism with respect to calcium and phosphorus,

the parents, in utero influences during pregnancy, the magnesium phosphoricum to help magnesium metabo-birth process, postnatal influences, influences during

lism, and cuprum metallicum to assist copper metabo-

the growing period and influences during adulthood. In

lism. It is well known that so-called mineral deficiencies

the farm context, one can see how breeding, pregnancy,

are rarely absolute deficiencies but can be more often *calving, rearing and general management or dietary*

a malfunction of the relevant absorptive, metabolic

regimens can affect the make-up of an adult cow. By

and eliminative processes for that mineral. Cases of

reading the response pattern of the animal (signs and

'relative' excesses and deficiencies can both be helped

symptoms) in the face of disease or situations, and by

by such methods. In the case of a hormone disturbance,

studying her conformation and behaviour, one can for-

a 'potency' of the hormone may help regulate and

mulate an idea of her 'constitutional type'. This whole

balance the body with respect to that hormone.

picture can be matched to a whole remedy picture, as

previously discussed. Not many remedies have a com-

Detoxifying

bination of wide enough or deep enough effects on the

body to rank as constitutional remedies and, in the

The detoxifying method of prescribing echoes very

world of cattle, the major nine examples can be listed,

closely the preceding remarks. Should a specific sub-

conveniently classified into three groups:

stance be causing a toxic effect, e.g. alkaloid, metal,

chemical, etc., then the body's natural ability to break

cific disease, there will be no remedy specific to the

down and/or eliminate such toxins will be enhanced by

disease but a whole host of possible remedies, the most

the administration of the specific substance, or a close

suitable of which must be selected for each patient.

relative, in 'potency' (homoeopathic dilution). Exam-

Having said this, it is possible that baptisia could be spe-

ples are the use of plumbum in cases of lead toxicity,

cific to salmonellosis (Chapter 15), mercurius cyanatus

coumarin or melilotus in cases of warfarin toxicity,

to calf diphtheria (see p. 250), mercurius corrosivus to

opium or nux vomica in cases of anaesthetic toxicity or

New Forest eye or even borax to foot-and-mouth

even of carbohydrate overdose in the ruminant. Such

disease (see Chapter 43(c)) (in those countries in which

methods have often been shown to produce unexpected

it is permitted to treat this disease).

results, even in extreme cases of toxicity.

Preventive

Historical

In herd medicine it is very important to apply preven-

The historical method of prescribing utilizes the body's

tive principles, in order to minimize or to obviate the

ability to respond to an appropriate curative homoeo-

risk of spread of a known or predicted infectious

pathic stimulus, long after the initial disease-producing

disease within the herd. This is the basis of effective

influence has subsided, should the body still be suffer-

veterinary involvement on the modern bovine farm

ing from the effects of that influence. Examples are:

unit. In an individual animal context, it is important to

using arnica long after an initial traumatic insult, should

prevent disease occurring in the face of a predictable

the body still be suffering disease from that injury; using

challenge or disease-producing event.

aconitum long after a mental or physical shock, if the

The greatest demands on the veterinarian using

body is still suffering effects or fears produced by that

homoeopathy are on a herd basis. Where infectious *shock; using a 'specific' remedy (see below) long after*

disease has either entered the herd, in which case the

a specific infectious disease has passed its acute phase,

healthy individuals must be protected, or is threatening

should the body still be suffering effects from that

the herd, in which case the whole herd must be pro-

disease.

tected, one would select for prevention a specific

All that is necessary, in order to utilize this method,

remedy. This would generally be a nosode (see Specific is to detect, in a chronic disease situation, a facet of the

prescribing, above) although it could be any remedy

history that leads one to believe that the current disease

from the homoeopathic Materia Medica that the pre-

has its origins in a specific historic incident. One can

scriber feels specific enough to a certain disease (see

then treat for that incident, as if it were in the here

Prescribing guide, p. 1091). In conventional medicine

and now, even though it may have occurred years

one would be reaching for a vaccine in this context, but

previously.

in the case of some infectious diseases, no effective vaccine is available or no vaccine exists at all. Nosodes may be considered as if they were vaccines, if it helps

Specific

the reader to understand the principle of their applica-

The specific method of prescribing would usually be

tion in this context. However, they do not produce any

used in an acute infectious disease context, where a

antibody response in the treated animal, due to the

known specific infectious disease agent is involved.

extreme dilutions in which they are usually used (30c).

Generally speaking, this method of treatment would

Neither do nosodes carry the potential hazards that

imply use of nosodes (remedies made from disease

vaccination sometimes can, e.g. strain 19 Brucella

material). Examples are: mastitis nosode in cases of

abortus vaccine (Day, 1986, 1987b).

mastitis (see Chapter 23), infectious bovine rhinotra-

These preventive remedies, in order to be swiftly,

cheitis (IBR) nosode in cases of IBR (see p. 286),

effectively and easily applied to the whole group at risk, *bovine virus diarrhoea (BVD) nosode in cases of BVD may be administered via the drinking water. Water (see p. 853) or salmonella nosode in cases of salmonel- troughs should be as clean as possible and should be losis. In the acute phase of an infectious disease, it may large enough or well enough supplied with water, so as be dangerous to use the nosode in an attempt to not to run dry on the day of dosing. The quantity of produce a cure. For this reason, this form of therapy is remedy used does not appear to be very critical but an usually reserved for use during the recovery phase of easy guide is to use 5 ml per drinking trough, unless the the disease, in order to prevent any tendency for the trough is unusually large or small. Frequency of dosing disease to become chronic. During the acute phase it is would depend upon the estimated properties of the always better to select an appropriate homoeopathic challenge. In an enzootic disease situation within the remedy for cure, according to the Law of Similars in the herd, the frequency would be selected corresponding to usual way. This implies that, in each case of acute spe-*

the estimated violence and virulence of the disease and

according to the animals' estimated ability to withstand

(2)

To select a combination of remedies for the group.

it. At times of high risk, when the disease agent is

This will allow the incorporation of the spectrum

perhaps given the upper hand by management factors

of signs shown by the different individuals. A

or by climate or the animal is compromised by similar

maximum of three different remedies should be

factors, then one would dose more frequently. In the

incorporated.

case of assumed risk from an epizootic disease, i.e. a

(3)

To select a number of different remedies

disease not yet met by the herd, dosing could be more

(maximum of three) to stimulate the individuals

sporadic.

at different levels, as in the foregoing section. A

The second sphere of use of the preventive technique *'constitutional' remedy, say, could work alongside*

is in the case of the individual animal, which may be

a 'specific' remedy and a 'local' prescription.

threatened by a predictable disease challenge. Thus

(4)

A single constitutional prescription may be pos-

with impending parturition, caulophyllum could be

sible, especially if the group all come from one

used to help prevent problems (Day, 1985, 1987b), or

family or from one breeding line.

for an anticipated stressful journey, aconitum could be

(5)

A specific or nosode prescription could be

used in advance of the challenge. Incidentally, aconitum

selected, as in the above section. This can be very

can be used on a group or herd basis, in order to prevent

successful in the case of a known infective disease

the production losses consequent on herd stress, such as

and lessens the need for more detailed homoeo-

the periodic tuberculin test.

pathic knowledge or skill.

Thus it can be seen that the application of the

(6)

The group could be 'repertorized', as if it were a

homoeopathic method has come a long way, since it was

single animal. The technique would be as outlined

first devised in humans some 200 years ago. Although

in the section describing how to match the remedy

the rigorous and in-depth diagnostic and prescribing

to the disease. This is an advanced technique and

processes may daunt the novice, the classification into

should not be tackled without experience.

different levels at which the method can be applied in

The reference given describes how these techniques are

bovine medicine makes it easier to start out. They

compatible with proper homoeopathic philosophy and

provide scope, for even the newly initiated and hesitant

principles.

prescriber, to test the principles of homoeopathy and its

efficacy at an easier level, without immediately being

committed to long-term study or to large and therefore

Materia medica

expensive stocks of medicines.

There follows a brief summary of the properties of some of the homoeopathic remedies most commonly used in a farm context and some of their possible clinical applications. This is not intended to be an exhaustive source on the subject but an introduction to these 30 useful remedies. Fuller works on this material can be found in the Further reading section. Remedies are presented in alphabetical order for simplicity, not in order of importance nor grouped according to possible application. The way in which these remedies are presented shows the emphasis placed upon the 'picture' presented

The challenge of herd treatment

Much has been made, in the foregoing pages, of the need to individualize therapy for best results. This high ideal is frankly not practical in a herd or group situation. If we consider, for instance, a group of calves suffering from pneumonia, treating each on an individual basis is not possible. What is needed is a modification of principles, while maintaining the essence of homoeopathic philosophy and methodology. This short section can only be a summary of the techniques involved, in

by the disease rather than upon its usual name. Rem-

order to show the options. Clearly, homoeopathy will

edies are taken from the plant kingdom, animal

not be a practical therapy on the farm if it is not adapt-

kingdom and minerals and are available in tablet,

able to herd applications.

pillule, crystal, powder, tincture, injection, cream, oint-

A detailed account of how this can be done is to be

ment or lotion forms. The thirtieth centesimal (30c)

found in the Further reading section (Day, 1999). In

potency is a useful potency of most remedies, for the

essence, there are six main possibilities:

purposes of beginners.

Aconitum napellus: this is a remedy suitable for use in cases (1)

To choose a single similimum (a homoeopathic

of sudden shock (physical or mental in nature), sudden-onset

medicine which is similar to the signs and symp-

fevers, disorders from chilling and cold winds, and in cases of toms displayed)
for the entire group. This will only

profuse bright red haemorrhage.

be properly effective in an epizootic situation, in

Affected animals tend to shudder in response to fear or

which all individuals are likely to be similarly

shock, display a rapid pulse, run a fever and suffer conjunc-

affected.

tivitis with fluid lacrimation and nasal discharge. Symptoms

tend to centre on the chest, so use in ‘shipping fever’ is an

in movement and responses, difficult to handle and more

obvious application (see p. 286).

fearful.

Antimonium tartaricum: this remedy is particularly suited Carbo vegetabilis: abdominal distension by gas, flatus, to respiratory signs. Indications are mucoid, rattly breathing flatulent colic, weakness of circulation and musculature, poor or coughing, frothy saliva and a tendency to cyanosis. Animals resistance to infection and even collapse characterize this

display minimal thirst and a rapid, weak pulse. Cold, damp

remedy. Its main application is in the treatment of the cold,

weather aggravates the condition and affected animals are

collapsed individual, in whom its results can be spectacular.

unwilling to lie on their sides. This remedy is one of several It has been dubbed the ‘homoeopathic corpse reviver’, on

useful pneumonia remedies and should be considered in cases *account of its prowess in such cases.*

of fog fever (see p. 866).

Caulophyllum thalyctroides: one of the Native North

Apis mellifica: it is useful in cases characterized by oedema.

Americans' so-called 'squaw-root' remedies, it has great appli-Urine retention, pulmonary oedema, oedematous swellings of

cation in all disorders of labour, at any stage (Day, 1984a,

vulva/perineum or udder, ascites, cystic ovaries, etc. may all 1985). It also has an effect on shifting lamenesses, particularly respond if concomitant signs agree. The patient is usually

if the origin is in the small joints.

thirstless and prefers cool open air. Cold bathing of affected Colocynthis (genus: Cucumis or Citrullus): this remedy areas produces comfort.

is of particular use in colic. The abdomen is distended and the Arnica montana: this is a remedy of use in all condi-back arched. Animals will roll and kick at the belly in cramp-

tions arising from trauma. Bruising, haematoma formation,

like paroxysms.

pain, swelling, shock and even resultant local infection will

Hepar sulphuris: if any homoeopathic remedy could be said respond to treatment. Patients often display a fear of being

to fill the role of antibiotics in septic conditions, then this is touched.

the one. Suppurative processes in their early stages respond

Arsenicum album: this remedy is a polycrest and therefore well. In suitable cases, there is always great sensitivity to pain, of constitutional importance.

Restlessness, chilliness and thirst with relief from warm applications. Pain is aggravated by the

characterize the patient. The remedy can be useful, on a more

least touch. Joint-ill and navel-ill usually respond (see pp. 249, local basis, in cases of diarrhoea, dehydration and collapse, if 255).

concomitant signs agree. Diarrhoea is usually profuse, watery

Hypericum perforatum: injury to nerves or to areas rich in and offensive-smelling.

nerve endings is an indication for this remedy. It has a very

Belladonna (genus: Atropa): a 'fever' remedy, this is useful rapid healing effect, both on the pain and on the physical

in cases where there is an acute febrile or inflammatory state damage. Not surprisingly (on account of modern knowledge

characterized by heat, redness, swelling, fullness and pain. The of the physiology involved and of the symptoms) the lesions

pulse may be full and bounding. There are often delirious or

and pain of photosensitization also respond well (see p. 884).

convulsive signs too. The animal is usually thirsty and displays Lycopodium clavatum: a polycrest, this remedy has an

a dilated pupil. Symptoms tend to centre on the chest, making

application constitutionally. With an affinity for the liver, the a useful distinction from the usual pattern of aconitum.

remedy is often used in this context. Possible digestive distur-Bryonia alba: this remedy has an affinity for serous membance, dry, withered appearance to the skin, tendency to flatus, branes. All suitable conditions are worsened by movement, so *abdominal distension, liver dysfunction, dyspnoea, tachyp-*

a major sign in the affected animal is unwillingness to move.

noea, movement of the nostrils with every breath and an

Affected animals are thirsty for long cold drinks. Guided by

overall anxiety distinguish this animal type in disease. Prob-

these three points one may prescribe confidently in cases of

lems are often right-sided and the animal prefers warmer

pneumonia, mastitis, arthritis, peritonitis, etc. The pneumonic water to drink (if offered).

calf will stand still, despite its fear, and will tend to lie on its Mercurius cyanatus: a thirsty patient with a paradoxically affected side to prevent movement. The mastitic cow would

wet mouth and possibly even drooling saliva may require a

allow herself and her hot swollen painful udder to be

mercury-type remedy. Mercurius cyanatus patients display examined, rather than move away.

offensive breath, offensive-smelling ulceration of mouth and

Calcarea carbonica:

throat and swollen glands. The picture fits that of calf

another polycrest, this remedy has con-

diphtheria.

stitutional applications. Disorders of production are an indi-

cation, e.g. fertility, lameness, mastitis. The animal has a heavy Mercurius *solubilis: as with all mercury remedies, there is a skeletal structure, large limbs, large joints and large feet. It tendency to thirst, to profuse salivation, to offensive breath, to usually has a good condition score and is generally peaceful*

swollen glands in the throat and to ulceration of mouth, bowel but dominant. Movements tend to be unhurried. The appetite

or teats. Ulcers will discharge pus. If there is diarrhoea, there is very good and, if a milking cow, the milk yield is high. The will also be a degree of tenesmus. Since the remedy is a poly-animal is susceptible to chilling and usually shows catarrhal-

crest, it has constitutional applications. The preceding disease type responses from the mucous membranes.

tendencies in a dominant, usually heavy, animal are an indi-

cation for its use.

Calcarea phosphorica: a polycrest, this remedy is suited to similar conditions to calcarea carbonica and the typical Nux vomica: as a polycrest, it has wide application in a con-animal is similar, although lighter in skeletal structure, quicker stitutional context in the bovine. Patients tend to be dull and

sluggish in movements, with paradoxically rapid or violent

teum, this remedy is a powerful aid in the treatment of sprains reactions when disturbed, bad tempered and thin. They suffer

and other damage to such tissues and regions of the body.

digestive complaints, characterized by cessation of rumen

Sabina (juniperus): sabina's main sphere of activity is the function and a tendency to constipation, having hard knotty

uterus, where bloody discharges and lack of tone may respond.

stools. Some cases of ‘acid’ or fermentative diarrhoea may

It is not indicated where sepsis exists. Retained fetal mem-

respond and complaints following from overeating of con-

branes may also be expelled under its influence.

centrate will respond well. Conditions tend to be worse in

the morning and worse for disturbance or chilling (Mahé,

Sepia: a polycrest, sepia has great value as a bovine consti-1987).

tutional remedy. It is predominantly of use in a female

context. Lack of tone and lack of tautness typify the condi-

Phosphoric acid: in common with all the ‘acids’, phosphoric tions and the constitutional type suited by this remedy. The

acid is indicated in cases of general weakness. More specifi-

animal takes on a worn-out, tired, sagging appearance and so,

cally there is debility, dehydration, pale flatulent painless

also, do individual body regions, e.g. uterus/perineum, limbs, diarrhoea with a dry mouth, thirst and possibly a degree of

udder, etc. Venous congestion and tendency to prolapse are

jaundice.

also characteristic. Fertility problems may respond, if con-

Phosphorus: because of its extent of action, it is a polycrest stitutional aspects agree.

and therefore of great value in a constitutional context. Phos-Silica: Better known for its ability to stimulate expulsion of phorus conditions are *characterized by sudden onset and by*

foreign bodies from the tissues or to awaken chronic low-

their serious nature, e.g. sudden-onset pneumonia, sudden

grade inflammatory lesions, silica is also a great constitutional haemorrhages, hepatitis, haematogenous jaundice, etc. The

remedy. Structural weakness and distortion, whether of skele-

phosphorus animal is also 'sudden' in temperament, being

ton or feet, with a poor immune response, typify the animal

averse to separation from the rest of the herd and apt to panic.

able to respond to the remedy.

The type is of lean build and averse to handling. Conditions

are worse for touch and change of weather.

Thuja occidentalis: The reputation of this remedy rests mostly on its action on papillomatous lesions (p. 882), espe-Phytolacca americana: this is the remedy above all others cially when they occur on neck or abdomen. Ill-effects of

with a reputation in mastitis. This reputation can lead to

vaccination also may respond. The constitutional and other

overuse in this context, as it will only produce results when

effects of the remedy are not so important in cattle work.

used in the correct homoeopathic manner. Lymph glands and

mammary glands become indurated swollen and painful.

Urtica urens: The lesions of nettle rash are well known to There is usually heat too. Milk becomes thickened, stringy and everyone, as is the pain that follows.

The remedy is of value in yellowish. Cold wet weather aggravates the symptoms.

such conditions. Apart from these properties, the remedy has

the ability, in high potency, to promote milk flow and, in low Pulsatilla nigricans: this is a common constitutional type in potency, to induce suppression of milk. This dual regulatory

the bovine, particularly in the case of heifers. The type is shy, power gives the remedy great value in bovine medicine.

feminine in appearance, suffers catarrhal complaints and has

Lesions respond favourably to warm applications and nega-

little thirst. Breeding problems respond well, if it is used in tively to cold applications, so too does the mastitis helped by the correct constitutional context. Catarrhal syndromes of

urtica.

respiratory tract, udder, reproductive tract, etc. are typical.

The animal prefers fresh, open air and symptoms are aggra-

It is hoped that the foregoing brief account of 30

vated by warm, stuffy atmospheres and in the evening.

remedies will allow a start to be made in homoeopathic

prescribing. It cannot be expected that, in so few pages,

Pyrogenium: fevers, particularly those of a septic nature, it will provide a comprehensive knowledge of the reme-respond well to this remedy, especially if pulse and tempera-

ture are not in agreement. In suitable cases, there is a tendency dies. The reader must also realize that these few reme-to toxaemia, offensive secretions, dark blood and offensive, *dies, although forming a good nucleus of prescribing*

dark-coloured, septic lesions.

material, actually represent only a fraction of what is

available. For each condition or syndrome mentioned,

Rhus toxicodendron: American poison ivy (the source of a great many other remedies have a potential value,

this remedy) produces, and is therefore able to help, severe

should they prove to have properties 'similar' to the

pruritic conditions or conditions characterized by rheumatic

or arthritic stiffness and pains with great thirst and an aggra-problem.

vation from cold, wet or damp conditions. Skin lesions are

often vesicular in nature, resembling cowpox lesions. Muscu-

Prescribing guide

loskeletal problems are further characterized by an aggrava-

tion when moving from rest, with a subsequent 'loosening' and

There follows a small vade-mecum, showing some indi-

easing of the stiffness and pain. Suitable diarrhoea cases

cated remedies that may prove effective in the named

display dysentery and tenesmus.

syndrome. Please be reminded that true homoeopathy

Ruta graveolens: with an affinity for fibrous structural does not rely upon the name of a condition for remedy tissues such as ligaments, tendons, joint capsules and perios-

selection but upon the similarity between disease

picture and remedy picture, on as many counts as pos-

position of confidence. Books giving a greater depth

sible. The following list only serves as a pointer to some

of homoeopathic knowledge are listed in the Further

commonly indicated remedies. Final selection between

reading section and accredited courses in Britain, on

those remedies mentioned (and many not mentioned)

veterinary homoeopathy, are conducted under the aus-

rests with the prescriber. All the remedies mentioned

pices of the Faculty of Homoeopathy, 15 Clerkenwell

below appear in the preceding section, so that section

Close, London EC1R 0AA. The Faculty has an exami-

can act as a brief guide to help selection of the most

nation structure, for postgraduate qualifications. On

relevant remedy. (Remedies may be given orally, by

an international basis, the Faculty does help courses in

injection, topically or orally via the drinking water.)

other countries, and the International Association for

Veterinary Homoeopathy both runs courses and sets

Acetonaemia (p. 793)

Lycopodium, nux vomica

examinations for veterinary homoeopathy.

Arthritis (pp. 454–458)

Bryonia,

caulophyllum,

phytolacca, rhus tox., ruta

graveolens

Acupuncture

Bloat (p. 832)

Carbo veg., lycopodium, nux

vomica

Acupuncture is a science of energy medicine, having its

Calf diphtheria (pp. 250,

Mercurius cyanatus

origins in ancient China anything up to 4000 years ago.

822)

The oldest medical textbook known, the Huang Ti Nei

Constipation

Nux vomica, sepia

Jing Su Wen (Veith, 1972), may have originally been

Convulsions

Belladonna, nux vomica

written as long ago as 1000 bc. Its origins are confused,

Dystokia (Day, 1984a,

Caulophyllum, pulsatilla

since it has undergone many alterations and commen-

1985)

taries since it was first written. (In fact the Su Wen was Fever

Aconitum,

belladonna,

possibly a later addition to a scaled down Nei Jing.) This pyrogenium

book has formed the basis of traditional Chinese

Foul-in-the-foot (p. 426)

Hepar sulphuris

medicine theory down the centuries, but there have

Haemorrhage

Aconitum,arnica,phosphorus

been myriad adaptations and variations applied since

Infertility (Chapter 36)

Apis mell., aurum, pulsatilla,

its inception, giving rise to traditional Chinese medicine

sepia

as we know it today. Acupuncture is but a component

Injury (Chapter 32)

Aconitum, arnica, calendula,

of this, Chinese herbalism also forming an integral part,

hypericum, ledum, rhus tox.,

along with moxibustion (the application of heat). The

ruta grav., symphytum

practice of traditional Chinese medicine is truly holis-

Joint ill (pp. 249, 255)

Hepar sulphuris

tic, in that it embraces an understanding of the part

Ketosis (p. 793)

See Acetonaemia

played by diet and lifestyle in the health of the individ-

Mastitis (Day, 1986)

Aconitum,

belladonna,

ual and it makes a positive effort to optimize these, as

(Chapter 23)

bryonia, carbo veg., hepar

an integral part of therapy.

sulphuris,

mercurius sol.,

The Chinese have long treated animals with acupunc-

phytolacca, silica, urtica

ture, so our veterinary use of this in the West is no new

Metritis (Chapter 34)

Caulophyllum,

pulsatilla,

thing. Dogs, cats, horses, cattle and other farm animals

pyrogenium, sabina, sepia

can be treated. In countries other than Britain, working

Navel ill (p. 249)

Hepar sulphuris, silica

animals such as elephants, llamas, donkeys, camels and

Papillomatosis (p. 882)

Thuja

buffalo are patients. In the UK, acupuncture is much

Placenta (retained)

Caulophyllum, sabina, sepia

more widely used on dogs and cats than in horses, and

(Chapter 34)

more in horses than in cattle. This is more a function of

Pneumonia (Chapters

Aconitum, antimonium tart.,

the pattern of specialization in the veterinary profes-

17, 49)

bryonia, lycopodium, phos-

sion and that more interest has been shown by those

phorus, pyrogenium

veterinarians who are in small animal practice, than a

This list is far from complete and is aimed at pro-

reflection of the efficacy and value of acupuncture in

viding an insight and a starting platform, for deeper

cattle. Cattle respond very well to the methods but

homoeopathic prescribing and learning.

chronic disease is less a feature of bovine medicine than

Having read this guide to the principles of

in the other species. This means that there is less call for

homoeopathy and having tried out some of the

a specialist second opinion than in equine or pet med-

methods and suggestions contained in this chapter, it is
icine. The call for acupuncture help in cattle is reduced,
hoped that the reader will go on to further study and
compared with the other species, since the species is
will venture into more ambitious prescribing, from a
kept more on a financial (productivity) basis than for

emotional, competitive or recreational reasons. The
of traditional acupuncture and encourage the diligent
reality is that there is less perceived value in the indi-
student to look further into the subject.
vidual as a result.
Acupuncture is a system of internal medicine

Theory

devised, in ancient times, purely from the outside of the
body. In ancient China, the human body was not to be
The theory of the science of acupuncture is based upon
violated, either in life or in death, so post-mortem
concepts of energy and forces which are rooted in Taoist
examinations and anatomical or physiological studies
philosophy. In this there exists no linear thinking, no

were not performed. The basis of the system is the
cause and effect. The order and pattern of life (and
relationship of points on the surface of the body to
therefore disease, which is a part of life) and of the uni-
the internal organs and their integrated functions. The
verse are governed by principles of inevitability. Con-
mechanism of the relationship is not clear to Western
cepts are not placed one under the other in a deductive
science and is unquestioned in the East, where such a
sequence or subsumption, but side by side in a picture.
different philosophy of life and living pertains as to be
Events follow each other, not by cause and effect but
incomparable. Clearly, as far as some of the acupunc-
by a kind of inductance. Light does not cause darkness
ture points are concerned, there is a cutaneous–visceral
and vice versa, one becomes or leads to the other
reflex at work but this does not satisfactorily explain
inevitably. Similarly, the concept of light cannot exist
the mechanism of acupuncture, any more than does
without a concept of darkness, nor the concept of good
the discovery of the release of endorphins or opioids

without that of evil.

in response to treatments.

Our Western way

It has been said of Taoism that it does not deny

of looking at life leads to a linear thought process,

reason, but that it remains just beyond its grasp. It is

trying to establish ‘cause and effect’, and an attempt

a concept of balance, of rhythm, of sustainability, of

to rationalize, classify and compartmentalize in a way

harmony. It describes a complex web of interrelation-

that does not sit well with the oriental philosophy and

ships, in which the whole is dependent upon and

method.

affected by its parts and in which each part is depend-

The Chinese discovered, empirically, a collection of

ent upon and affected by the whole and each of the

points (some 700 forming the basis of the system) that

other parts. There is an essential understanding of flux,

related to bodily function and to disease patterns or

of dynamism and of interconnectedness.

pictures. In order to explain the indisputable facts and

The two forces that maintain the universe, and the life

verifiable correlations so discovered, they wove a web

within in it, are called Yin and Yang and represent of philosophical concepts, in harmony, of course, with

philosophical polarities. They are the eternal opposites.

their philosophy of life (so turning an empirical art into

They are aligned to other pairings of polarities, ranging

a science). In ancient China, and still today, medical lore,

over the whole of our existence. Examples are, respec-

religion and their way of life are inextricably entangled

tively, dark and light, cold and hot, female and male, low

and form a unity not found in any comparable form in

and high, sluggish and fast, lower and upper, night and

Western culture, where it seems that all three tend to be

day, soft and hard, earth and heaven, light and heavy,

considered as separate entities. This chapter does not

passive and active, inside and outside, empty and full,

argue which view may be the more correct, valid or

water and fire, weak and strong, under- and overactiv-

healthy, but merely presents comparisons.

ity, humble and exalted, front and back (more logical in

The philosophical lattice work, developed so long quadruped terms than in the human biped, i.e. ventral ago, is not there to confuse the would-be student but to and dorsal, in that dorsal is higher, therefore repre- explain and elucidate the empirical findings. This is not senting Yang) and so forth. It should be becoming clear apparent to the sceptical Western observer, who will that these two polarities act both simultaneously and undoubtedly find the concepts not only confusing but antagonistically within the universe (and within its amphigoric. Atavism and Taoism are indigenous to microcosm, the body). There is, however, no absolute in the oriental way of thinking and are totally foreign to life and so with Yin and Yang. There is no Yin without us. However, acupuncture was devised in the East and Yang. They are forever transforming into one another, developed in the light of oriental concepts. It must be on an almost imperceptible basis. Nothing is all Yin, taken or left at face value, at present, until some more nothing is all Yang. All systems are composed of Yin readily assimilable theory may be formulated that can *and Yang. Within Yin there is Yang and within Yang*

explain the observable phenomena as well as the origi-

there is Yin. Within any given Yin/Yang system under

nal. This development is not in the offing. It is hoped

discussion, there is a further yin/yang system and, within

that by presenting a rapid overview of the theory and

that, another. This applies over and over, ad infinitum.

philosophy, it will not confuse the reader but will serve

Zou Yen, the philosopher of the third century bc,

to give an introduction to the principles and methods

observed: ‘ Heaven is high, the earth is low, and thus they

Table 65.1

The paired (tsang/fu) organs, relating to Yin and

Yang.

Yin (tsang organ, ventrally/

Yang (fu organ, dorsally/

medially-routed meridian)

laterally-routed meridian)

Heart

Small intestine

Kidney

Bladder

Pericardium

Triple heater

Liver

Gall bladder

Lung

Large intestine

Spleen/pancreas

Stomach

Fig. 65.2

The Taoist T'ai Chi T'u symbol.

are fixed. As the high and low are thus made clear, the

energy on the point of materializing. They did not

honourable and humble have their place accordingly. As

trouble to define, merely to observe its function. It per-

activity and tranquility have their constancy, the strong

vades the entire universe, so is not simply life energy.

and weak are thus differentiated. . . . Cold and hot

The Qi of the body is called normal Qi or upright Qi.

season take their turn . . . and Heaven knows the great

This is derived in equal parts from each parent, as the

beginning, and Earth acts to bring things to completion.

original Qi or conceptual Qi. It is nourished and replen-Heaven is Yang and Earth is Yin' (Kaptchuk, 1983).

ished throughout life by grain Qi and air Qi, which are Thus are embodied the consistencies and (apparent)

combined with each other and with normal Qi, to per-

inconsistencies of the oriental approach and there is

meate the entire body.

no way to determine the beginning or the end. The

Chinese theory also gives the ultimate power of life

classic 'chicken and egg' situation holds, and one

to the kidneys, in that the kidneys store the Jing. This can only observe the continuum/perpetuum. The Taoist

is an undifferentiated 'substance', which is most closely

T'ai Chi T'u symbol (Fig. 65.2), more correctly a sphere associated with life itself. It contains the potential

rather than a two-dimensional object, is the tradi-

for birth, maturation, decay and death. It supplies the

tional and elegant attempt to represent this concept

potential for differentiation into Yin and Yang, in other

diagrammatically. In this yin-yang model, the dark

words, the capability of life. Since all organs require *area represents Yin and the light area, Yang. The dots*

Jing, the kidney bestows the gift of life on each organ.

represent yin-within-yang and yang-within-yin. As the

Since Jing also controls conception, future life is gifted

sphere turns, so the interplay of yin and yang are

by the kidneys. The anatomical relationship of the

illustrated.

gonads to the kidney would have escaped the ancient

Yin and Yang act together and antagonistically within

Chinese. Jing gradually diminishes in quality and quan-

the body and are components of the life energy – Qi

tity with time, so ageing is controlled in this way. Death

(pronounced 'chee'). This energy is said to circulate

is inevitable when there is not enough Jing to maintain

continuously and rhythmically (to a circadian rhythm)

life. It is said 'The kidneys are the root of life, the resi-through twelve paired (left and right) channels. These

dence of Yin and Yang, the channel of life and death'.

channels are often also called meridians. The correct

This makes a lot of sense in Western terms, since the

balance and harmony of Yin and Yang within the body *kidneys, once damaged, cannot regenerate.*

and the even and regular circulation of energy (Qi)

The channels are related to organ function, thus the

within the channels maintain perfect health. The con-

twelve meridians, or channels, have names indicating

verse applies: an imbalance of Yin and Yang and

these relationships. The organs, to which they relate, are

an interrupted flow of energy will imply disease. Thus

each said to be either Yin or Yang in nature and, need-

disease is considered to be more Yin or more Yang,

less to say, there are six Yin and six Yang organs/chan-

relative to the state of health. This can occur as a rela-

nels (Table 65.1) in order to maintain balance. The Yin

tive deficiency of one or the other, or as a relative excess

organs are the solid ‘ Tsang’ organs, the Yang organs are of one or the other. Each would produce an apparent

the hollow or ‘ Fu’ organs. Each Tsang organ is related excess of one over the other. There is unlikely to be an

to a Fu organ, e.g. (respectively) kidney is related to

absolute deficiency or excess, since life could not then

bladder.

be supported.

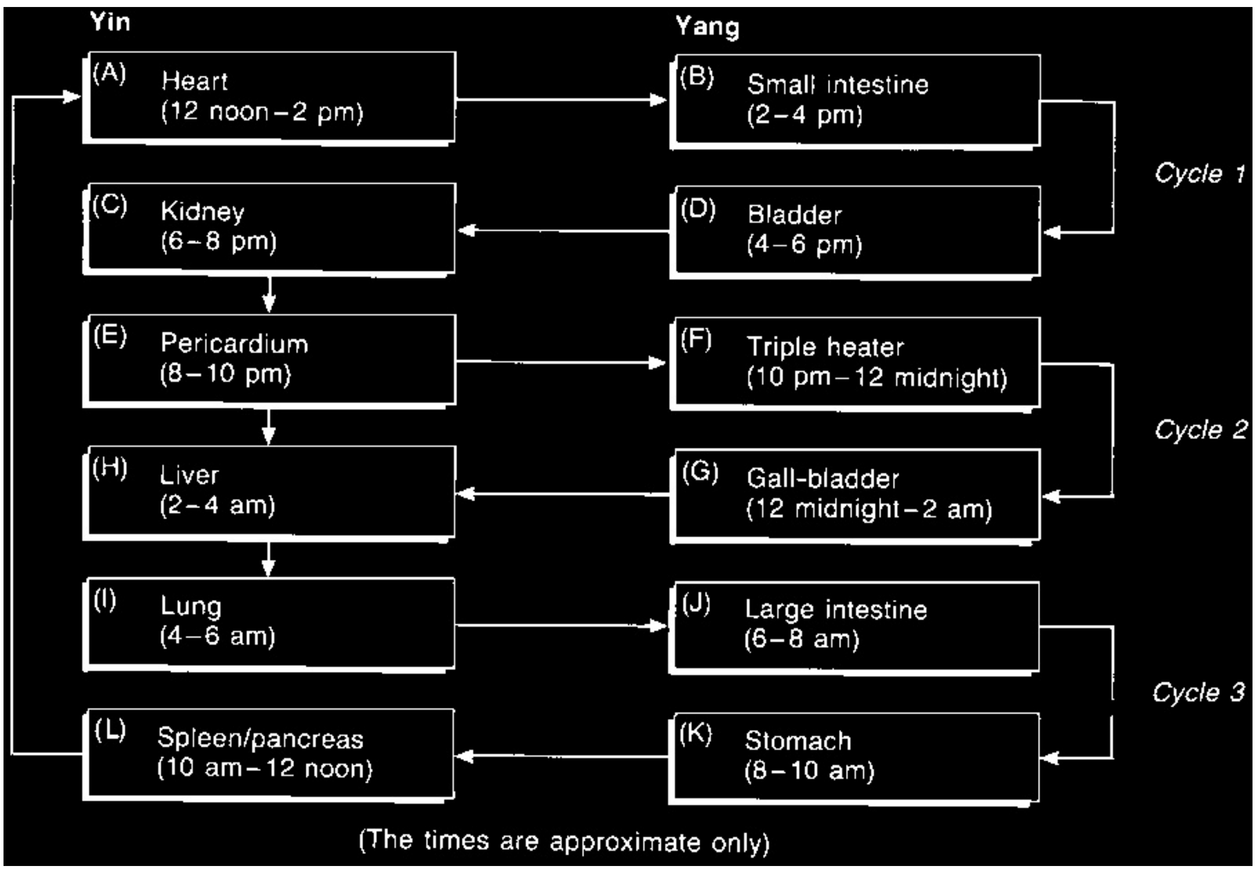
The energy (Qi) dwells in any single channel for two

Qi itself has many facets. To the Chinese, who did

hours and the flow pattern follows a '-Yin-Yang-Yang-

not distinguish between matter and energy, Qi could be Yin-' cycle, repeated three times. We are then able to

described as matter on the verge of becoming energy or draw a flow chart, built from the preceding lists



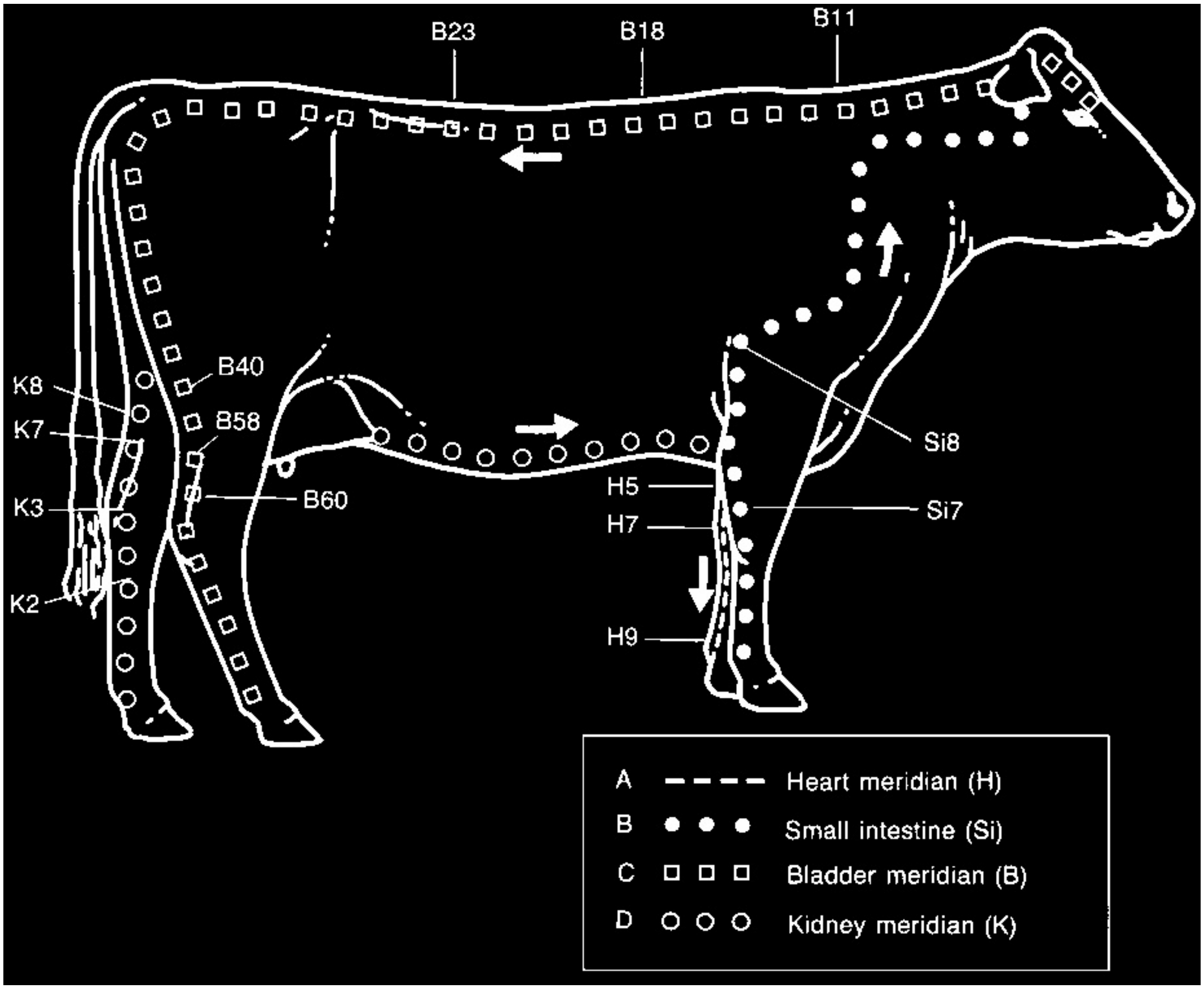


Fig. 65.3

An energy flow chart for the

'-Yin-Yang-Yang-Yin-' cycle.

Fig. 65.4

Cycle 1 of the energy flow

chart for -Yin-Yang-Yang-Yin-.

(Fig. 65.3). On the body, these are represented in

interpretation (Fig. 65.8) and different authors disagree

diagrammatic and simplified form in Figs 65.4–65.7.

in detail. Experienced practitioners, nonetheless, are

Routes of meridians, and point locations thereupon, are

able to develop their own working models and to

approximate guides only. Accurate point location

achieve the desired results.

requires reference to more substantial works; the titles

Having read that the channels are each related to an

of important reference works can be found in the

organ, the reader is probably wondering about the

Further reading section. Owing to the loss of digits on

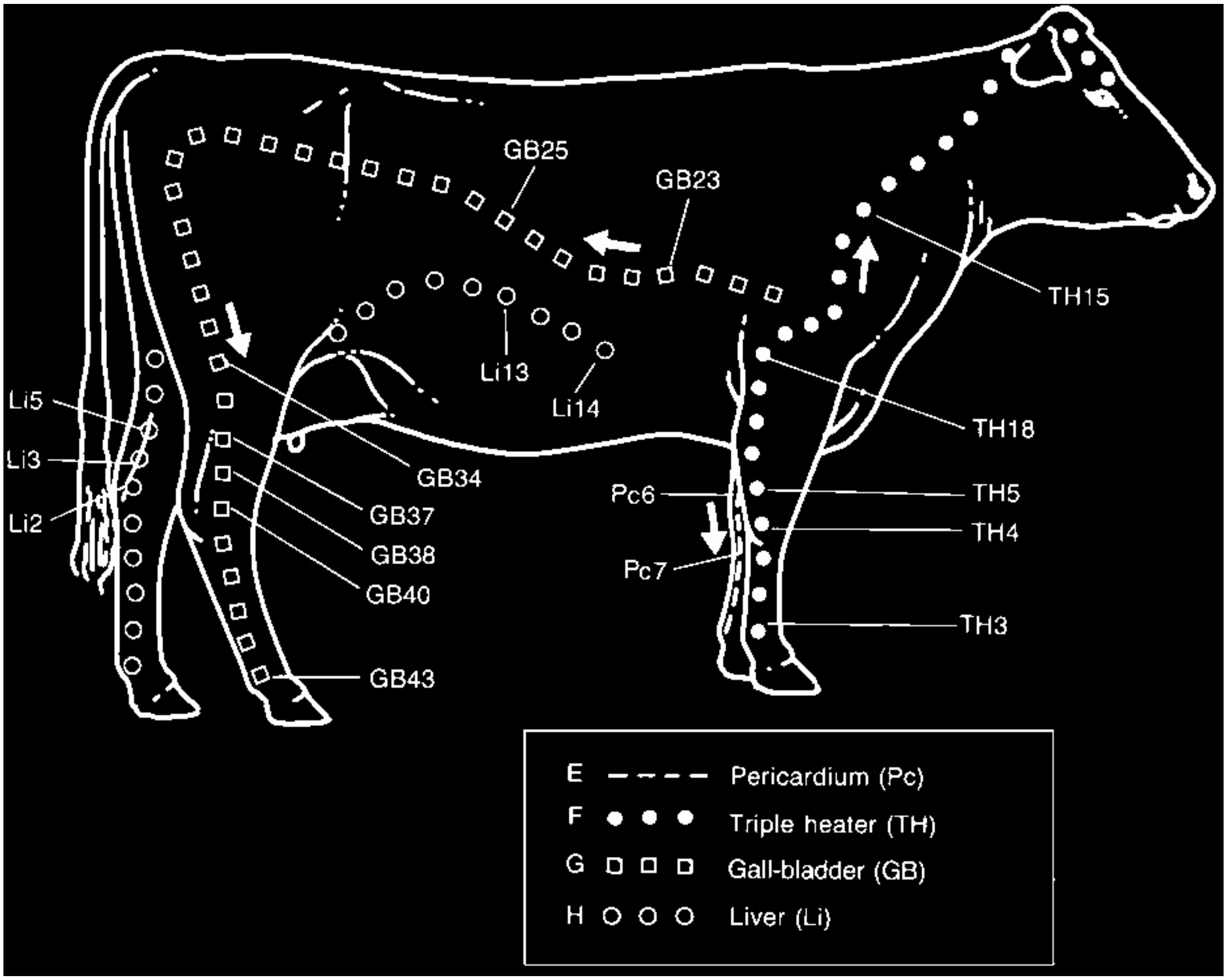
triple heater. This 'organ' represents thorax, abdomen

the bovine limb (compared with the human five per

and lower abdomen (pelvic), and therefore takes in the

limb) the distal sections of some meridians are open to

functions of respiration, digestion and the urogenital


GB25
GB23
TH15
Li13
Li14
TH18
Li5
Li3
Li2
GB34
GB37
GB38
GB40
GB43
Pc6
Pc7
TH5
TH4
TH3
E Pericardium (Pc)
F Triple heater (TH)
G Gall-bladder (GB)
H Liver (Li)

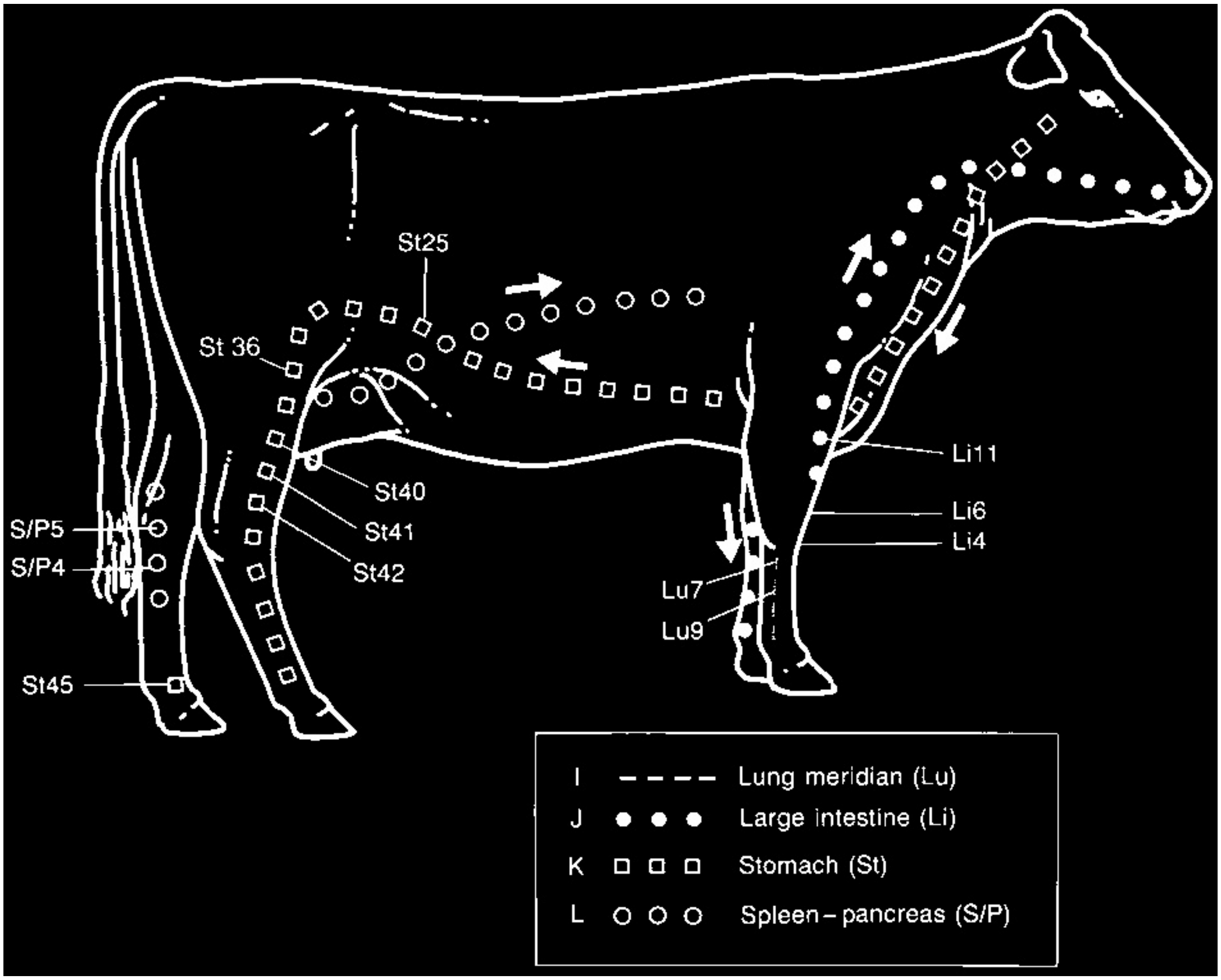


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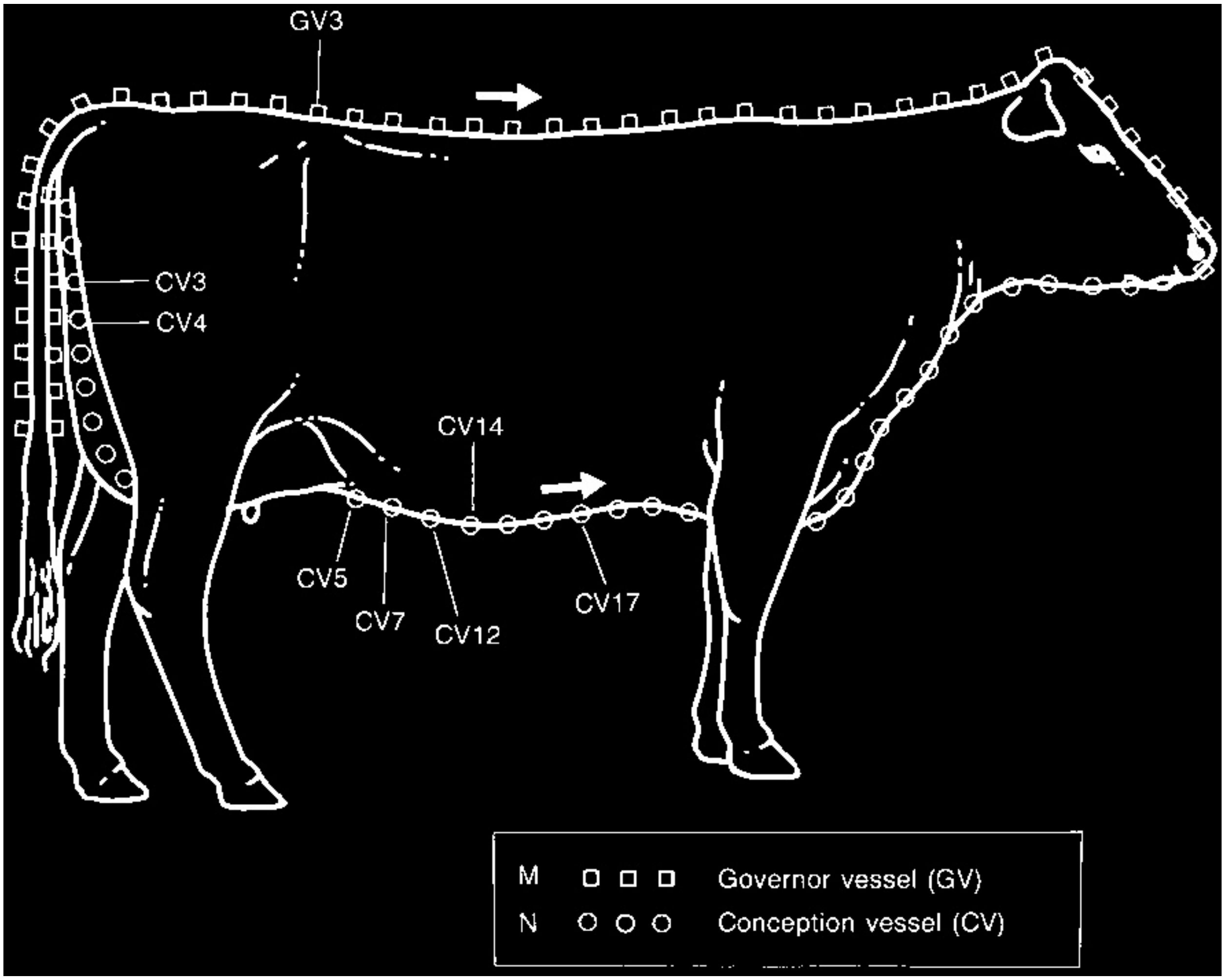
Fig. 65.5

Cycle 2 of the energy flow chart for -Yin-Yang-Yang-Yin-.

Fig. 65.6

Cycle 3 of the energy flow chart for -Yin-Yang-Yang-Yin-.


GV3
CV3
CV4
CV14
CV5
CV7
CV12
CV17
M Governor vessel (GV)
N Conception vessel (CV)

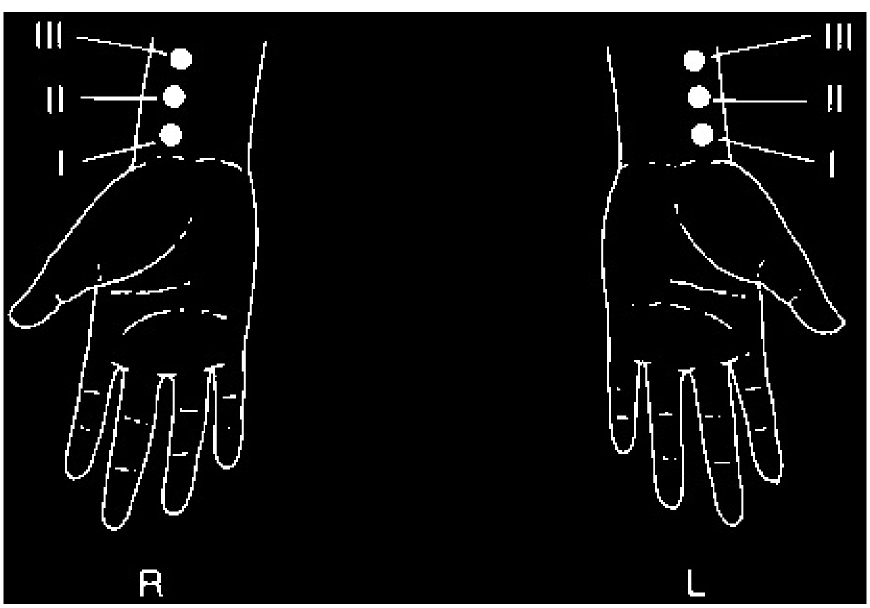

III
II
I
III
II
I
R
L

Fig. 65.7

The two extraordinary

(unpaired) meridians (Governor vessel

[yang] and Conception vessel [yin]).

deep internal connections, creating continuity proxi-

mally and of the exterior 'secondary vessels', creating

continuity at the extremities.

The opposing forces of Yin and Yang are constantly

at work in the body and are supposed to be in total

balance, flowing evenly through the 'channels' that the

meridians represent. In fact it is better to picture a con-

stant strife between Yin and Yang with alternating

conquest and defeat but, in a state of health, with a bal-

anced result throughout the 'championship'. It is impor-

Fig. 65.8

Pulse positions on the human wrists. Each position

tant to note that the 'correct' balance for each

has a deep and superficial pulse.

individual is unique, and that a female will tend more

towards Yin and a male more towards Yang.

Any stimulus that leads to an uneven 'contest', with *system. It can be considered also as the seat of humoral*

one or other side in the ascendancy on balance, will lead

control and interconnections.

to disease. The Chinese called such adverse forces the

There are two other (extraordinary) vessels or merid-

‘pernicious influences’. These are wind, cold, heat/fire,

ians, which are of similar importance to the six pairs and

dampness, dryness and summer heat. They also believed

these are the conception vessel and the governor vessel.

disease could originate under the influence of emotions

These follow, respectively, the ventral and dorsal mid-

(joy, anger, sadness, grief, pensiveness, fear and fright),

lines. The energy flows from anus to mouth in both and

way of life (departure from Tao – ‘the way’), diet, sexual

therefore the vessels are not ‘paired’. They differ from

activity and physical activity. Further factors were rec-

the other meridians in that they also lack special toni-

ognized, that did not fit into these categories, e.g. burns,

fication and sedation points, etc. as described later for

bites, stings, trauma, etc.

the other meridians, and are not an integral part of *the circadian energy circulation system. The governor*

Diagnosis

vessel is dorsal and therefore Yang, the conception

vessel is ventral and therefore Yin (see Fig. 65.7).

Diagnosis of the nature of disorders in the body in

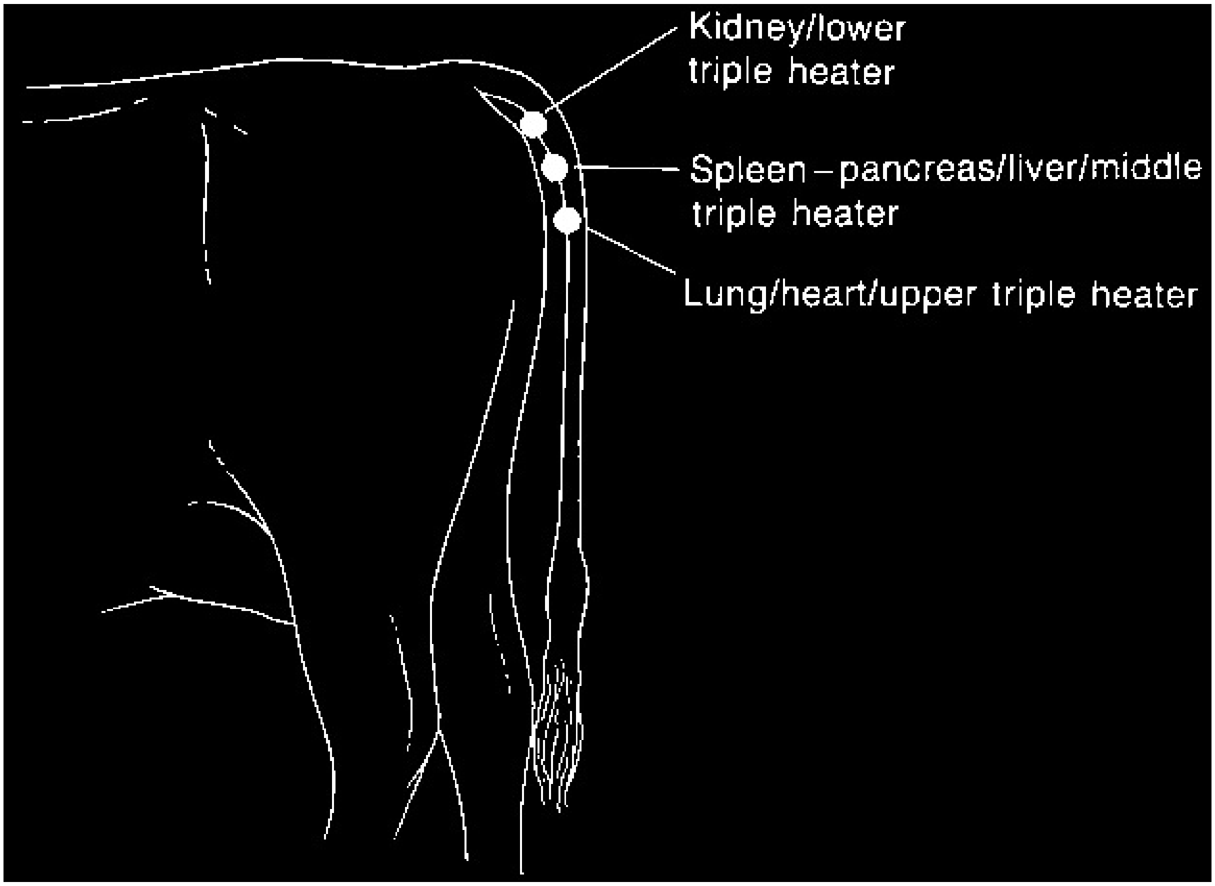
The circulation of the energy (Qi) is allowed to occur terms of the information given in the preceding pages

through the 12, seemingly-disconnected channels, with

was by pulse diagnosis in the human wrist (Fig. 65.8 and

apparent open circuits at each end, by means of the

Table 65.4). Kothbauer and Meng (1983) give a method



using the midline caudal artery in the bovine (Fig. 65.9),

patterns of pathology and in diagnosis. The five element

but this is sadly a long way from the complex and

theory is not respected by all practitioners of acupunc-

refined method developed for the human (through no

ture, but holds the key to many important deductions

fault of the authors, more of anatomy and practicality).

about health and disease for those who uphold its

General quality of pulse can still be determined and can *tenets.*

be very helpful. Overall impressions only can be gained

Water destroys Fire but creates Wood

by this method.

Wood destroys Earth but creates Fire

Inference can be made from the signs of disease, dis-

Fire destroys Metal but creates Earth

played by the body, as to the nature of pernicious influ-

Earth destroys Water but creates Metal

ence and which meridians or organs are disturbed by

Metal destroys Wood but creates Water

this influence (Kaptchuk, 1983). This requires a great

deal of further study, if the reader is to develop these

The (tsang/fu) organs and the emotions are related to

skills and it is too large a subject for this small treatise.

these elements. Thus, for example:

Help can, nonetheless, be derived from the following

Liver/gall bladder

–

Anger

–

Wood

charts of relationships, which provide information

Heart/small intestine,

on the possible route of pathology, once the disease

pericardium/triple

–

Joy

–

Fire

process has gained entrance (Table 65.2).

heater

An important and functional model for the ancient

Spleen (+pancreas)/

–

Pensiveness

–

Earth

Chinese was the concept of the ‘five elements’. In this

stomach

abstraction there are cycles of creation and destruc-

Lungs/large intestine

–

Sadness/grief

–

Metal

tion/control, which can be of great help in establishing

Kidneys/bladder

–

Fear/fright

–

Water

In addition, the organs and functions of the body are

related to each other, for example:

The kidneys are connected with (control) the bones and

rule over the spleen

The heart is connected with (controls) the pulse and

rules over the kidneys

The lungs are connected with (control) the skin and rule

over the heart

The liver is connected with (controls) the muscles and

rules over the lungs

The liver nourishes the muscles and the muscles *strengthen the heart*

The heart nourishes the blood and the blood strength-

ens the spleen, etc.

Fig. 65.9

Pulse diagnosis in the bovine (according to

These connections are not so far-fetched, even in

Kothbauer & Meng, 1983).

modern Western terms.

Table 65.2

Pernicious influences on disease.

Yang

Yang

Yin

Yin

Season

Spring

Summer

Late summer

Autumn

Winter

Climate

Wind

Heat

Dampness

Dryness

Cold

Direction

East

South

Centre

West

North

Organs (Tsang)

Liver

Heart/triple heater

Spleen

Lungs

Kidneys

Organs (Fu)

Gall-bladder

Small intestines/pericardium

Stomach

Large intestines

Bladder

Orifices

Eyes

Ears

Nose

Mouth

Urogenital orifices

Tissues

Ligaments

Arteries

Muscles

Skin and hair

Bones

Elements

Wood

Fire

Earth

Metal

Water

Odour

Rancid

Scorched

Fragrant

Rotten

Putrid

Emotions

Anger

Joy

Sympathy

Grief

Fear

Fluids

Tears

Perspiration

Saliva/mucus

(Mucus)

Spittle

Wood

Water

Fire

Metal

Earth

Fig 65.10

The creation (sheng) and

destruction or control (ko) cycles of five

element theory. The large arrows denote

creation, dashed lines denote destruction/

control.

What has been described, although briefly and there-

scriber has arrived by following the foregoing para-

fore not to do it full justice, is an attempt on the part of

graphs. Treatment of the body in traditional Chinese

the ancients to explain the rhythm and dynamics of life

medicine, whether by diet, herbs, moxibustion or

and disease, albeit often by metaphor, which can be off-

needles, attempts to restore the balance in the constant

putting to the Western mind. The explanation does

conflict between Yin and Yang. This treatise really only

seem to embrace the reality of the integrity of the whole

deals with treatment by insertion of needles.

body and its interconnectedness, both in anatomy and

Moxibustion is the application of heat to specific

function, and its relationship to the outside world.

points of the body to supply heat energy (yang) to the

Disease does not come in tidy parcels, affecting only

system. Usually, artemisia vulgaris herb is used for this one part of the body in a single way, but in complex pat-purpose, as a 'wool'. Heat is applied directly to the area

terns of whole body dysfunction. The philosophy

or a few millimetres above it. Needles can also be

behind traditional Chinese medicine embraces this

inserted at the point and heated by burning moxa. It is

essential concept very satisfactorily and provides a

not a practical method for the beginner, for general

means of arriving at a 'diagnosis'.

farm use. It is mentioned briefly here, merely to put it

From the platform of the diagnosis, in the traditional

in context and to introduce the reader to the concept,

Chinese sense, a treatment rationale or treatment prin-

which may otherwise confuse when it is encountered in

ciple can then be devised. This will be based on the need

other texts.

to balance Yin and Yang, to restore harmonious flow

There are many different categories of points that

of Qi, to counteract the pernicious influences and to can be utilized in acupuncture prescriptions, in an

support the stressed organs. What may be surprising, to attempt to restore the desired balance. The major ones

the uninitiated, is that this allegorical methodology

are listed below.

can provide the clinician with a valid working model for

effective diagnosis and successful therapy.

The points

Acupuncture points are not anatomically represented,

***Treatment** (Plates 65.1 and 65.2)*

although there are histological and physiological prop-

The acupuncture prescription for the patient should be

erties which are peculiar to them. A good account of

devised from the treatment principle, at which the pre-

this phenomenon is given by Kothbauer and Meng

(1983). Their exact positions are described in relation

alone are unlikely to be far-reaching. Like master

to anatomical landmarks,

measurements being

points, the symptomatic points may also be used in

expressed in terms of units which relate to the dimen-

reverse as diagnostic tools, the reliability being ques-

sions of specific parts of the body. The measurement

tionable unless they are used as part of the whole

units are:

picture.

Tsun or cun: this is the acupuncture inch. In human Pilot points are used properly to redistribute or balance acupuncture it is traditionally equal to the length of

the Yin–Yang conflict. Main points are the tonification

the second phalanx of digit 3 of the human hand.

points, which increase energy in an energy deficient

Fen: One tenth of the above.

meridian (gold needles are often used) and sedation

Finger breadth, thumb width, forearm length, pubis-nates, points decrease energy in overactive meridians (silver shin length, etc. are all as they state, and apply to

needles are often used). Each meridian has one of each

human measurement, but sources vary as to their rela-

of these.

tionship to the cun. It is usually accepted that a thumb width is 1 cun, two finger breadths are 1.5 cun, four The source (yuan) point on each meridian acts as an *finger breadths are 3 cun, cubital crease to carpal*

adjuvant to one or other of the two above-mentioned

crease is 12 cun, etc.

points. The metal used for needling is selected accord-

It may be thought strange to have this unique form of

ing to which function it is wished to augment.

measurement, but it allows for measurement propor-

tional to the size of each individual patient. In horses,

The passage or connecting (luo) points, situated on each some texts refer to the 'inch' as the width of the 16th

meridian, will help to 'shunt' energy from the meridian

rib, at the level of the tuber coxae. The provision for

in question to its partner. Energy usually flows 'down-

measurement in animals is not good, so sources can

hill' (i.e. from 'mother' to 'son' or from the meridian

refer to precise anatomical descriptions, rather than

earlier in the cycle to its paired neighbour).

measurement units.

The alarm (mu) points may or may not lie on the meridian to which they relate but may be used for diagnosis

The point types

or treatment if sensitive. A sensitive point indicates

Locus-Dolendi needling, using Trigger (ah-shi) points is stress in its related organ.

the use of points of local pain, which are directly related

to the site of injury or illness. The effect is not very long-

The association (shu) points, lying on the bladder

lasting but provides relief from pain in local conditions.

meridian, are also of value diagnostically or therapeu-

It requires little knowledge on the part of the pre-

tically and relate to specific organs and meridians. For

scriber, but should probably be reserved for localised

example, the association point for the spleen/pancreas

locomotor pain or injury.

is bladder 20, for the heart it is bladder 15 and for the

stomach it is bladder 21.

Master points relate to individual organs or tissues and It is helpful to list some useful points for earlier selec-can be used regardless of the nature of the pathology

tion by the beginner; see Table 65.3 and refer to Figs

or dysfunction which that target suffers. These master

65.3–65.7.

points may be sensitive to stimulus when there is a dys-

Table 65.3 is clearly by no means comprehensive (as *function or injury in the influenced organ/tissue but are*

can be seen from the numeration), but represents a

unreliable diagnostically, unless taken as part of the

useful reference list for the main functional points. For

wider picture. Effects of using these points alone, as a

more comprehensive point descriptions the reader is

method of prescribing, will lead to disappointment.

referred to much fuller works on acupuncture therapy.

There is no deep and lasting influence on disease if the

Their location, as shown on Figs 65.4–65.7, is a syn-

prescriber sticks to this elementary process. The master

thesis of information from personal experience and

point of the musculature, for instance, is gall bladder 34.

the work of Klide and Kung (1977), Lewith (1982),

Kothbauer and Meng (1983), Bishchko (1983), Gilchrist

Symptomatic or influential points have an influence over (1984) and Janssens (1984). The nomenclature of the

certain specific functions. For instance, bladder 31 influ-

points is in accordance with the IVAS standard, in order

ences female hormonal function very strongly and gall

to prevent confusion and to enable the reader to *bladder 39 influences the function of marrow. They can*

compare with all IVAS-derived texts. When reading

be used in a prescription when such problems predomi-

other texts, many different conventions of nomencla-

nate (Plate 65.1). The action of these points is usually

ture and classification will be encountered. The reader

fairly narrow so, again, prescriptions based on these

should not be confused by this, but should develop the

Table 65.3

Useful points.

Heart (HT) meridian

34. Master point of muscles

5. Passage point

37. Passage point

7. Sedation point and Source point

38. Sedation point

(9.) Tonification point

40. Source point

43. Tonification point

Small intestine (SI) meridian

(site open to interpretation)

}

(3.) Tonification point

Liver (LIV) meridian

(4.) Source point

2. Sedation point

(medial hock)

}

7. Passage point

3. Source point

8. Sedation point

5. Passage point (postero-medial tibia)

8. Tonification point (postero-medial stifle joint)

Bladder (BL) meridian

13. Alarm point for spleen/pancreas (caudal to last rib)

11. Bone disorders

14. Alarm point of the liver

13. Association point, lung

14. Association point, pericardium

Lung (LU) meridian

15. Association point, heart

1. Alarm point for lung (between shoulder joint and third rib on 18. Association point, liver

chest wall)

19. Association point, gall-bladder

5. Sedation point (medial elbow)

20. Association point, spleen/pancreas

7. Passage point

21. Association point, stomach and master point, stomach

9. Tonification point and source point

22. Association point, triple heater

(II.) Master point for the throat (not clearly identifiable in the 23. Association point, kidney

bovine)

25. Association point, large intestine

27. Association point, small intestine

Large intestine (LI) meridian

28. Association point, bladder

(1.) Master point for teeth

(site open to interpretation)

}

31. Master point, female hormones

(2/3.) Sedation points

58

Passage point

4. Source point

(medial carpus)

}

60

Master point for pain

6. Passage point

(64) Source point

II. Tonification point

(65) Sedation point

(site open to interpretation)

}

(67) Tonification point

Stomach (ST) meridian

25. Alarm point for large intestine

Kidney (KI) meridian

40. Passage point

1/2. Sedation point

41. Tonification point

3. Source point

42. Source point

4. Passage point

45. Sedation point

7. Tonification point

8. Master point blood

Spleen/pancreas (SP) meridian

(II.) Alarm point pericardium (not clearly identifiable in

(2.) Tonification point

(site open to interpretation)

}

bovine) (in groin)

(1) Source point

4. Passage point

Pericardium (PC) meridian

5. Master point for connective

(anteromedial tarsus)

}

1. Alarm point pericardium (lateral thorax in posterior

tissue and sedation point

axilla)

6. Passage point

Conception vessel (CV) (Fig. 65.7)

7. Sedation point and source point

3. Alarm point for the bladder

(9.) Tonification point (anterolateral of second digit)

4. Alarm point for small intestine

5. Alarm point for triple heater

Triple heater (TH) meridian

7. Alarm point for lower triple heater

3. Tonification point

12. Alarm point for stomach and alarm point for middle triple

4. Source point

heater (caudal to xiphoid, cranial to navel)

5. Passage point

14. Alarm point for the heart (caudal to xiphoid)

10. Sedation point

17. Alarm point for upper triple heater and pericardium (on

15. Master point for forelimbs

sternum, rib 7)

Gall bladder (GB) meridian

Governor Vessel (GV) (Fig. 65.7)

24. Alarm point for gall bladder

No main or special points.

25. Alarm point for kidney (caudal to last rib)

20 and 26 are very important points for advanced manipulation

of Qi.

Table 65.4

The relationships based on the human pulse system.

Position

Right

Left

Superficial

Deep

Deep

Superficial

III

Large intestine

Lung

Heart

Small intestine

II

Stomach

Spleen/pancreas

Liver

Gall bladder

I

Triple heater

Pericardium

Kidney

Bladder

(Yang)

(Yin)

(Yin)

(Yang)

ability to ‘translate’ these into the ‘standard’. In texts on

the rule will operate upon stimulation of the relevant

TCM, another potential confusion arises from the use

points with appropriate needles. Using the three rules

of the various conventions of westernization or roman-

together can achieve a rapid restoration of harmony

ization of the Chinese language (e.g. Pinyin or Wade-within the body. The system of acupuncture thus used

Giles). Again, it is important not to be daunted by this, is not only complete but also quite simple to apply, pro-but to compare texts in order to find the *correlations.*

viding infinite combinations of therapy. It is sad that

pulse diagnosis is not so refined in animals, but the

general quality of pulse can still be ascertained. The

Use of these points

relationships of the meridians are still valid and so too

The meridians are interconnected energetically in

is the correspondence of disease patterns with the

various 'rules' of therapy. Treatment strategies may be

effects from the pernicious influences and other origins

based on these relationships. Again the Chinese show

of disharmony. Conclusions about meridian malfunc-

their proclivity towards metaphorical description. The

tion are inferred from the disease patterns displayed by

first relationship is based upon the human system of

the patient and by the demonstrable point sensitivities.

pulse diagnosis and relates to the position of pulse-

taking in the human wrist (Table 65.4; see also Fig.

65.8).

Technique of needling and treatment

(1)

The 'husband–wife' rule relates meridians sharing

Steel, gold or silver needles are selected according to

the same positions on either wrist. Tonifying one

the effect required. Alternatively, the different effects

will sedate its partner and vice versa. They oppose

can be achieved by varying the needling technique or

each other.

by varying the duration of insertion. The needles should

(2)

The 'mother–son' rule relates to the sequence of

be inserted confidently into the skin, as near to the

the meridians in the circadian rhythm. A meridian

centre of the point as possible. Depth of insertion is

preceding that in question is its mother and that

generally up to 1 cm, but varies from point to point.

succeeding it is its son. It is logical to assume that

During a treatment the body 'reacts' with the needles

the mother is ready to give energy, the son to

in a way that has not been defined physiologically or

receive it. Tonifying the meridian in question and

anatomically. During this time, the needles are firmly *its mother will produce extra effects. Similarly,*

held by the tissues. When a treatment is over, perhaps

sedating both the meridian in question and its

between 5 and 20 minutes later, the needles may be

son will increase the effects of sedation. Passage

removed with ease.

points may be used instead when the meridians in

After treatment there may be a 'slump' in the

question are partners.

patient's apparent energy for the next 24 hours. The

(3)

The 'midday–midnight' rule relates meridians

author has observed this less in cattle than in other

most active in a similar time period, am and pm.

species. Treatments may be repeated at intervals of

One will be Yin and one Yang, e.g. lung (Yin), 4

several days to several weeks, but a useful guide for an

am to 6 am., bladder (Yang), 4 pm to 6 pm. Toni-

initial course of therapy is a 3 to 14-day interval for

fying a meridian in its active time will sedate its

three or four treatments. If no improvement is noted in *opposite number.*

this period, it is possibly a sign of a poor prognosis. Most

of the author's successful cases have shown definite

These three rules should always be borne in mind

improvement within the initial three treatments. After

because, even if it is not the intention of the prescriber,

a good initial result, in chronic conditions, treatment

may need repeating at longer intervals (say six monthly,

and using it in isolation is not at all in accordance with

but the patient's condition should determine this).

the holistic principles of herbal medicine. The obvious

Up until recently, it has been very difficult to obtain

danger of this practice, leading to potential side-effects,

meaningful training in veterinary acupuncture. At the

is that the synergistic effect of the other constituents of

time of writing, however, courses are available run by

the plant is lost.

the combined efforts of the International Veterinary

Western herbs are classified according to their per-

Acupuncture Society (IVAS), the Association of British *ceived actions, as per the following examples.*

Veterinary Acupuncturists (ABVA) and Exeter Uni-

versity.

Alterative, anodyne, anthelmintic, antibacterial, antica-

tarrhal,

antiemetic,

anti-inflammatory,

antifungal,

antilithic, antispasmodic, aperient/laxative, aromatic,

Homoeopathy and acupuncture

astringent, bitter, cardiac, carminative, cathartic/purgative, ***combined***

cholagogue and anticholagogue, demulcent, diaphoretic,

diuretic, ecbolic, emetic, emollient, expectorant, febrifuge, Since both homoeopathy and acupuncture are address-galactagogue, hepatic, hypnotic, nervine, rubefacient,

ing the same entity or challenge, the living and inter-

sedative, sialogogue, soporific, stimulant, styptic, tonic, connected body, in disease, it stands to reason that they

vesicant and vulnerary.

must overlap if they are truly effective. The different

Chinese herbs are classified according to their ability rationales and strategies merely express the fact that

to modify the course of action of the pernicious influ-

they represent two different windows on the same

ences. The usual oriental pictorial language prevails.

room. It is possible to combine the two therapies, only

Examples, with an approximate Western equivalent

if the rationale for selection of treatments is harmo-

where appropriate, are:

nized. Failure to do this will produce disharmony and

will inevitably be counterproductive. If in doubt, the

Release externally

(diaphoretic?),

purge down

best advice is not to attempt it.

(purgative?), clear heat, transform moisture (damp),

It is beyond the scope of this text to go into detail on

facilitate urine (diuretic?), expel wind-damp, dispel this facet of therapy, but there is a reference to further

cold, etc.

study in the Further reading section below (Day, 1993).

Because material doses of herbs are utilized, there is

the inevitability of tissue or milk residues. Some of

Herbal medicine

these will be totally harmless or even beneficial to the

consumer. Some may be harmful. Because the residue

The use of plants and plant material in medicine is as

side of the use of herbs is so poorly researched and so

old as human existence. Those plants which form the

beyond our control, it is wiser not to use herbs in food-

basis of herbal medicine are called medicinal herbs, but

producing animals unless absolutely sure of the conse-

probably represent only a fraction of the plants which

quences. A fuller account of veterinary herbal medicine

could prove to be of benefit, if researched. They are

is to be found in the Further reading section (Day,

classified according to origin (whether ayurvedic,

1998).

traditional Chinese, Western, Australasian, etc.), or

according to effect. This latter would be a different

classification system, depending upon the culture which

Essential oils

devises it. Broadly speaking, in the West, we classify

according to the perceived pharmacological effect.

The use of essential oils in medicine (aromatherapy) is

A large proportion of modern conventional drugs also a very ancient tradition around the world. Further owe their existence or their origins to herbal medicine. reading is recommended (Grosjean, 1994). The appli- The rationale of the use of herbs is to exploit their cation and rationale are not dissimilar to those for primary effect, rather similarly to the rationale of herbal medicine. The active principles are distilled aro- modern drug medicine and unlike homeopathy, which matic compounds derived from plants and represent exploits the secondary effect (the body's reaction), very powerful and effective medicines. The classifica- although it uses many of the same plants that are used tion of the oils is as for Western herbs.

in herbal medicine. Although there are similarities Since the same caveats apply to aromatherapy for between drug medicine and herbal medicine, the tradi- food-producing cattle, as have been detailed for herbs, tion of herbal medicine is very holistic in the truest with the additional worry of powerful taints of meat or sense. The more modern fashion for establishing a sup-

milk, the use of aromatherapy in production cattle is

posed active ingredient of a medicinal herb, purifying it

not advised.

Other therapies

is best used on those animals with which we develop

close emotional ties. This is because we are then better

Two other therapies lend themselves to specialized use

able to discern the necessary prescribing clues. There is

in cattle and bring with them no risk of meat or milk

not much application in farmed cattle, for this reason.

residues, they are Schüssler's Tissue Salts and Bach's Further reading is recommended, for a deeper under-Flower Remedies.

standing (Chancellor, 1971; Ball & Howard, 1999)

Bach's 39 remedies include agrimony, beech, cen-

Tissue Salts:

In the latter part of the nineteenth

taury, clematis, elm, holly, oak, olive, rock rose, scleran-century, Schüssler, who was a homoeopath, devised a

thus, vine and willow. The system is included in this

system of medicine based upon the mineral nutrition of

chapter, esoteric though it may seem, for two reasons.

cells. His 12 mineral remedies were prepared to the

It introduces the reader to the medical modality and it

sixth centesimal potency, according to homoeopathic

presents the opportunity to use of one of Bach's medi-

methodology. The 12 remedies are:

cines, which can be of great value in cattle medicine:

Rescue Remedy.

Calcarea fluorata,

calcarea phosphorica,

calcarea

Rescue Remedy is composed of Bach's cherry plum,

sulphurica, ferrum phosphoricum, kali muriaticum, kali

clematis, impatiens, rock rose and star of bethlehem. It is phosphoricum, kali sulphuricum, magnesia phosphorica,

of great virtue in the treatment of stress, fear and shock

natrum muriaticum, natrum phosphoricum, natrum

situations, and can be used just as well in cattle as in

sulphuricum, silica.

other species. Situations demanding its use are post sur-

These remedies, according to the founder, are able to

gical trauma, disbudding, herding of unhandled cattle, *correct cellular chemistry in order to achieve health*

injuries, entrapments or ‘casting’, bereavement or dis-

(Goodwin, 1980). The rationale appears to work in part,

tress on handling for procedures such as foot trimming.

and the practice persists in modern times. The author

It can be given by mouth or to a group via the drinking

believes that these remedies act as facilitators, regula-

water and can represent a very positive welfare input.

tors or modulators of those cellular processes which

involve those minerals. A more detailed description of

Conclusion

this action of potentized substances is found in the

section on homoeopathy, presented earlier in the

It is to be hoped that the reader, having studied this

chapter. Knowing what we now know about enzymes

chapter or one or other part of it, will have experienced

and their cofactors, this is easily comprehensible in

adequate stimulation to take a deeper look into alter-

modern terms.

native medicine (see Further reading section). It is also

In view of modern knowledge and understanding, *hoped that he or she will have gleaned sufficient infor-*

and recognizing the adverse effect of artificial nitroge-

mation to take the first steps in applying one or both of

nous fertilizers on the soil mineral content in modern

the main therapies described therein. What should be

times, it is logical to extend the range of 'tissue salts' to

clear is that either of those systems of medicine is a very

include chromium, cobalt, copper, iodine, manganese,

large and complex subject. Should the reader wish to

selenium, zinc, etc. The potential for helping cattle back go further, it must be said that a great deal of motiva-to balance, in terms of mineral metabolism, particularly

tion and dedication will be required. If this chapter has

in those situations of relative or marginal insufficiency

provided the motivation, that is good. If not, then it

as can be encountered on farms, is an interesting devel-

should at least serve to dispel some of the mists of igno-

opment. No one could pretend that such dilutions

rance and suspicion that enshroud the art and science

amount to material supplementation, but the aid to

of both homoeopathy and acupuncture. This should

absorption and metabolism, which they can offer, can *allow for more productive cooperation between con-*

amount to a significant benefit. The use of these poten-

ventional veterinarians and those who have diverged

tized salts, in place of some of the mineral supplemen-

into 'alternative medicine'. Those who choose to apply

tation now required by most farm livestock, should be

themselves to diligent study and to professional appli-

particularly attractive in the case of organic farm units,

cation of these methods will be able to enjoy a life full

where outside inputs need to be minimized (Day, pers.

of surprises and rewards commensurate with effort, but

comm.).

will not have chosen an easy option.

Bach Flowers:

In the 1930s, another homoeopath,

Edward Bach, devised a system of medicine which

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would treat disease more via the psychology and per-

sonality of the patient than via the obvious physical

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signs. This system can be applied well to animals, but it

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Chapter 66

Aspects of Bovine Surgery

G. Wyn-Jones

Introduction

1105

Secondly, use plenty of anaesthetic solution. It is cheap

Anaesthesia

1105

and the added expense of using 50 per cent more is

Preparation of the surgical site

1105

easily outweighed by better results. For example, most

Surgery

1106

descriptions of paravertebral anaesthesia advocate

Rumenotomy

1106

15–20 ml spread between the upper and lower branches

Dilatation and displacement of the abomasum

1109

of each nerve. Increasing the amount to 25 or 30 ml

Intestinal obstruction

1113

greatly increases the percentage of successful blocks,

Caesarean section

1115

Amputation of a digit or claw

1119

especially in relatively inexperienced hands. Thirdly,

Surgical correction of an umbilical hernia

1122

despite the refinement of the techniques nerve blocks

Dehorning of an adult

1124

are still relatively imprecise methods of inducing anal-

Eye enucleation

1126

gesia. To offset this, spread the anaesthetic solution

Teat surgery

1127

more widely to create a larger block of saturated tissue

and to increase the chances of affecting the target

nerve. Finally, do not 'line-block' at the site of the inci-

Introduction

sion if at all possible as this creates a sodden, jelly-like

tissue which is difficult to dissect and which has reduced

The following chapter deals with those surgical situa-

initial healing properties. Use either a regional block or

tions which most commonly arise in dairy practice.

a field block.

There are always several ways to achieve the same end

and there are probably as many variations in the tech-

niques described here as there are surgeons. The

Preparation of the surgical site

methods detailed in this account are only one variation.

However, they are based on many years of experience

Whenever we operate on large or small animals we

in practice and in the more rarified environment of the

have to accept that we cannot create a sterile field. At

university teaching hospital and every attempt has been

best we can hope to make it 'surgically clean' and

made to keep the contents practicable and pragmatic.

reduce bacterial contamination to a level where it can

Although each individual technique is dealt with com-

effectively be controlled by antibiotics and body

prehensively, there are some general points which

defences. The weakest link in sterility is always the

relate to them all and are most sensibly made at the

patient itself and this is where most attention should be

outset.

directed. Physical removal of hair and dirt is important;

use proper clippers whenever possible and clip a big

enough area to give a good margin around the incision

Anaesthesia

site. Initially wash the area with copious amounts of *water and antibacterial soap, although elbow grease is*

Most procedures described here will be done under

probably more important than antisepsis at this stage.

local anaesthesia or regional 'blocks'. The author's

Finish with an antibacterial agent which will persist on

guide to success with these is based on several points.

the skin; although pure surgical or methylated spirits

Firstly, for most 'blocks' in cattle use 3 per cent ligno-

poured onto the skin is comforting it does not, in fact,

caine with adrenaline. The rate of development of the

achieve very much.

block is faster and it persists for much longer than when

Drape as extensively as possible. For abdominal

a 2 per cent solution is used. However, use the latter

surgery prepare several large drapes that will hang over

alone without adrenaline for subcutaneous infiltration

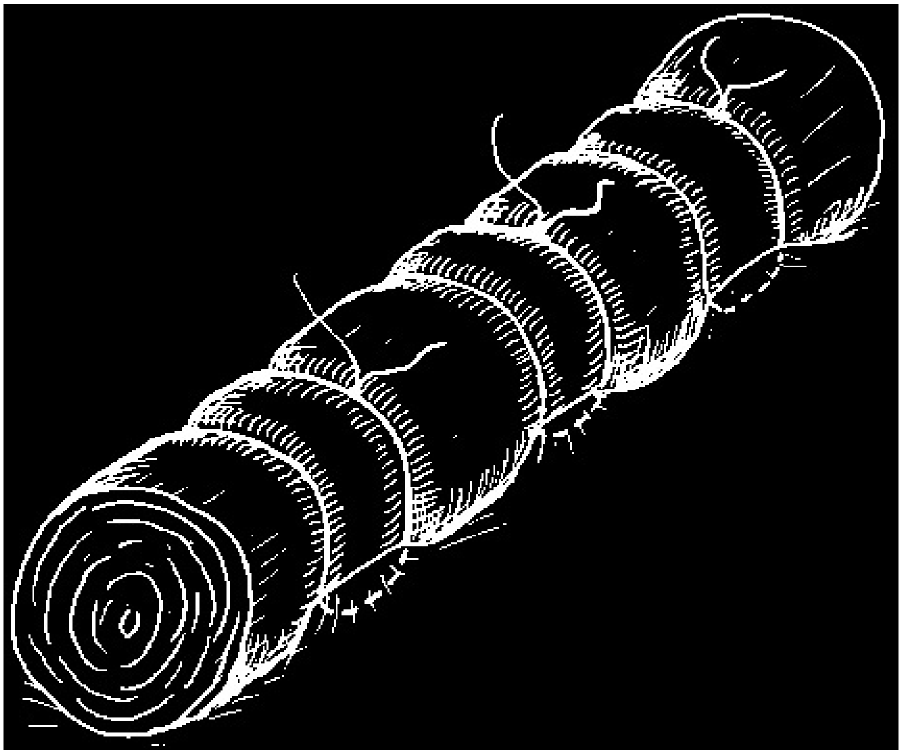
the animal's back, each with holes appropriate for a

as occasionally the vasoconstrictive effects of adrena-

certain technique. Only two variations are really

line can lead to local skin ischaemia, necrosis and death.

needed, one with two holes for abomasal and rumen



approaches and one for caesarean sections. The synthetic material used for tent making is now widely available and is ideal, being impervious to fluids, mouldable and capable of being sterilized. The use of drapes makes the maintenance of a clean site so much easier and imparts a professional air to the operation.

The choice of suitable dress for the surgeon is difficult. Abdominal surgery requires extensive intra-abdominal palpation or manipulation. A long-sleeved *gown is inconvenient in that the material abrades the*

wound edges and rapidly becomes sodden and uncom-

fortable; in a rumenotomy it also becomes severely

contaminated. For the same reasons the use of gloves

for these procedures is often impractical too. A good

Fig. 66.1

A Stent bandage. The cylinder is made of rolled up

compromise which should be encouraged is a short-

gauze swabs; it should be sutured firmly, tenting the surrounding skin at the suture attachment points. It can be left in place sleeved gown worn over a disposable plastic apron.

for about 48 hours, although it must be removed earlier if it

Even if only freshly laundered and not sterilized they

becomes sodden. It protects the wound and exerts inward pres-

are still infinitely preferable to the calving gowns which

sure which prevents fluid accumulation.

many practitioners use. If these are the same garments

which are used for routine obstetrics they will

inevitably be grossly contaminated and will impregnate

the wound edges with a good variety of pathogenic

Cows can afford to lose a great deal of blood before

organisms.

showing any ill-effects, but even if no haemostasis is

Having eschewed gloves for abdominal surgery, there

done they will never lose more than a few hundred mil-

are some occasions when they should be used. The

lilitres during a routine procedure. Consequently only

hands of a dairy veterinary surgeon are, of necessity, fre-

those vessels which are a persistent nuisance should

quently in contact with faecal or septic material and

have time spent on them. The others will dry up very

even with a full surgical scrub they are unlikely ever to

rapidly. The most efficient method of dealing with them

be surgically clean. For those surgeries where maximum

is to clamp them in the tip of a pair of artery forceps

cleanliness is essential, e.g. in an umblical hernia repair

then to twist them about eight to ten revolutions.

where non-absorbable sutures are to be buried, the

Although this advice may sound heretical to some, it is

practitioner should overcome his prejudices, accept the

sound, and surgery which is done rapidly but deftly

limitations and wear gloves!

without unnecessary frills will result in less tissue *trauma, less contamination from the environment and*

substantially better healing.

Surgery

For suturing, plain catgut is entirely adequate and

cheap. Despite purist objections the variety obtainable

The old adage 'time is trauma' still holds true; for large

in long lengths in plastic cassettes is perfectly accept-

animal clinicians it could be supplemented by 'time is

able. In its thickest size it is suitable for closing even the infection', 'time is tiredness' and practically 'time is

largest abdominal wounds and should there be infec-

money'. An inexperienced surgeon cannot be expected

tion, its rapid lysis is beneficial in that the sutures do not to be rapid but there are some things which help. Most

form a persistent nidus of sepsis. The suture wound can

novices spend more time nerving themselves for the

be protected effectively by means of a stent bandage

next action than actually doing it and then more time

(Fig. 66.1). This will help absorb wound seepage fol-

contemplating what they have done. If these delays are

lowing umbilical hernia repair or eye enucleation, and

omitted then the duration of a procedure can be sharply *will effectively reduce post-operative swelling.*

reduced without spending less time on the actual

surgery. In addition, if gratuitous and uneccesary tissue

Rumenotomy *(see p. 837)*

handling is abolished, tissue trauma will be greatly

reduced to the benefit of healing.

The indications for rumenotomy are: confirmation and

Another area where a great deal of time can be

treatment of traumatic reticulitis (‘wire’, ‘hardware

wasted is that of haemostasis. The concept of a blood-

disease’) and examination of the cardia, oesophageal

free field is dear to the heart of many surgical teachers

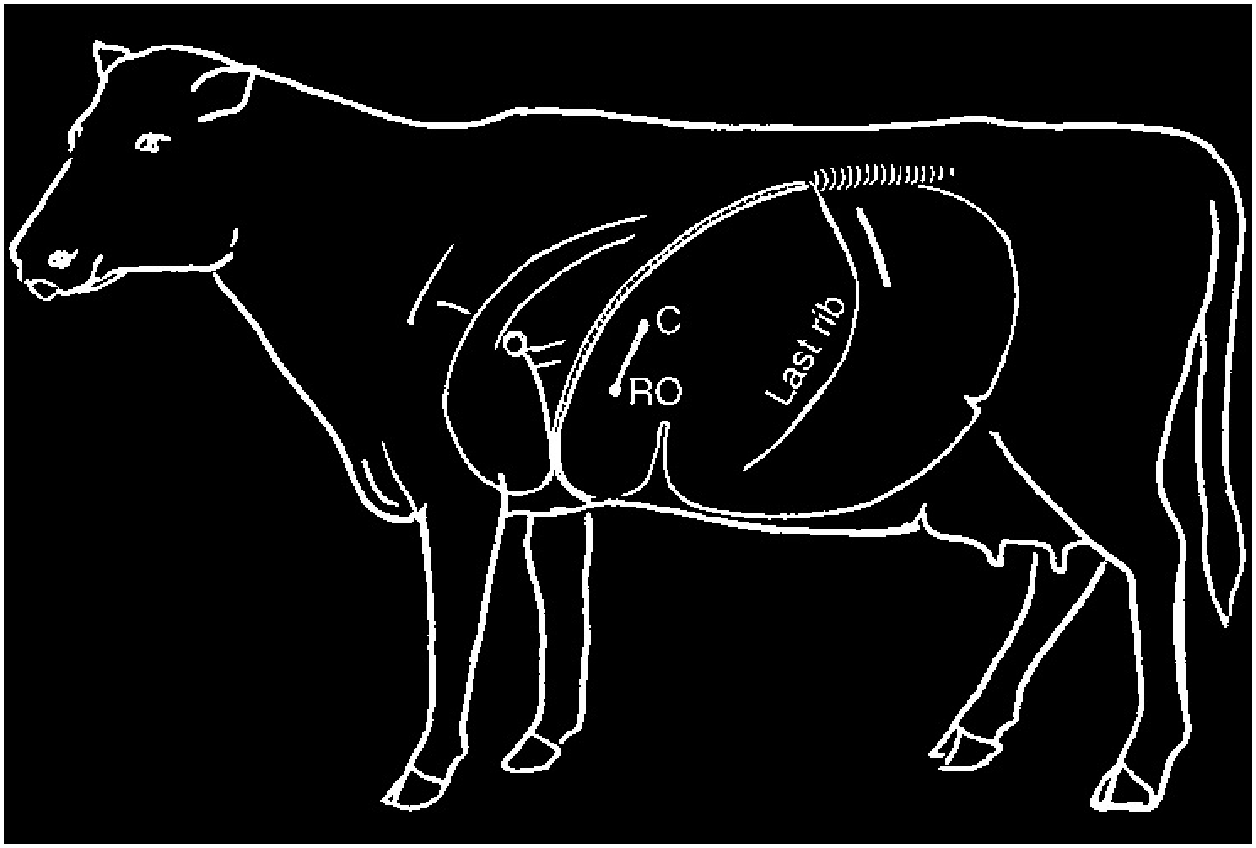
groove, reticulo-omasal orifice, reticulum and rumen.

and newcomers often devote a great deal of time and

The abdominal wall incision is also suitably placed for

effort to stopping every bleeder.

exploration of the left and caudal abdominal cavity.



Aspects of Bovine Surgery • 1107

Anaesthesia

The peritoneum must be cut carefully to avoid possible damage to the rumen wall, which is often tightly

This procedure must be done with the animal standing.

applied to its underside because of the concurrent

Fractious patients must not be given too much sedation

rumen tympany. The safest method is to pick up a fold

otherwise there is a risk of them going down during

of peritoneum in tissue forceps and to incise with a *surgery with disastrous results. In most cases, local*

scissor tip. Once a hole is created, air will rush into the anaesthesia of T13, L1 and L2 spinal nerves using the

abdomen with a characteristic sound and the rumen

paravertebral technique is satisfactory without need for

should fall away. Insert two fingers into the hole and,

sedatives.

with one each side of the scissor blade acting as tissue

guards, lengthen the incision to its full extent.

Prior to entering the rumen it is worthwhile explor-

Technique

ing the left cranial abdomen. Pass the right or left arm

No specialized instrumentation is needed for the tech-

coated with some sterile lubricant e.g. KY jelly, into the

nique described here. However, the surgeon should

incision and then forward between the rumen and inner

wear a short sleeved gown to avoid gross contamina-

left abdominal wall. The ribs can be felt laterally and on

tion of the sleeves and, for exploration of the rumen,

the dorsal cranial rumen the free 'tongue' of the spleen

gloves should not be worn as they promptly fill up with

can be palpated. In the case of a recent wire penetra-
rumen liquor! Surgeons with short arms must recognize
tion the cow will begin to show signs of resentment at
that they may not be able to reach the reticulum in a
this point and the first adhesions may be encountered.
large cow. Under these circumstances there is a definite
In early cases, this feels as if the hand is separating two
need for a long-armed assistant.
freshly buttered pieces of bread and their extent is sur-
The site for the incision is high up on the left flank
prising! With time, they become organized and more
just caudal to the last rib (Fig. 66.2). This is so that the
difficult to disrupt.
rumen can be entered above the likely level of ingesta
If no adhesions are present then the reticulum can be
and to minimize the distance from the incision to the
reached and palpated. If this engenders no obvious pain
reticulum. Following routine preparation of the area,
response then it is unlikely that the animal is suffering
start the incision some 6–7 cm ventral to the transverse
from traumatic reticulitis and another cause for the

process and some 5–6 cm behind the last rib and con-

symptoms must be sought.

tinue ventrally for some 15 cm parallel to it. Remember

The problem of contamination of the peritoneal

that the aperture must be large enough to accommo-

cavity during rumenotomy has long worried surgeons

date easily the upper part of the surgeon's arm without

and many methods, some extremely complex, have

traumatizing the tissue. Once through the skin there is

been devised to avoid this. However the bovine peri-

no great muscle thickness, though it is important that

toneum is remarkably tolerant to the presence of the

the three mainly aponeurotic abdominal muscle layers

rumen contents in small amounts and, while excessive

be identified so that the peritoneum can be recognized

contamination is obviously to be avoided, these labori-

and dealt with carefully. During this stage, haemorrhage

ous methods are time-consuming and unnecessary.

is not usually a problem and only the occasional spurt-

In preparation for entering the rumen, place a small

ing vessel needs attention.

folded cloth in the ventral commissure of the abdomi-

L

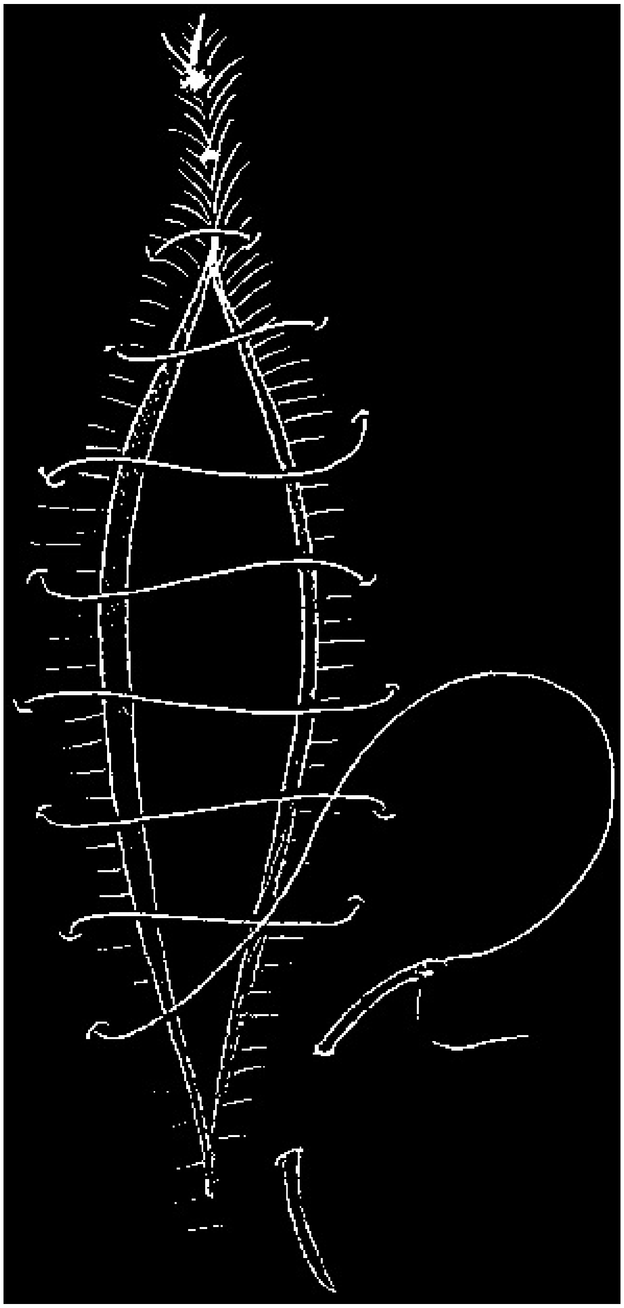
Fig. 66.2

This shows the position of the incision line (IL)

for a rumenotomy. Note that the reticulum and heart apex

are separated only by the thickness of the diaphragm. C,

cardia; RO, reticular-omasal orifice.



nal incision so that half lies between the rumen and

completely penetrated and has begun a migration

peritoneum and half outside on the skin. This will mop

through the abdominal or thoracic structures. While this *up most of the inevitable spillage of rumen contents.*

is likely to have further grave repercussions, with

Pick up a fold of rumen wall from approximately 5–

chronic peritonitis, liver abscesses, pleurisy or peri-

6 cm caudal to the abdomenal incision and exteriorize

carditis all being possible, the occasional wire can

it. Retain this vertical fold of rumen by clamping it

migrate out through tbe body wall or become encapsu-

firmly with two pairs of strong Vulcellum or other tissue

lated in omental tissue and be rendered harmless.

forceps, some 15 cm apart. The upper pair is held by an

At this point, terminate the search, withdraw the arm

assistant who stands on the right side of the cow and

carefully from the rumen and scrub up again while the

who is instructed to maintain a gentle upwards and out-

assistant maintains traction on the rumen incision,

wards traction.

holding it clear of the abdominal wall.

Incise the rumen fold between the two forceps and

Clean the surface of the rumen by gentle wiping with

expose the lumen. There is some haemorrhage from the *a moistened swab. Close the incision in the rumen with cut wall but haemostasis is rarely needed. Apply a third a continuous inverting pattern of absorbable suture tissue forceps to the mid point of the caudal cut edge material (Fig. 66.3). Catgut is ideal. Start the inversion and ask the assistant to maintain a mild degree of several centimetres dorsal to the dorsal commissure caudal traction to open up the rumen incision. Hold the and be sure to include the areas traumatized by the lower pair of forceps in the left hand and insert the right forceps in the inversion. Invert at least 2 cm of each hand and arm into the rumen. Follow the dorsal wall of margin and continue the inversion pattern for several the rumen downwards and forwards over the mass of centimetres ventral to the ventral commissure. Pull the contents. The reticulum is identifiable by being at arms suture material tight as each suture is laid to ensure a length, being full of fluid and having a distinct honey-watertight seal. One layer is usually sufficient but there comb pattern to its mucosa.*

is always enough slack rumen for a second inverting

Sometimes the wire is immediately palpable, pro-

layer to be inserted for maximum security of closure.

truding from the reticular wall; if so, grasp it firmly and

The rumen is now allowed to fall back within the

withdraw it. Note the angle and depth of penetration as

abdominal cavity. Because the initial fold was taken

these factors can influence the prognosis; e.g. a cranial

from caudal to the abdominal incision the rumen suture

penetration of even 1 or 2 cm could have impinged on

line now lies several centimeters caudal to its abdomi-

the pericardium; a medial penetration could well result in the localized peritonitis affecting the vagus nerve and inducing 'vagus indigestion'. Bring out the offending wire, holding it firmly all the way, rinse the arm and explore the reticulum again. Further foreign bodies may be found within the silt that invariably lies on the reticulum floor as may all kinds of other, harmless items such as bolts, pebbles etc. Take the opportunity to examine all aspects of the reticulum, cardia, oesophageal groove, etc., for abnormalities and try to assess where the bulk of the adhesions lie. This is best *done by attempting to pick up folds of reticular wall. In the normal state this can be done fairly easily, but where induration of the wall and peritonitis exist it is impossible and attempts will be met by evidence of severe discomfort from the patient. The disposition of the inflammatory process also has implication for the prognosis; major involvement of the medial reticulo-rumen wall could well lead to damage to the stretch receptors located there.*

If no foreign body or penetrating wire is discovered at the first examination, the reticulum wall must be searched carefully, honeycomb by honeycomb. If no trace of a wire is then found (and fresh adhesions are present) it must be assumed that either the wire has

Fig. 66.3

An inverting ('Cushings') type suture pattern which

dropped back into the lumen and has been swept into

may be used for closing an incision in the rumen, abomasum or

the rumen food mass or, more commonly, the wire has

uterus.

nal wall counterpart and the risks of adhesions and partial atony of the abomasum will lead to gas accu- fistula formation are diminished. mulation and instability of the organ. Normally the abo- It is the author's practice to close the abdominal inci- masum lies within the right, ventral aspect of the cranial sion in three layers: an everting continuous pattern of abdomen; when it fills with gas it acts much as a hollow absorbable material in the peritoneum and transversus, ball pushed down into a swimming pool: it wants to rise a series of large simple interrupted sutures, again of and it can do so with some force! Whether the aboma- absorbable material, to close the remaining subcuta- sum rises to the right or the left of the rumen probably neous layers and, finally, horizontal mattress sutures of depends on factors not yet fully understood, but an non-absorbable material for the skin. If the margins of important one is likely to be the physical size of the the abdominal wound appear somewhat traumatized, rumen relative to the abdominal cavity. In diets defi- discoloured or contaminated, debridement by slicing a

cient in roughage, as are many fed to the modern dairy
thin sliver of tissue off each incision edge will create
cow, the bulk of the rumen diminishes; its mesenteric
fresh bleeding surfaces for apposition and virtually
attachments force it to contract dorsally thus creating a
eliminate the potential for major infection and
potential space ventral to it. Nature and a closed cavity
dehiscence.
such as the abdomen abhors a vacuum and the nearest
In the normal course of events, removal of a pene-
mobile organ, the abomasum, becomes drawn down
trating foreign body should result in a dramatic clinical
and across to occupy a more ventral mid line position.
improvement over two to three days, recovery being
If distension occurs now, the greater curvature of the
hastened by the use of broad-spectrum, systemic
abomasum is able to rise on the left hand side. In coun-
antibiotics. Occasionally the penetrating portion of the
tries such as the UK, left side displacement seems to
wire will have instilled infected material into important
predominate while in some European studies, right side

sites such as the pericardium and despite foreign body

dilatation, displacement and associated torsion are

removal the symptoms of pericarditis will progress.

much more common.

Similarly induration of the medial reticulum/rumen can

Factors which have been implicated in the aetiology

result in the development of 'vagus indigestion' even if

of atony include a high concentrate, high fat diet,

surgery was successful (see p. 835).

chronic hypocalcaemia, stress of parturition, abomasal

Locally, the most likely complication is the develop-

ulcers, accumulation of silt within the abomasum and

ment of an abscess or abscesses at the incision line. This

vagus nerve damage. Of these the most important are

will show 10–15 days post surgery as a small lump or

likely to be the high concentrate, high fat diets com-

lumps which can eventually rupture and discharge pus.

monly fed to parturient dairy cows. Others, such as abo-

These abscesses are almost invariably located around

masal ulcers and silt impaction, are probably due to the

the nidus of a buried suture and, for rapid treatment, *same aetiological factors or they are a mechanical con-*

the abscess is incised, the suture located and removed.

sequence of the atony.

This is facilitated by having used interrupted sutures for

closure of the bulk of the abdominal wall. Sometimes

Left displacement of the abomasum (LDA)

the sutures are difficult to locate and in this eventual-

ity, if absorbable material such as catgut was used, the

Diagnosis is based on the presence of a non-pyrexic,

suture will lyse and disappear of its own accord, fol-

sudden onset 50–75 per cent drop in milk yield within

lowing which the abscess will dry up. If non-absorbable

the first few months after calving, coupled with a very

material was used the suture will have to be removed

characteristic selective appetite where the cow is reluc-

otherwise the infection will persist indefinitely. After

tant or refuses to eat concentrate food. The heart rate

two to three weeks there is no risk involved in either

is normal, except when there is severe distension of the

searching for or removing these sutures. There will be

displaced abomasum. The faeces are characteristically *enough thickening and induration at the site to prevent*

firm and may be mucus covered, although occasionally

accidental penetration into the abdomen, and enough

and confusingly there may be diarrhoea. A ketonaemia

healing to prevent dehiscence.

may be present but the condition is distinguished from

simple ketosis by the local symptoms related to a dis-

tended, abnormally positioned abomasum.

Dilatation and displacement of

Auscultation over the last two or three ribs on the left

***the abomasum** (see also pp. 839–842)*

side will, when the abomasum is distended, often reveal

This is a 'production' disease. It is seen primarily in

the characteristic splashing and pinging noises associ-

dairy cattle within the first three to four months after

ated with a gas/fluid interface. However, if the cow is

calving. The aetiology of condition is still not com-

immobile these may have to be instigated by firm bal-

pletely elucidated but is certain to be multifactorial.

lotment. This is best done by placing the right ear over

Any set of circumstances which creates a complete or *the mid point of the last-but-one rib and using one's*

knee or fist to rhythmically indent or ballot the left

and the rumen and pushing the latter medially. (This

lower abdomen. A second method is to tap the upper

accounts for the hollow looking sublumbar fossa of

last two ribs sharply while listening at the same point

many LDA patients.) If one surgeon is operating on

as before. If there is a gas distended viscus, i.e. aboma-

both sides, open the left flank first, protect the wound

sum deep to the ribs, the tapping noise will have a clear

with a towel laid across it and then open the right side.

resonant quality not heard in the normal cow.

The position of the right incision is critical to the

Both tests are easy to perform, take only a few

success of the operation. Make a vertical incision about

seconds and should be part of a routine examination of

15 cm long with its centre point about half-way up the

any anorexic cow. If positive, they are virtually pathog-

flank and some 6–7 cm caudal to the last rib. Higher, and

nomic for a displaced abomasum. Although both 'vagus *there could be difficulty reaching the abomasum.*

indigestion' and the much rarer pararumenal abscess

Lower, and the small intestine will persist in prolapsing

can under some circumstances produce similar noises,

through the incision. The internal abdominal oblique

these will extend much further caudally in the flank and

muscle is the thickest at this point and its fibres, cut

be associated with other symptoms.

obliquely, hide some large vessels. Only the largest of

The absence of these characteristic sounds does not

these need to be dealt with and they can be stopped

mean that an LDA is not the cause of the problem, only

quickly by clamping with artery forceps. Do not leave

that the abomasum is not distended with gas at the time

these hanging on the wound as they will inevitably fall

of the examination. Any previous vigorous movement,

off or be carried accidentally into the abdomen. Cut the

e.g. being brought in from the collecting yard, can result

peritoneum carefully with guarded scissors. Visible

in the escape of gas and fluid from the abomasum,

through the incision will be a curtain of fat-filled mesen-

either back to the reticulum or forward to the duode-

tery and omentum, with the descending duodenum

num. If possible, re-examine the animal in about half-

running horizontally across the middle of the incision

an-hour or come back the next day. Sometimes several

and separating them.

examinations are necessary.

Lubricate the right arm and pass it into the incision

downwards and slightly forwards between the abdomi-

Treatment: All the techniques described, and there are nal wall and the omental sheet. Advance across the mid

many, are directed towards returning the abomasum to

line and as far over to the left as possible. Simultane-

the right and anchoring it there. The most commonly

ously the assistant on the left starts to deflate the abo-

used techniques will be described here, although the

masum by rhythmic downwards ballotment using the

author does recognize that others or variations may be

flat of the hand or a fist. Even if at first the abomasum

used successfully. The 'toggle' method is described on

seems reluctant to empty, persistent intermittent pres-

page 842.

sure will usually cause release of gas and fluid through

the pylorus or cardia with a characteristic burbling

The bilateral flank technique: Of those techniques done sound. As the body of the abomasum becomes slacker

in the standing animal, this is probably the most con-

it is pushed further and further down the left flank to

sistently successful. Its great advantage is the ease with

meet the surgeon's awaiting hand. Grasp a large

which in most cases the abomasum can be returned to

handful of the tissue which is being pushed ventrally

the right. This is especially important when the organ is

and attempt to draw it across the mid line. Establish a

tightly distended and apparently immobile. Its only real

push–pull sequence and continue until the abomasum

disadvantage is that it does need two people, though

has completely disappeared from the left flank. Some-

one can be a lay assistant.

times the tissue being pulled can be felt to tear; this is

almost certain to be omental tissue and not abomasal

Anaesthesia: Bilateral paravertebral anaesthesia of *wall. If this happens grasp a fresh handful and try again.*

T13, L1 and L2 spinal nerves. Sedation is usually not

If the abomasum does not collapse with ballotment,

required, but if needed it should be used sparingly to

relieve the initial tension by puncturing the gas cap with

avoid the possibility of the animal going down.

a 14 g needle. Further rhythmic bouncing should then

cause it to deflate. If the organ still remains fixed in

Technique: No special instrumentation is needed.

position it is worthwhile checking for adhesions

Make the left side incision as for a rumenotomy. Incise

between it and the peritoneum or rumen. They can

the peritoneum carefully as the distended abomasum

form as a consequence of the abomasal ulceration that

may be lying up against its deep face and an accidental

is present in many cases.

incision in the organ would result in its collapse with

In the majority of cases the abomasum and its abo-

serious contamination of the abdomen with acidic and

masal attachments come over easily. Pull a handful of

irritant abomasal contents. Through the incision the

the displaced tissue up into the right incision. First to
abomasum is seen lying between the abdominal wall
appear will be folds of fat-filled omentum. Search then

for an area where the fat deposits are thickest and
being composed of rectus sheath and aponeurotic
firmest. In this region lies the pylorus which is instantly
rectus abdominis muscle. On entering the abdomen,
recognizable as an obvious, shiny, serosa-covered blind-
identify the abomasum which is likely to have risen to
ending sac. Occasionally some degree of upwards trac-
lie at, or near the incision line. Push the organ, prob-
tion on the omentum is needed before the pylorus
ably in a collapsed state, over onto the right side, identi-
comes into view. Palpate the pylorus, the pyloric antrum
fying the attachment of the greater omentum to the
and the body of the abomasum to determine whether
greater curvature. Grasp a fold of the greater omentum
there is any abnormality such as gravel impaction. If all
some 7–10 cm from, and parallel to the insertion of the
is well proceed with the omentopexy.

omentum to the abomasum and incorporate it in the

The earliest techniques sutured the pylorus to the

closure of the peritoneal incision. This is done with a

inner face of the abdominal wound. However, this put

continuous simple suture of catgut or similar. This has

too great a tension on the abomasum and animals

the effect of interposing a barrier between the aboma-

would take many days to accommodate. Current prac-

sum and the left side, preventing displacement in that

tice is to allow the pylorus to sink back to a more

direction or upwards on the right.

anatomically correct position and anchor it via its

Close the fibrous aponeurosis with strong non-

omental attachments.

absorbable sutures laid in simple interrupted fashion

Grasp a fold of thick omentum some 12–15 cm from

(absorbable material is unlikely to remain strong

the pylorus and fix it with Vulcellum or similar forceps.

enough for long enough in this high stress, poor healing

Start the abdominal incision closure with a continuous

site). Coapt the skin with horizontal mattress sutures *simple suture pattern picking up peritoneum and trans-*

and protect the wound with a Stent bandage (Fig. 66.1)

versus, but with every deep needle pass pick up a deep

sewn firmly in place.

bite of the omental fold. Do this for the whole length of the incision in order to ensure a strong adhesion.

Other techniques: A non-surgical method for correc-

Then close both wounds in the routine manner as

tion of LDA is the 'rolling technique'. Although quite

described for the rumenotomy.

effective at correcting the displacement, its major draw-

With this technique there is usually a good strong

back is the very high rate of recurrence. It was popular

adhesion formed and the recurrence rate is low.

in the early days following the discovery of the condi-

However, some do tear away and the owner should be

tion, but it does have a place in modern therapy as a

instructed to lessen these chances by feeding a high

means of returning the abomasum to its correct posi-

roughage, low concentrate diet for 7–10 days and

tion prior to surgical omentopexy by a surgeon working *keeping the animal quiet, in a loose box if possible.*

through a single, right sided incision.

An alternative technique is performed through a

Cast the cow onto her right side and hobble her. Pull

paramedian incision. It has the advantage of needing

her gently onto her back (dorsal recumbency). Rock

only one surgeon, though the animal must be heavily

her gently over this 90° arc for two to three minutes to

sedated or under general anaesthesia. This in itself

allow time for the gas-filled abomasum to move from

carries some risk in the cow and the animal must be

the right to a higher position, i.e. into the ventral

starved of food and water for 24 hours prior to surgery

abdomen. Finally, allow her to roll into left side recum-

to minimize the risk of regurgitation. Also heavy faecal

bency when the buoyant abomasum should slide

matting of the ventral abdomen in some cows can make

around to her, now uppermost right side. If this is done

asepsis of the surgical site impossible to achieve.

as a prelude to sugery, the operation should commence

Position the animal on its back (wedge-shaped sup-

immediately as redisplacement can occur within a very

ports can be made if this operation is done frequently)

short time.

and support her firmly. Prepare the area that lies in the

Another technique used by single-handed surgeons

triangle between the costal arches, then if necessary

is to deflate the distended abomasum using a 14 g

carry out a 'field block' to anaesthetize the incision site.

needle attached to a length of giving-set tubing. The

This lies some 5 cm from the mid line with its cranial

needle is taken into the abdomen guarded by the left

margin some 20–25 cm behind the xiphisternum. Be sure

hand, passed between the abdominal wall and the

to identify the course of the mammary vein before

omentum, lateral to the rumen and up to the abomasal

cutting as this runs within 10 cm of the mid line in places.

gas-cap. The wall is punctured, as much gas as possible

The 'milk-well' or foramen through which the vein

released and the partially deflated organ manhandled

enters the abdomen can usually be easily papated and

into its correct position. The drawback of this method *this gives a guide to the course of the vein which, as the*

is that the needle often becomes blocked and it is some-

animal lies in dorsal recumbency, is completely collapsed.

times impossible to deflate the abomasum sufficiently

Incise the skin parallel to the mid line; below, the

to reposition it. A larger needle gauge would help avoid

abdominal wall at this point is almost entirely fibrous,

this, but would increase the risk of subsequent leakage.

Some techniques have been developed which involve

and, frequently, diarrhoea and melaena. A marked dif-

operating through the left flank alone. One such

ference between this condition and LDA is that right

method attempts to create a barrier to redisplacement

side dilatation and displacement frequently progresses

by suturing either the omentum or the actual rumen

to a complete torsion of the organ around either a

wall to the peritoneum and musculature of the left mid

caudo-cranial, vertical or transverse axis. This leads to

flank. The abomasum is first repositioned and a series

compromised blood supply to the organ, sequestration *of sutures is laid to create the adhesions. This is a rather of fluid and gas within the lumen, further distension and imprecise method and the results are distinctly variable. a marked increase in the severity of the symptoms. The The rumen can occasionally be penetrated resulting in animal becomes profoundly depressed, totally anorexic abscess formation. Another method involves placing and the heart rate increases to between 120–140 bpm. long, 100 cm (3–4 feet), heavy synthetic sutures through The aetiology of the condition is probably similar to the cranio-ventral fundic area of the abomasum. After LDA. However, in many cases of RDA large amounts deflation, the organ is repositioned whilst keeping the of sand or silt are found, often impacted into the pyloric free ends of the sutures outside the incision. These are antrum. There is still dispute as to whether this is cause threaded, one at a time, on to a large straight needle or effect, although it does suggest either a high intake which is then taken into the abdomen and used to pen- of mineral matter, e.g. through the feeding of root crops, etrate the ventral abdominal wall immediately caudal* *or possibly a chronic, low-grade atony which leads to to the xiphoid process. The sutures are tensioned to the reduced passage and hence accumulation of this bring the abomasal wall into firm contact with the peri-solid material. Other suggested aetiologies are mechani-toneum and then tied outside. Again, the aim is to cal strictures, or pyloric dysfunction consequent to abo-create adhesions which, this time, it is hoped will bind masal ulceration or maybe pyloric nerve damage. the abomasum into its correct position. The sutures are Diagnosis is by detection of a distended viscus on the left in place for three to four days before being right side. Auscultation and ballotment of both flanks removed. It is suggested that because of the risk of take little time and should be a routine part of any leakage of abomasal contents, both intraperitoneal and clinical examination. The sounds are identical to those systemic antibiotics are used. Although the author has heard in a case of LDA and they occur in a mirror-no personal experience of these techniques, both have image position, i.e. over the last two ribs. If dilatation is* *their advocates, with the latter method especially being*

severe or torsion has occurred, the distended viscus can

popular in some countries.

often be seen distending the cranial, right sublumbar

A final technique, which is occasionally described is

fossa just behind the last rib. The organ can also be felt

known as the 'ventral abdominal blind approach'. It has

per rectum as a spherical, taut structure at arm's reach

few adherents because of its imprecision and the very

on the right side of the abdomen. The animal's general

high risks of serious complications. The cow is cast in

demeanour, and especially the heart rate, will indicate

dorsal recumbency and an area behind the xiphoid is

whether torsion has occurred.

surgically prepared. The animal is rocked from right to

left until the abomasum is auscultated in its normal

Anaesthesia: A right side paravertebral block of T13,

position. A large, full-curved needle threaded with 6

L1, and L2 spinal nerves or a field block.

mm (1/4 inch) cotton or synthetic tape is passed blindly

through the abdominal wall, hopefully through the abo-

Technique: The only special item of equipment needed

masal wall and out again. The sutures are pulled tight

is a stiff plastic tube, about 1.5 m long and with a bore

and tied off. They are left in place for several days to

of some 1 cm. This will be used to syphon off the fluid

allow adhesions to form before being removed.

sequestered within the abomasum prior to correction of

the displacement or torsion. If available, a stirrup type

pump is also useful to speed up the evacuation.

Abomasal dilatation and right sided

Make an incision in the right flank as if for an LDA

displacement (RDA) (see p. 842)

correction. Palpate the swollen abomasum and try to

In the UK this variation is seen much less frequently

assess visually the condition of its wall. In general terms,

than left side dilation and displacement. As with LDA

the larger the organ and the darker its colouration, the

the symptoms are usually manifest within the first few

less favourable is the prognosis; where torsion has been

weeks after parturition. Insidious in onset, with inap-

present for some hours it can be enormous, contain *petance, reduction in milk yield and a variable ketosis,*

many gallons of fluid and, when its blood supply has

the animal's condition soon deteriorates with signs of

been compromised, it will be a dull, dark reddish-blue

abdominal pain shown by lifting of the hind legs

in colour.

towards the belly and looking around at the flank.

The first step in the management of this formidable

There is elevation of the heart rate to about 100 bpm

looking organ is to reduce the tension in its gas-cap.

Pierce the most dorsal accessible point with a 14 g

the section on LDA), grasp it firmly between the thumb

needle attached to a length of plastic giving-set tube.

and forefinger and incise parallel to the lumen axis

When the wall is reasonably slack, insert a purse-string

through the serosa, circular muscle and submucosal

suture in the serosa and muscularis layers in a position

layers until the mucosa bulges from the inside. (If the

above the fluid line. Make a small incision within the

mucosa is accidentally punctured it can be repaired with *purse-string and thrust the plastic tube through into the*

a catgut suture.) An alternative method is to carry out

lumen, drawing the suture tightly around it. Foul-

the procedure while the abomasal evacuation incision is

smelling, coffee-coloured and often blood-stained fluid

still open, inserting an index finger into the sphincter

will run out of the tube and can be collected for diposal.

lumen and cutting down very carefully on to the site indi-The stirrup pump will speed up the process and can be

cated. When these procedures are complete the aboma-

reversed to blow out the tube if it becomes blocked.

sum is anchored in the usual manner.

The next step is to reposition the abomasum, a rela-

Some idea of prognosis can be gained by studying the

tively simple procedure if only dilatation is present.

abomasum after its deflation and repositioning. If the

However, in a case of torsion the direction of the twist

discoloured wall assumes a more normal healthy colour

must first be established.

and acquires a degree of tone, the outlook is reason-

After removing the evacuation tube and tightening *able. If it stays discoloured and flaccid the prognosis*

the purse-string suture, try and feel at the extremities

is not good. Pre- and postoperative fluid replace-

of the organ, i.e. the omaso-abomasal junction and the

ment therapy will be of course very beneficial and the

pyloric end, to see if the twisted tissue there gives some

choice of fluid should take into account the massive

indication of the torsion axis. If not, a process of trial

sequestration of sodium and chloride ions that has

and error repositionings often proves successful. In the

occurred. Intravenous normal saline or Ringer's (not

author's experience most torsions occur along a caudo-

bicarbonate-containing Hartmann's) solution at 5 l/h to

cranial axis with the direction of twist being anticlock-

a 450 kg cow has been recommended. This can be

wise when viewed from behind, so it seems logical to

'spiked' with potassium (up to 40 mmol/l).

try correcting that version first. Using the flat of the left

In the first days after surgery the patient should

hand on the most dorsal part of the partly distended

receive routine antibiosis and be fed small quantities of

abomasum, push downwards and obliquely forwards; if
hay only, though with unlimited access to water. During
this is the correct direction, the twist unravels itself and
this period, foul smelling diarrhoea is inevitable but
the area reverts to a relatively normal anatomical state.
temporary.
If not, the organ will resume its previous abnormal posi-
tion, begin to distend and another direction must be

Intestinal obstruction *(see p. 847)*

tried. Fortunately, gentle perseverence usually pays.
Once repositioned, the abomasum can be anchored by
The theoretical causes of intestinal obstruction include
the standard omentopexy technique.
volvulus, gut tie, strangulation in scrotal or umbilical
Unfortunately, there is a high rate of recurrence of
hernias, caecal torsion and others. However, intussus-
this condition. Many authors, believing that pyloric dys-
ception would seem to be the one most commonly
function contributes greatly to the development and
encountered in practice situations. It may be seen in any
persistence of the syndrome, advocate either a pyloro-

age of animal, but most often is encountered in young

plasty or a pyloromyotomy with or without evacuation

stock.

of silt.

Acute intestinal obstruction differs from most of the

Although there is not enough information available

other abdominal conditions in that it causes abdominal

to decide which combination is the correct one, it seems

pain which manifests as a colic-like syndrome. The

illogical not to carry out the relatively simple pyloric

bovine reaction to this is much more subdued than the

surgery and to remove any silt which seems to be

more excitable horse, but it does show in restlessness,

forming an obstructive mass. This author has had

with frequent getting up and down, looking around at

encouraging results with the simpler pyloromyotomy

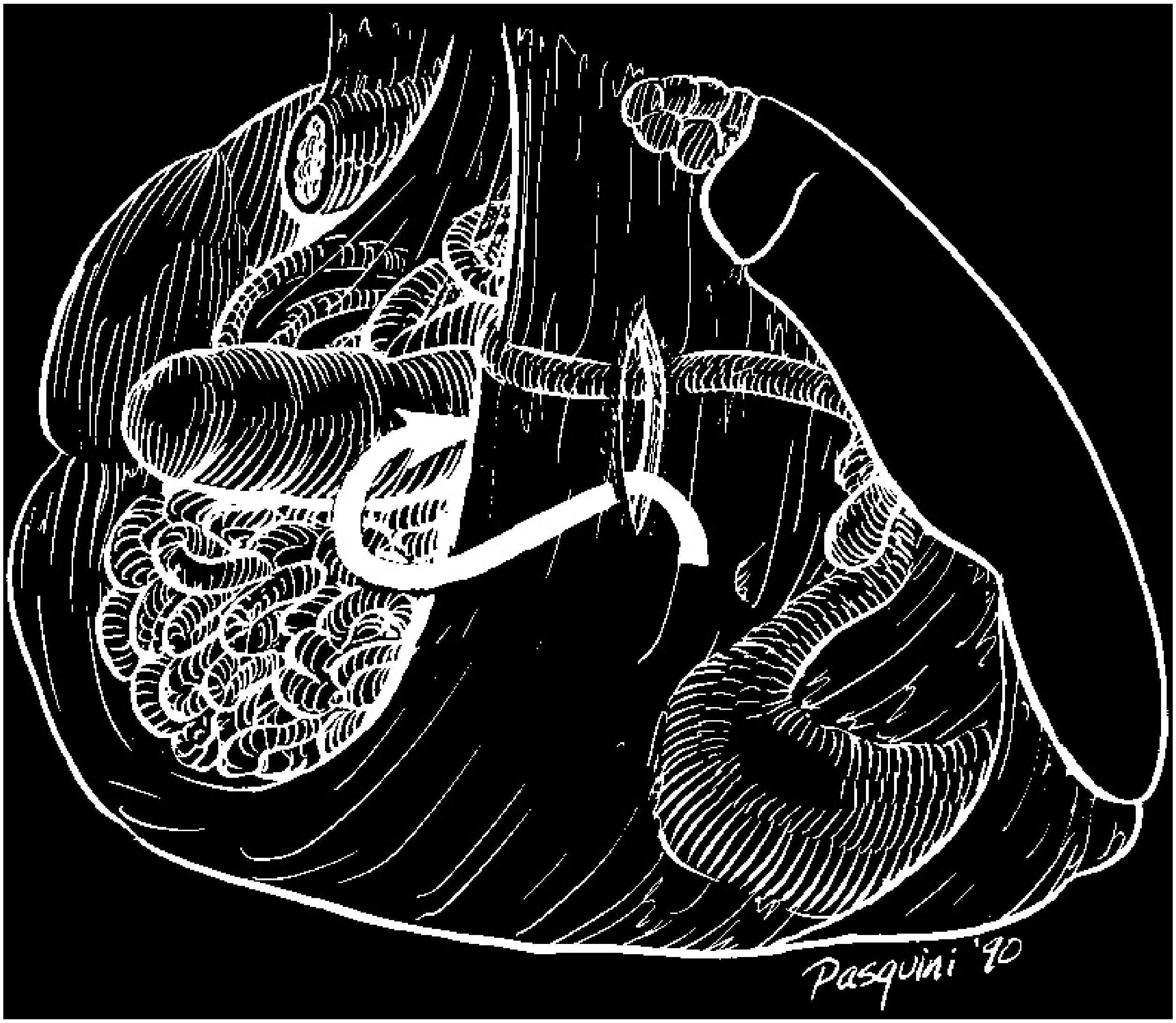
the flanks and lifting of the hind legs to kick forward at

coupled with silt removal.

the belly. Some people describe a ‘trestle’-like stance

To evacuate the sand, exteriorize a portion of the

which affected animals adopt with a dipped back and *flaccid abomasum, make a 10 cm incision in the wall and, spread legs. Rectal temperature can vary and is no having protected the abdominal wound margins with a guide but as the condition progresses the heart rate will sterile towel, manually remove the contents. Close the cross the 100 bpm barrier and reach a high of 120– wound in two layers; firstly the mucosa with a simple con- 130 bpm. Faeces are passed at first but on the second tinuous pattern and then the muscularis and serosa with day only scant, tarry material is seen. The colic phase a continuous inverting suture, both of catgut. To perform may only last 12 hours or so and the animal often looks the myotomy, identify the thick muscular spincter (see brighter for a time before becoming dull and depressed*



as the obstruction leads to gut necrosis, peritonitis, tox-

preferably under paravertebral anaesthesia of T13, L1

aemia and shock.

and L2 spinal nerves. Avoid making the incision too low

This set of signs presented to the clinician fairly obvi-

in the flank otherwise small intestinal loops will persist *ously indicates an abdominal problem and in theory*

in prolapsing out of the wound. The small intestinal

there are a number of conditions to consider. However,

mass is reached by first going caudally between

the absence of a distended single viscus rules out LDA,

duodenum and the flank, then medially and finally

RDA or torsion. Hernias can be examined externally

cranially into the omental sling, or recess in which the

for signs of strangulation and traumatic reticulitis can

bowel loops lie (Fig. 66.4). The intussusception is

be virtually eliminated by, amongst other differences, a

usually easy to feel and once located it should be

failure to elicit pain by ballotment of the xiphoid region

exteriorized. Sometimes the mass will not come to the

and by the fact that it rarely causes such an elevated

incision. In these cases surgery cannot be performed

heart rate or signs of colic.

and the procedure must be abandoned. Most, however,

A rectal examination is important both for elimina-

can be exposed although the mesentery is short and

tion and possible positive findings. Where an obstruc-

access to the affected area and to the surrounding

tion is present, some distended small intestinal loops

normal bowel is always limited. This fact makes the

may be palpable in the right abdomen and occasionally,

help of an assisant essential since a constant traction has

in small cows, an intussusception can be felt as a

to be maintained to keep the mass in view of the

sausage-shaped mass about 6 cm in diameter and of

surgeon.

variable length. However, distended gut loops alone or

Several additional problems now have to be over-

the presence of taut bands of mesentery are a strong

come. In other species it is usual to remove the intus-

indication of an abdominal catastrophe and the need

susception along with a reasonable length of normal

for an exploratory laparotomy.

bowel each side so as to ensure viability of the anasto-

Bearing in mind the simplicity and straightforward

mosis. In the cow, however, the mesenteric frill is so

nature of the procedure, a laparotomy should be

short that only the intussusception itself and a minimal *regarded as a diagnostic tool; there is an immense*

margin of normal gut can be removed otherwise the two

amount of diagnostic and prognostic information to be

cut ends might not come together.

gained and there is the opportunity for immediate cor-

Before attempting resection, it is worthwhile seeing

rective surgery; it is therefore surprising how often it is

if the invaginated length (the intussusceptum) can be

shunned by both veterinary surgeon and owner.

pulled clear of the enveloping bowel (intussuscipiens).

If this can be done easily and the wall looks pink and

Surgical correction of intussusception: Make the

healthy then there is no need for resection. Usually

laparotomy incision in the mid point of the right flank,

though, adhesions have fixed the two parts together or

Fig. 66.4

This illustrates the route taken to gain

access to the small intestine from a right flank

laparotomy incision. (Courtesy of Chris Pasquini.)

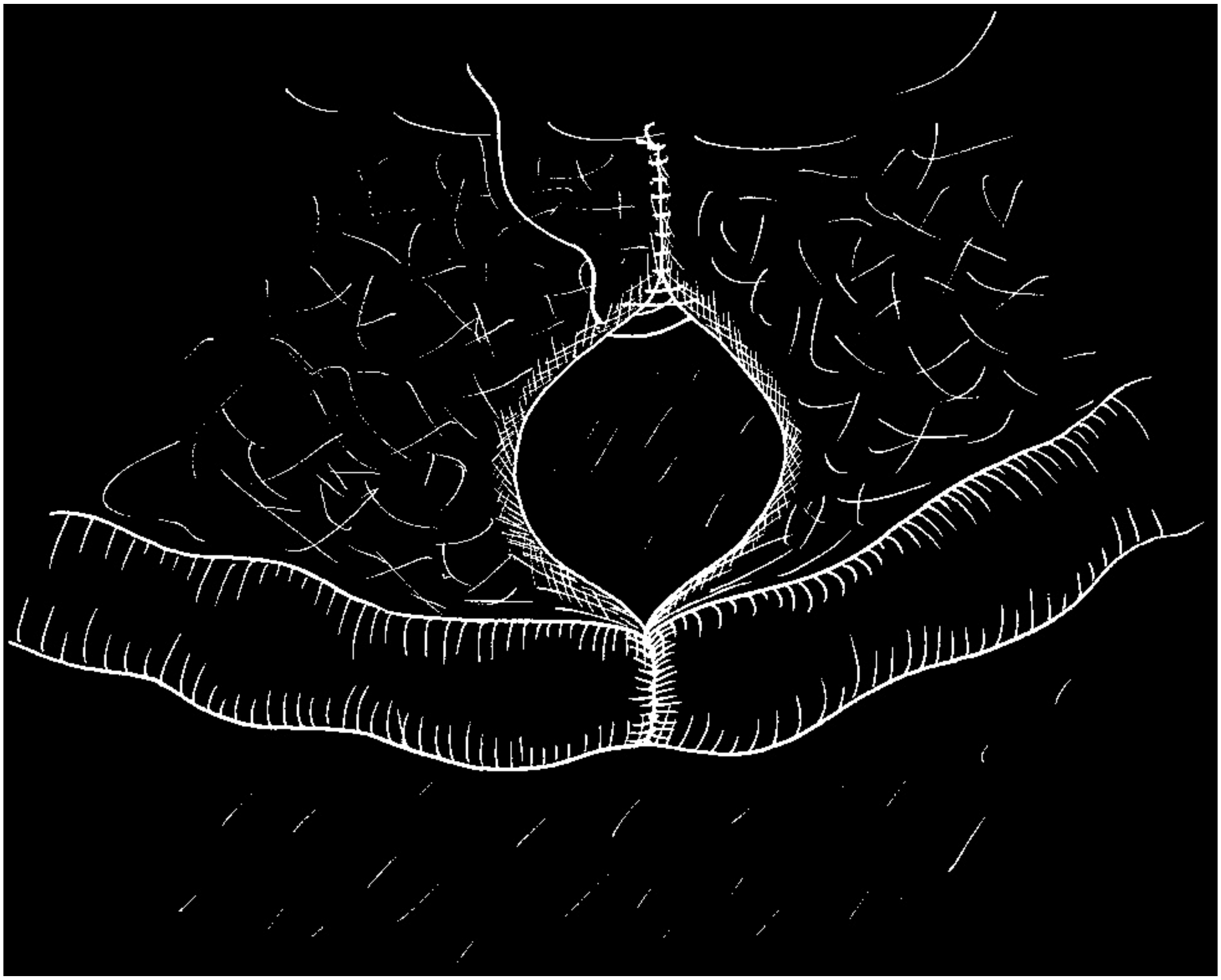


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Fig. 66.5

This illustrates the problem in closing the defect in the mesentery following a small bowel resection.

if they are separable the intussusceptum is discoloured

chosen, insert the first four sutures at the poles of the

and friable and must be removed.

lumen, the first being inserted at the mesenteric border.

Use bowel clamps to isolate the intussusception.

There is likely to be a disparity in size of the lumen of

(Use the minimum compression needed to avoid

the proximal and distal segments and if this disparity is

trauma to the remaining gut.) Place each pair about

large then apposition may be difficult. If there is enough

5 cm apart and try to ensure that the bowel between

slack, the distal stump can be cut at an angle to try and

them has a good blood supply. Again, unlike other

equate the circumferences (see Fig. 66.5). An alterna-

species the cow provides unique problems, as the blood

tive is to take longer bites of the proximal end to try

vessels to the small intestine, although large, are com-

and pull it down to the size of its opposing partner.

pletely obscured under a thick layer of mesenteric fat;

When completed, test the seal by removing the

ligating individual vessels supplying the intussusception

clamps and massaging gut contents at pressure through

is therefore difficult. To ensure that all are sealed start

the anastomosis. If it holds, the next step is to close the

the ligation procedure at the level of one of the inner

hole in the mesentery. Use an absorbable material *clamps. Take bites of the mesentery and fat with strong (catgut) and a continuous simple pattern, starting from absorbable suture material and lay down an arc of over- the inner aspect of the defect and working outwards. lapping blind ligatures from one end of the intussus- Because of its short length that part of the mesentery ception to the other. Occasionally large lymph nodes adjacent to the bowel may not come together (Fig. 66.5) will get in the way and the ligature line must deviate and the hole so formed will have to remain.*

around these. When all the ligatures have been laid, Clean the anastomosis, return the bowel to its correct resect the affected length, cutting the bowel close to the position and close the abdominal incision routinely as inner set of clamps. This leaves a good length of free described elsewhere in this chapter.

bowel protruding from the remaining forceps and makes the subsequent surgery easier.

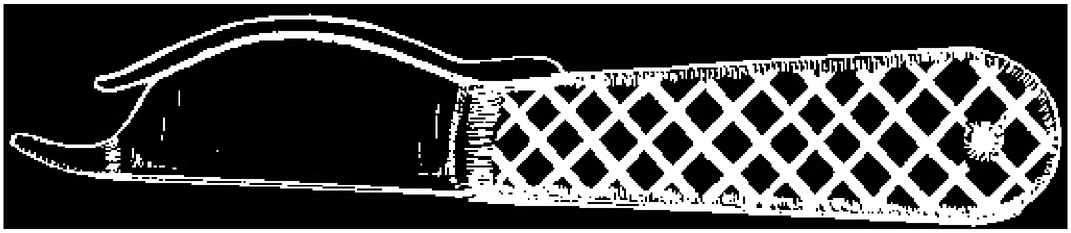
Caesarean section

Either an everting or inverting suture pattern can be used to join the two ends, although the latter gives a

This is probably the commonest major surgical proce-

more secure union with better healing. Whichever is

dure in cattle practice. It is carried out in all sorts of cir-



cumstances; from the ordered serenity of a teaching

school clinic to the murky depths of small hill-farm

barns at 3 am by torch or car headlight. It is therefore

a procedure performed in sometimes difficult and

adverse conditions, often by a surgeon tired by the

Fig. 66.6

A Charles Roberts embryotomy knife.

attempt to calve the animal, and frequently under pres-

sure of other calls to attend. It therefore, more than

most, requires the establishment of a routine which can

not work. This is presumably because gravity causes the

be carried out in all forseeable circumstances. The tech-

anaesthetic solution to affect only the dependent

nique described here is a routine which the author has *side and the straining reflex is an 'all-or-nothing'*

developed over the years and which has worked suc-

phenomenon!

cessfully and consistently.

Technique: This technique requires the use of a Charles Indications: These are dealt with exhaustively else-Roberts embryotomy knife (Fig. 66.6), but no other

where. However, one point needs to be stressed: the

special instruments.

decision to carry out a caesarean section is one that

If the surgery is to be carried out in the standing posi-

should be made at the earliest stage possible. Far too

tion, put the patient's right side up against a barrier of

many of these procedures are carried out after heroic

some sort to prevent her swinging away. Mild restraint

attempts at normal delivery and avoiding surgery have

can be achieved with a nose twitch or 'bull-dog' but, if

failed, with a bone weary clinician operating reluctantly

at all possible, always have someone standing at her

on an exhausted and traumatized patient.

head to exert control if necessary. If the cow is down,

or cast, position her in sternal recumbency with her

Anaesthesia: A decision must be made early whether hind-quarters tipped towards the right. Hobble both to operate on a standing or recumbent animal. The fore and the right hind legs together but pull the left standing position is infinitely preferable so if the cow hind gently backwards to stretch the left flank. Take is tractable, use little or no sedation, merely manual care not to put too much traction on the leg as this can restraint. If the animal is wild enough to require heavy cause peripheral nerve injury. Again it is sensible to sedation then the author recommends that the animal have someone at the cow's head to restrain her if she be cast at the outset and hobbled to keep her down. attempts to get up. Some surgeons operate with the Nothing is more chaotic than operating on an ataxic animal in full lateral recumbency. This provides for cow struggling to keep her feet and collapsing, good restraint, but lifting a calf out of the abdomen at inevitably on the wrong side during surgery. arms' length with bent back is extremely difficult and Anaesthesia of the flank is best achieved by paraver-

uncomfortable, not to say dangerous and the author

tebral block of T13, L1, L2 and L3 spinal nerves, the

does not recommend it for this reason alone. In addi-

latter included because the top 2 cm or so of the inci-

tion there is the distinct impression that abdominal

sion often intrudes into this dermatome. In addition the

wound closure is more difficult with more tension being

author strongly recommends epidural anaesthesia for

required, probably because of the increased upward

all caesareans other than early elective cases. If not

intra-abdominal pressure and the convexity of the

done, any cervical stimulation, for example by the calf

upper flank.

moving aginst it, will trigger abdominal contractions

The only technique to be described here will be the

even in exhausted cows. At best these are disconcert-

sloping, left flank incision principally because the

ing, at worst they can cause massive prolapse of the

author has had no indication to do any other. Right side

rumen through the abdominal incision. However, the

'caesareans' should be avoided because of the propen-

epidural injection must be done with care since too
sity of the small intestine to prolapse profusely out of
much volume will cause the cow to start knuckling on
the abdominal incision for the duration of the surgery.
her hind legs (usually the right one first) and to become
Occasionally though, old left side lesions may make this
unsteady on her feet. Only the barest minimum, suffi-
necessary and the surgeon should be aware of this com-
cient to stop straining should be given and this is usually
plication of operating on the right side.
the same as that required to produce vulval anaesthe-
Begin the abdominal incision about 12–15 cm ventral
sia. A small cow should require no more than 1.5–2 ml
to the tuber coxae ('pin-bone') and, at an angle of about
of 3 per cent lignocaine (2–3 ml of 2 per cent). Also be
30–35° to the vertical, extend it downwards and for-
sure to carry out the injection with the cow standing or,
wards. Make the incision long enough to remove the
if already down, with the animal's hindquarters in a
anticipated size of calf at the outset. Extending it later,
horizontal position. If the animal's pelvis is tipped to

when the calf is stuck half way out, is difficult; an ade-
one side or other to any degree, the block will probably
quate size makes for easier delivery and much less

trauma to the wound edges. Cut through the fatty sub-
ing at first; however, the novice should take heart from
cutaneous fascia and the external abdominal oblique
the fact that the author has never experienced or heard
muscle whose fibres cross the incision at right angles
of any damage being done with this instrument. Hold
and which, at about this level, merge with the relatively
the knife in the palm of the left hand with the blunt,
avascular aponeurosis. Deep to this lies the principal
probe-headed blade away from the palm and pointing
muscle layer, the thick internal abdominal oblique with
forwards. Push this blunt point vigorously through the
its fibres running approximately parallel to the incision.
uterus wall over the extremity of the calf, then push
Reverse the scalpel and with its blunt handle separate
the knife along the greater curvature of the uterus for
a small gap in these fibres at mid incision level. Insert

the required distance, preventing loops of bowel from
the index finger of each hand into this gap and pull
possibly straying into the cutting area by using the first
apart. The muscle then splits easily and bloodlessly
two fingers of the same hand extended alongside the
along the incision line to the required length.
knife guard. If the knife is sharp it cuts effortlessly,
Below lies the transversus muscle whose fibres run,
pushing cotyledons aside with its blunt probe tip and
like the external oblique, across the incision. At the mid
thus minimizing haemorrhage.
point there is usually a fairly large segmental nerve and
To remove the calf grasp a leg, through the fetal
accompanying blood vessels and it pays to ligate this
membranes if they are not cut, and bring it to the
bundle before cutting. For some reason this nerve
abdominal incision. This may necessitate careful
branch often seems to retain sensation, so it is wise to
manipulation and flexion of the joints, especially in the
stand away from the hind leg whilst it is quickly cut.
case of the hind limbs. Deal with each leg separately,

Take care cutting through the peritoneum as the rumen

and the head too if the calf is in posterior presentation.

is usually tightly applied to its deep face.

Break through the fetal membranes and extract the calf

Pass the right hand and arm behind the rumen and

by lifting it as gently as possible from the incision.

then medially to feel the uterus lying in the mid and

Remember that some part of the calf may be within the

right caudal abdomen. Palpate it thoroughly to feel the

pelvis and traction downwards and cranially may be

lie of the calf within. If the calf is in anterior presenta-

needed. If the calf is alive, try not to let it fall and snap

tion relative to the cervix, feel for the distinctive outine

the umbilical cord precipitously; rather move the calf

of the hocks and, if in posterior presentation, locate the

away from the cow slowly, breaking the cord in a con-

head and nose. Once these are found the uterine inci-

trolled movement. If possible, let someone else deal

sion can be made without delay.

with resuscitation of the calf and return to the cow.

The principles are: begin the incision over the extrem-

Even in this short time, the uterus will have con-
ity of the calf which is furthest away from the cervix (i.e.
tracted considerably, but in the majority of cases it is
over the hocks or nose of the calf) but not too close to
perfectly feasible now to exteriorize the incised horn to
the fallopian tubes or ovaries; continue the incision over
make closure easier. This has to be done carefully to
the dorsum or back of the calf, along the greater curva-
avoid damage to the uterine wall and is best done with
ture of the uterine horn, making the aperture big enough
flattened cupped palms and a scooping motion. Where
to extract the calf without tearing the uterus in the
the placenta has separated, the membranes can be
process. However, the incision must not be so large that
peeled away easily, but when the calf is delivered alive
it extends too far towards the cervix and therefore to a
this is not feasible and attempts to separate the fetal
position which will be difficult or even impossible to
and maternal parts of the cotyledonary attachments will
reach and suture. As a general rule this means an inci-
result in severe damage and bleeding. However, if the

sion length of between 30–50 cm depending on the size
placenta remains in its entirety, it will make closure very
of the calf. Also the more friable the uterus (e.g. after a
difficult. A simple remedy is to grasp the mass of mem-
torsion), the longer it should be to help prevent tearing.
branes close to the uterine incision and to cut the bulk
If these lengths sound excessive, remember that follow-
away with a scalpel keeping about 10–15 cm away from
ing removal of the calf, uterine contraction will substan-
the cotyledons. Some of the large placental vessels
tially reduce them within minutes.
bleed transiently but this is not a problem. By this
Many texts refer to exteriorizing the uterus or visu-
method, suturing the uterus is simplified and expulsion
alizing it before making the incision. However, few
of the remaining membranes is not affected.
people are strong enough to manipulate, let alone lift
Begin the uterine closure at the cervical end of the
this huge and heavy organ (often 75 kg or more) at
incision some 3 cm away from the wound commissure
arm’s length, and in trying to do so, accidental damage

and invert 2–3 cm of the wound edges to bring serosa in

is often done. It is far better to learn to use a Robert's

contact with serosa. Any continuous inverting suture

knife which has a protected blade and is used to incise

pattern will suffice but a Cushing's pattern (Fig. 66.3)

the uterus in situ. The prospect of using a knife blindly provides for the most rapid closure. Use an absorbable

in a site surrounded by small intestinal loops is daunt-

material such as catgut and penetrate only the serosa

and muscular layer. Pull each suture bite snugly as it is

are far more likely in torsion cases so make sure that

laid and be careful not to trap strands of placenta in the

the uterine incision is made long enough to extract the

closure. If a 'T' or 'Y' tear has occurred suture the

calf easily. Also sutures tend to pull through the soft

branch tear(s) first then treat the remainder as a single

wall and it is invaluable to have an assistant scrub up to

incision. If there is any doubt as to the seal achieved,

help oppose the edges of the incision. Always oversew

oversew the whole incision with a second inverting *in these cases and check that the torsion is completely layer. Clean the uterus of blood and fibrin tags and relieved before closing the abdomen. replace it in the abdomen.*

Close the peritoneum and transversus together with Removal of a dead, contaminated calf: The bovine a continuous everting suture to appose peritoneum to abdominal cavity is, by and large, a tolerant organ, but peritoneum. This is not a weight-bearing layer so the the gross contamination by infected fluids, membranes, closure can be rapidly attained with large tissue bites. hair, etc. that occurs in a caesarean delivery of long Oppose the remaining layers of muscle and fascia with dead fetuses leads to a high incidence of maternal endo- a row of large, simple interrupted sutures. As there is toxaemia, peritonitis and abdominal wound dehiscence. tension on this part of the closure the knots can be dif- However, with suitable modification to the basic tech- ficult to tie, with the first throw slackening before the nique the level of post operative morbidity and mor- second throw is laid to lock it. If the first throw is made *tality drops to such a low level that surgery becomes a*

a triple or even quadruple slippage does not usually

viable alternative to sending the animal for slaughter.

occur and tissue opposition can be maintained. The skin

These modifications were adopted successfully by the

is closed with horizontal mattress sutures of non-

author and others at the Liverpool University Veteri-

absorbable material.

nary Field Station.

The choice of suture materials for the deep layers of

In anticipation of the massive abdominal contamina-

the abdominal wound is the subject of controversy.

tion give the animal 10 million units of crystalline peni-

However, the author has no doubt that an absorbable

cillin G intravenously just prior to surgery. Open the

material such as catgut is indicated. The thickest gauge

abdomen in the conventional way but then attempt, if

is easily strong enough and, in the event of infection,

at all possible, to bring the gravid horn up to the

these sutures will not act as persistent, individual

incision. (Take care not to damage the friable uterine *foreign bodies, will lyse rapidly and will not have to be wall in the process.) Incise the horn over an extremity painstakingly removed before healing can take place. and try to extract the calf and membranes with the As soon as the surgery is over, release the cow and, minimum of spillage into the abdomen. To make this if it is alive, allow her access to the calf. In an uncom- easier, make sure that both the abdominal and uterine plicated caesarean section there is no indication to use incisions are of adequate length to prevent sticking or any drugs other than the routine pre and post operative tearing. Close the uterus carefully as described for antibiotics. However, if the uterus seemed slow to uterine torsion and oversew the first closure. Clean the contract down, as often happens when a dead calf is uterus, reposition it and then begin the task of cleaning removed, oxytocin can be given and, of course, if there out the abdominal cavity. This is achieved by repeated is any suspicion of hypocalcaemia, appropriate therapy lavage. Use 2 litres of saline each time, warmed and is indicated.*

poured through the incision. Use the saline to literally

wash the viscera before scooping as much as possible

with cupped hands. Repeat this process twice. Instill 10

Special cases

million units of crystalline penicillin G into the peri-

Caesarean section in cases of torsion of the uterus: The toneal cavity and begin the closure.

operation proceeds routinely until the stage of incising

The margins of the abdominal wound will be severely

the uterus. If this is done without first correcting the

contaminated so remove a 4–5 mm strip of the incision

twist, suturing will be extremely difficult because in

margin of each muscle layer by sharp dissection. The

the, by then, untwisted uterus, the incision will lie on the

bleeding edges are then sutured in the usual way using

deep face of the horn. It is therefore the author's prac-

plain catgut. Strip the contaminated fascia from below

tice to try and correct the torsion at this stage if at all

the skin margins and close the skin with horizontal mat-

possible. Use the flat of each hand to start the heavy

tress sutures of a non-absorbable material. Use high *uterine body swinging in the copious peritoneal fluid*

levels of penicillin and streptomycin to supplement the

that invariably is present in these cases. Be very careful

initial intravenous therapy for about 5 days and to

not to allow stray fingers to penetrate the oedematous,

ensure the maintenance of high concentrations in the

friable uterine wall and if this seems likely, or the twist

peritoneal cavity inject 10 million units of penicillin G

is resistant to correction, abandon the attempt and

directly through the abdominal wall in the right sub-

proceed to incise the twisted horn. Uterine wall tears

lumbar fossa on the first and second post operative day.

Despite these precautions, wound infection can occur

whose success rate and ease of execution improves con-

and can be recognized by a swelling of increasing size

siderably, the earlier it is done. Too often the clinician

at the ventral aspect of the wound which is painful on

and owner delay the decision to amputate, just in case

palpation. Needle puncture will confirm the presence of

the animal improves, and are only persuaded that it is

*pus. In these cases remove the sutures from the lower
necessary when the infection has extended above the
third of the incision and open the wound to allow
hoof and the distal limb is swollen and excruciatingly
drainage. Penetration of infection into the abdomen is
painful. By this time, the unfortunate patient has lost a
not likely at this stage and the only treatment needed
great deal of condition and most of her milk, has taken
is daily wound irrigation. It is in these circumstances
up a great deal of time and money and is a prime can-
that the use of catgut sutures is vindicated. The mate-
didate for humane slaughter, not surgery.
rial lyses rapidly in the infected tissue and does not
Probably the commonest instigating condition for
form a series of permanent niduses of infection which
this type of deep infection is solar ulceration. Typically
would have to be removed before healing could take
the lesion remains unnoticed because of its bilateral
place. Whilst these open wounds look extremely
nature and only when infection penetrates through the
serious, provided drainage and irrigation are main-*

keratogenic layer into the deeper structures does the tained they heal well with minimal long term scarring. lameness worsen sufficiently for the farmer to notice and bring the case to the attention of his veterinary Caesarean section for treatment of Hydrops allantois: surgeon. By this time involvement of the deep flexor Hydrollantois in the cow develops within the last three tendon (DFT) at its insertion into the pedal bone has months of pregnancy. It results in a massive fluid accu- usually occurred. This extension of infection to the level mulation within the allantoic cavity and caesarean of the DFT is easily established by probing down section is the treatment of choice. Initially a two stage through the granuloma which is always present by this operation was devised in an attempt to avoid the stage at the ulceration site. If the probe tip strikes bone splanchic pooling and vascular embarrassment which or penetrates to a depth of 2.5–3 cm, then DFT involve- might occur if the fluid was allowed to escape too ment is certain. In these cases it is the author's practice quickly. On the first day, a drainage tube was inserted *to excise the granuloma and the infected deep tissue*

into the uterus and fluid was evacuated slowly

once only. If, on a repeat examination some 5–7 days

overnight; on day two a routine caesarean section was

later, the granuloma and sinus have reappeared, then,

carried out. A development of this technique was to

as the chances of success a second time are minimal,

drain fluid through a larger bore tube over an hour or

amputation is recommended. At this stage, infection is

so before completing the caesarean procedure.

usually localized within the hoof and has not spread to

The author has modified this technique further so

the soft tissue of the pastern region or, worse, to the

that delay is minimized.

flexor tendon sheath.

Begin the abdominal incision in the usual way but

Done at this relatively early stage, the operation is

open only the top or dorsal 50 per cent of the wound.

easy to perform and is usually successful in its aims. The

The fluid-filled uterus invariably bulges out of the aper-

animal heals rapidly and begins to improve in condition *ture. Make a small 2 cm stab incision into this bulging almost immediately after surgery. However, a warning portion and slowly release some of the fluid. As the note must be sounded: the remaining digit will now be intra-uterine pressure drops, slowly at first, then faster carrying all of the animal's weight. It will therefore be and faster, the abdominal and uterine incisions can be subjected to a great deal of extra wear and tear and is progressively enlarged. If the evacuation of fluid is con- likely to support the cow for only one or two more lac- trolled to take place over 15–20 minutes the animals tations; in small cows, with a good clean management show no sign of discomfort or vascular embarrassment system it can be much longer.*

and the caesarean section can proceed as normal. Bear in mind, however, that the calf is likely to be small, so Anaesthesia: For the technique to be described here, the incision does not need to be as large as normal, and the animal must be sedated and cast to lie in lateral that the vastness of the uterus and prolificacy of the recumbency. For sedation use xylazine or chloral *membranes can occasionally make locating that calf*

hydrate. The latter drug, now sadly out of fashion, is in

rather difficult!

many ways superior to modern sedatives for this type

of work and is also unlicensed in the UK. Onset of

sedation is quiet and unmarred by bellowing or saliva-

Amputation of a digit or claw *(see p. 430)*

tion and the depth of sedation can be profound if so

The main indications for this procedure are severe

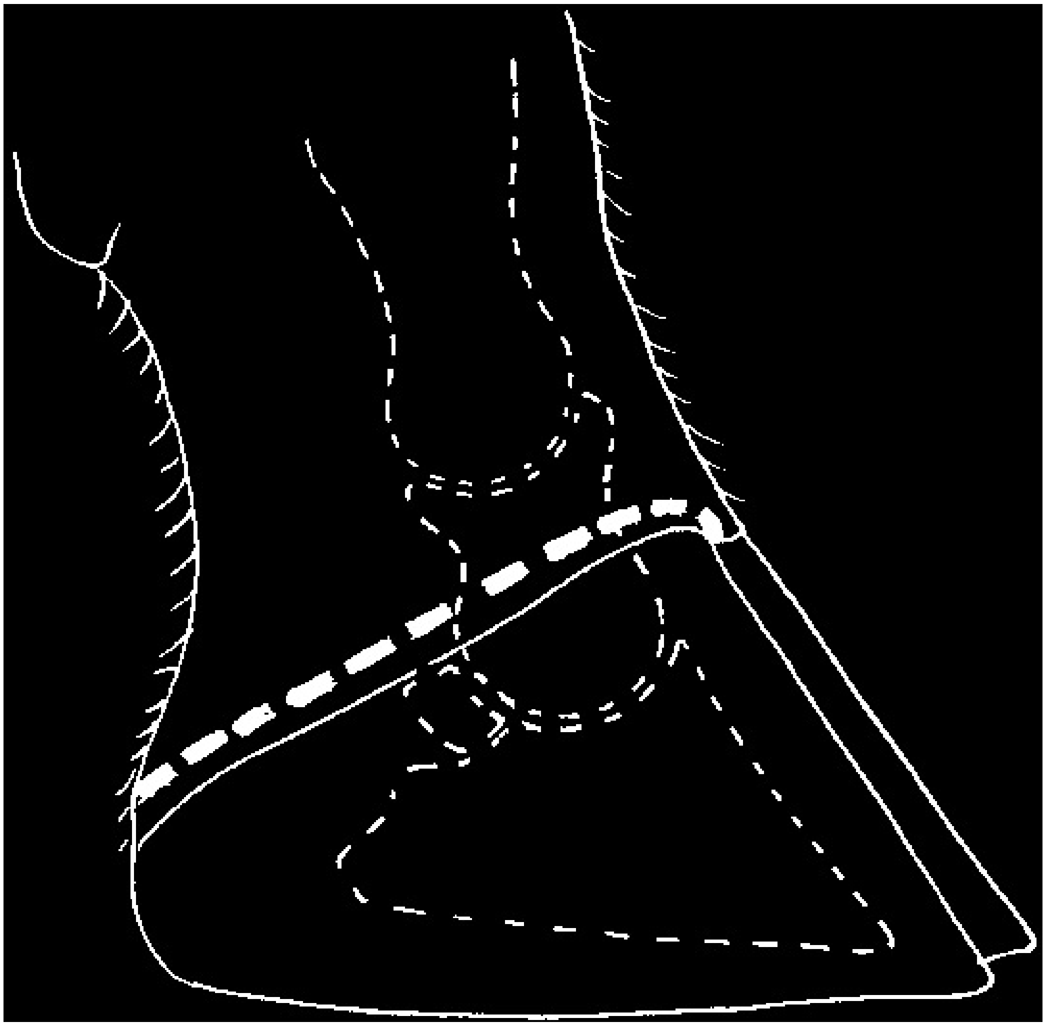
desired. Its analgesic effect is good and its duration of

trauma to the hoof and associated internal structures

action, after oral dosing and a 10–15 minute induction

and intractable infection of the foot. It is a procedure

period, is 45 minutes or longer; this allows plenty of



time for surgery by even the most inexperienced. The

Technique: No special instruments are necessary,

recovery phase is calm and uneventful and it is cheap!

although a proper curette is a great help.

The oral dose is between 60 and 90 g, depending on

With the cow in lateral recumbency, and the affected

the size of the animal, and it can be given through a

claw uppermost, prepare the foot for surgery. The claws
stomach tube, dissolved in about 1 litre of warm water,
can be difficult to clean and a combination of paring
or as a drench. If using the latter method allow the
and scrubbing with a stiff brush is often needed. To
animal plenty of time to swallow and to avoid inhala-
clean the interdigital area use three or four lengths of
tion of the liquid. Make sure that the solution does not
cotton bandage soaked in surgical scrub and see-sawed
contact the eyes as it is extremely irritant.
briskly backwards and forwards in the cleft.
Chloral hydrate can also be given intravenously, vir-
Make the incision about 5 mm proximal and parallel
tually to effect, although again its irritant nature means
to the coronary band–skin junction. Extend the incision
that care must be taken to avoid perivascular injection.
through the thick skin all the way around the outer
Whatever sedative is used, local analgesia of the foot
hemicircumference of the pastern and into the inter-
is essential. The method of choice is, without doubt,
digital cleft. Here, cut the skin 2–3 mm axially to the

intravenous regional anaesthesia (IVRA).

horn–skin junction, carrying the incision through the

The secret of successful IVRA is the application of

cleft to rejoin the skin wound. Always take care to cut

an effective tourniquet. Use thick (2 cm diameter)

towards (or into) the affected claw. Some force is

rubber tubing of the type used in milking machine

needed to penetrate the thick skin of this region and

pipelines, applying it just proximal to the carpus or

one inadvertent slip of the scalpel blade into the sound

the hock. To improve compression in the latter case,

claw can ruin the animal. Once through the skin, angle

place 15 cm (6 inch) bandage rolls into the lateral

the incision proximally to aim for the proximal inter-

and medial depressions which lie just anterior to the

phalangeal joint. This lies in the dorsal (anterior) half

Achilles tendon. Wind the tubing around the leg at least

of the pastern thickness and some 20 mm proximal to

4 times applying maximum effort to ensure a high

the coronary band (Fig. 66.7). Careful dissection is not

degree of tension and compression; if necessary, use two *necessary and the fascia, ligaments, tendons and sheaths*

people. Whilst doing this do not lift the leg above the

can be cut rapidly with fairly bold strokes.

horizontal or the limb veins will collapse and be diffi-

Finding the proximal interphalangal (pastern) joint

cult to inject. Clip a strip over one of the superficial

can be difficult at times, especially if chronic infection

veins and clean it thoroughly. Using a wide bore (16 g)

has resulted in extensive fibrous reaction or the depo-

needle inject about 30 ml of 2 per cent lignocaine or

sition of periarticular new bone. The easiest way is to

20 ml of 3 per cent, rapidly into the vein; withdraw the

put an axial (inwards) force on the claw and then to

needle and syringe and apply pressure to the injection

make a series of cuts parallel to where the joint is

site immediately. (If the injection is done slowly the

believed to be. When one of these cuts is made in the

animal often kicks after about 50 per cent of the solu-

tion is injected and frequently the needle pulls out of

the vein.)

Once injection is completed, full analgesia will *usually develop in about 10 minutes or so. However, before starting the incision, this must be checked. Within a volume of tissue subjected to IVRA the initial effects are random, with blocks of anaesthetized tissue lying adjacent or deep to other tissue blocks which are fully sensitive. It is therefore essential to check, not just by skin pricking, but by driving a needle down to the bone all the way around the claw. (It needs little imagination to picture the consequences of completing half the operation only to find the deep layers of tissue are entirely sensitive!) The interdigital cleft and especially its caudal aspects seem to be the last tissue to be affected and these areas should be carefully checked. If anaesthesia has only been partially achieved after 10–15 minutes, repeat the intravenous injection using the same amount of local anaesthetic solution. If it is still*

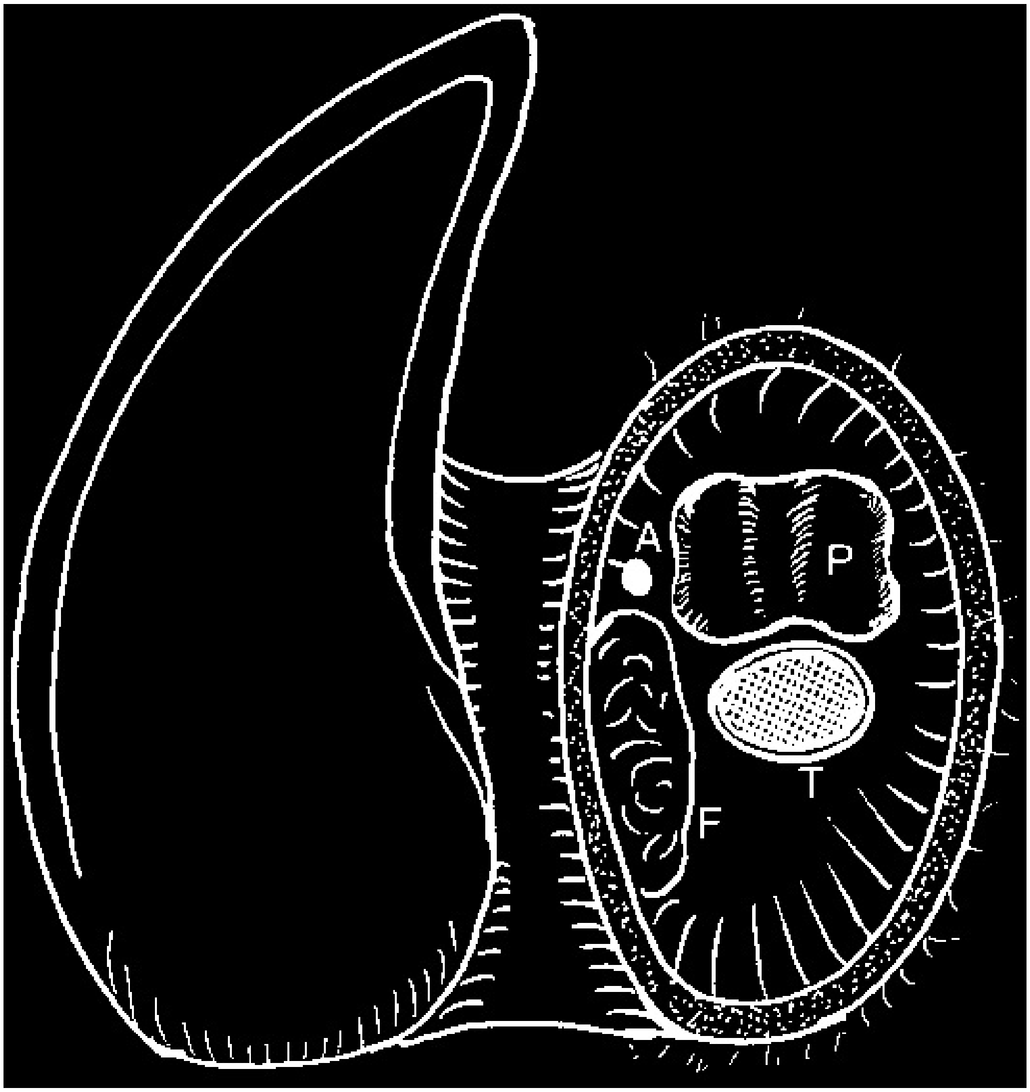
Fig. 66.7

The heavy dotted line shows the course of the initial

not fully effective then it is likely to be the tourniquet

skin incision when amputating a digit. Note the position of the which is at fault.

proximal interphalageal joint relative to this incision.



correct place the tautly stretched collateral ligaments

tic sign as the sheath usually remains infected; it also

and joint capsule part easily with the release of some

occasionally communicates with the sheath of the

synovial fluid and an increase in joint laxity. Carry this

sound claw at the level of the fetlock. The final step is *incision on and around the articulation, bearing in mind to curette the articular cartilage. This must be done its deeply curved profile. Take care when cutting its thoroughly to expose the subchondral bone over the deep attachments not to penetrate too far towards the entire surface of the articulation. If it is not done care- sound digit. During this phase twisting and turning the fully, granulation tissue will not grow from the bone partially amputated claw can help to expose and tense end, or adhere to it, and a persistent sinus will develop the tissues for cutting. At this point, scalpel blades are in the healing tissue. The use of a proper curette greatly often broken and it is a good idea to have a few spares simplifies this part of the surgery, but if one is not avail- available. Complete the removal of the claw by sever- able a scalpel can be used as a substitute.*

ing any remaining attachments.

Careful bandaging of the wound is vital, not only for During surgery, haemorrhage is not a problem its protection but as the only means of post operative because of the tourniquet; however, if some pre-

haemostasis. Place a layer of non-adhesive dressing on

emptive action is not taken it can be quite considerable

the exposed tissues then overfill the wound cavity with

once the latter is removed. The only vessel of real sig-

gauze, swabs or cotton wool. Wrap the stump and the

nificance is the dorsal digital artery and its cut end is

entire pastern region with a layer of cotton wool and

usually fairly easily found in the dorso-medial quadrant

use a cotton elastic bandage to keep it in place. Finally,

of the wound axial to the stump of the first phalanx (Fig.

apply a 10 cm (4 inch) elastic adhesive bandage.

66.8). Ligatures should not be used as the wound is to

Starting from the tip of the remaining claw, progress

heal by second intention. Instead, grasp the severed end

upwards, increasing the tension over the stump and

of the artery in forceps and twist it some 8 to 10 times

continuing up to and above the fetlock. The latter is

to seal its lumen. Debride the wound if necessary,

necessary to anchor the bandage securely; if it were to

cutting off any obviously infected or necrotic tissue. Do

come off the consequences would be disastrous! Take *not remove any of the large interdigital fat pad which care not to crush the accessory digits; the bandage can prolapses into the wound unless this too is infected. be laid over them, but its tension should be slackened Check the flexor tendon sheath: if the fluid that can be and they should be packed around with liberal wedges milked out of it is turbid or flocculant it should be of cotton wool prior to wrapping. This will prevent the repeatedly irrigated with saline and antibiotic solution. skin necrosis that can occur deep to them if they are Although not disastrous, this finding is a poor prognos- subjected to too great an inward pressure.*

Once the bandage is secure, the tourniquet can be removed. By this stage it will probably have been on for at least a half to three-quarters of an hour. This does not seem to be harmful in any way and the author has often seen tourniquets in situ for an hour or more without deleterious effect. Remove the hobbles and assist the patient onto her sternum. Do not force her to her feet, rather let her get up in her own time. As soon as she puts weight on the foot blood is frequently forced *through the weave of the bandage – if this is minor it*

can be ignored, but if it persists for 10–15 minutes or is

excessive in amount, apply a second elastic adhesive

bandage over the first and, if necessary a third. Do not, under any circumstances, remove the existing bandage.

Leave the bandage in place for four to five days. If

it is taken off before that time the fragile clot is easily

disturbed and haemorrhage can be severe. Thereafter,

change it every five to seven days depending on the

amount of exudate produced by the healing wound.

The wound cavity will begin to contract about seven

to ten days after surgery rather like a flower closing and

the wound area diminishes rapidly. Concurrently, gran-

Fig. 66.8

This shows the anatomic relationships of the struc-

tures remaining after amputation. A is the arterial stump; F is the ulation tissue grows from the cut surfaces and at five to

fat pad; T is the transected flexor tendon bundle and P is the six weeks is usually flush with the skin edge. Skin con-distal end of the first phalanx.

traction continues and when the wound is about 30 mm

across the bandage can be left off. Exuberant granula-

regarded as clean and never sterile. Sutured wounds in
tion tissue is not a problem at this site.
this environment always succumb to infection and to
Occasionally a cleft persists in the granulation tissue
post operative haemorrhage and swelling and always
bed and wound closure stops. This usually shows three
dehisce.
to four weeks after surgery and the likely cause is
incomplete stripping of the articular cartilage. If there

Surgical correction of an umbilical hernia

is no progress over one week, reanaesthetize the site,
cut out the granulation tissue and recurette the bone
The reasons why umbilical hernias develop in some
end.
animals are not fully understood. It is presumed that in
If surgery has been delayed, infection may have
some there is a failure of the normal closure mechanism
established itself proximal to the amputation site. In
(see p. 182), although there is no doubt that many pre-
these circumstances, and especially where tendon
viously normal calves are found to have hernias fol-

sheath is involved, the lameness and swelling will persist

lowing a bout of ‘navel-ill’ or umbilical infection. This

despite some wound closure. No hard and fast rules can

also accounts for the incidence of navel abscesses which

be given as to when to give up hope of healing but, if

can mimic hernias and for the fact that hernias and

there is no improvement in the condition of the distal

abscesses can co-exist.

limb or the lameness within two weeks of surgery, then

Hernias are broadly classified into those where the

resolution is very unlikely and the animal should be

contents are easily returned to the abdomen, i.e.

slaughtered on humane grounds.

‘reducible’, and those where the contents are not, the

‘non-reducible’. The former, which are in the majority,

Other techniques: The disarticulation technique de-

are easily diagnosable and cannot be confused with an

scribed here is somewhat more complicated than those

abscess. The latter, however, present as a firm swelling

which use an embryotomy wire, either to cut through

which could be either an abscess or a combination of *the phalanges or to carry out the entire amputation. Its*

both abscess and hernia. In these suspect cases, use

use is justified because transection of either the second

needle puncture and aspiration to determine which is

or first phalanx opens up their medullary cavity to an

what. Puncture the swelling from both its caudal and

infected environment, resulting in a fairly high inci-

cranial aspects, using a separate needle for each punc-

dence of osteomyelitis following such procedures.

ture to prevent possible transmission of infection. Use

In addition the nutrient foramen of the bone may

a large gauge needle and much suction as the pus in

also be destroyed leading to necrosis of the remaining

these abscesses is often quite thick.

fragment. A second distinct advantage of the disarticu-

Small hernias, i.e. those with rings which are two

lation method is that it produces a cup-shaped wound

fingers' width or less, do not usually need repair. The

cavity which maximizes the potential for healing by skin

animal grows around the hernia and it is insignificant.

contraction. In contrast, the use of an embryotomy wire

Some surgeons recommend closure because of the risk

for the entire amputation produces a flat wound sur-

of strangulation of herniated viscera; this risk is very

face. This does not favour skin contraction and wound

small and the author has seen only one case in over 20

closure is often considerably delayed.

years. In addition, the hernial content is almost always

However, there is no doubt that this technique takes

omentum rather than the vulnerable small intestine.

much less time than disarticulation and it can be per-

However, hernias which are 3 fingers' width or more are

formed without casting the cow; for these reasons alone

often quite pendulous and can become traumatized.

many busy practitioners prefer it. With the foot anaes-

They can also become significant cosmetic blemishes in

thetized, locate the wire loop in the interdigital space,

later life. Occasionally, the abomasum can become

checking that it begins to bite above the coronary band.

lodged in large hernial sacs although this does not seem

The aim is to amputate through the distal third of P1

to create any clinical problems for the animal.

(i.e. distal to the nutrient foramen) so initially angle the

direction of cut proximally. When the wire is at the

Technique: No special instruments are needed.

correct level, change the plane of incision to lie at right

The calf should be prepared by being starved of all

angles to the long axis of the phalanx and complete the

food for 24 hours. As well as being a routine prepara-

amputation. It is worth checking carefully to ensure

tion for anaesthesia this creates a slack abdomen during

that it is indeed P1 that has been cut and not P2, oth-

surgery which helps with ring closure. The surgery

erwise ischaemic necrosis of the remaining fragment of

should be performed under general anaesthesia, or

the second phalanx is very likely. Otherwise postoper-

under heavy sedation, with the surgical site anaes-

ative management is the same as for disarticulation.

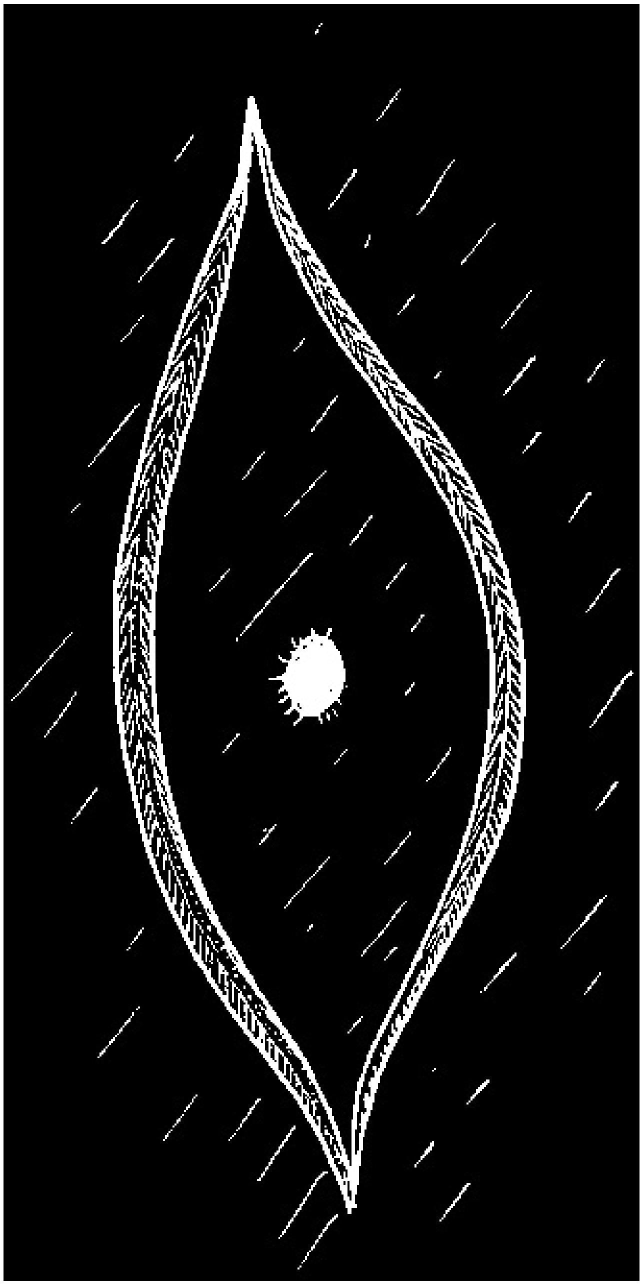
thetized by a field block. With the patient in dorsal

Avoid techniques which call for sutured flaps of skin

recumbency, excise a fusiform (Fig. 66.9) shaped area of

over the stump. This operation at best can only be

skin centred on the cicatrix at the hernial apex. Try and



sac can be inverted into the abdomen. There is no need to suture the sac, only to close the now enlarged ring in the usual way.

For closure, use strong, non absorbable suture mate-

rial which forms a secure knot. Monofilaments are not ideal and the author prefers a sheathed multifilament type of suture. There is no need to use any complicated suture patterns to overlap the ring margins, e.g. the so-called 'vest-over-pants' technique, as a simple apposition with simple interrupted sutures is entirely sufficient. The former creates a bulky mass of tissue which in turn creates a poor cosmetic effect. Also there is no need to 'freshen' the ring edges.

Insert the first suture some 1 cm beyond the caudal or cranial ring edge, then progress along the ring laying sutures every centimetre or so to finish one centimetre beyond the ring edge at the opposite pole (Fig. 66.10). Use the finger of the 'spare' hand to protect the abdominal viscera from the point of the needle. Lay all the sutures before tying and clamp each pair of free ends with artery forceps to prevent them from pulling out

Fig. 66.9

A fusiform incision around the cicatrix.

or becoming tangled. Tie the sutures one by one, starting with the outer ones and progressing towards the *middle. Pull each suture tightly enough to appose the ring margins and then a little more to create a mild com-estimate how much surplus skin is to be removed and pression effect. If tied in the conventional way the first adjust the width of the excised portion accordingly; err throw often slips as tension comes on it; to prevent this on the cautious side as more can be removed later. Sep-either use a stitch holder while the second throw is arate the skin of this area from the underlying fascia being applied or, alternatively, make the first throw a by blunt dissection, though at the cicatrix it is firmly triple rather than a double. This will usually resist the attached and may need to be cut. Next, using blunt dis-applied tension sufficiently for the locking throws to be section with a scissors tip, and beginning at the cicatrix, completed.*

dissect back the multiple layers of fascia in a radial Close the fascial layers over the ring sutures with a fashion to expose the discrete, thick, peritoneal hernial simple continuous pattern using absorbable suture, sac which lies deep to them. This is facilitated by grasp-

having first trimmed off any excess tissue that may

ing the cicatrix with an Allis or similar forceps and

prevent a flat closure. If the skin edges are still apart,

applying upwards traction to tense the tissues. As the

put in a subcuticular layer to bring them together. More

fascial layers peel back, the sac becomes more obvious

likely there will be some surplus skin and this too can

and eventually becomes completely exposed, along

be trimmed away, being careful to maintain the fusiform

with the now easily discernible edge of the hernial ring.

shape of the final deficit. Close the skin with either a

Clear the fascia back from the edges of the ring for at

simple interrupted or interrupted horizontal mattress

least l.5 cm all the way round so that there is a clear

suture pattern. Finally, to apply pressure to this ventral

shelf of aponeurosis into which the closure sutures can

and dependent wound, and to protect it, sew on a Stent

be laid.

bandage (Fig. 66.1).

Invert the sac and contents into the abdomen; if they

go easily, as most do, there is no need to open the sac.

The repair of large hernias: To repair hernias which

If the contents are irreducible, the ring will need to be

have large rings over four to five fingers in width, most

enlarged. Carefully, so as not damage the hernial con-

surgery texts advocate the use of stainless steel or syn-

tents, make a small opening in the sac at the caudal or

thetic mesh to fill the defect. The author has had little

cranial ring margin. Using a grooved blade director if

success with these as, no matter how tightly they are

available, or any blunt instrument which can be inserted

sutured in place, they invariably sag under the weight

between the contents and the ring as a shield, enlarge

of the viscera so that the final result is little better than

the ring by cutting caudally or cranially as appropriate.

the original hernia!

In most cases the ring only needs to be enlarged to a

An alternative and effective method is to create a

small extent before the contents and subsequently the

slack abdomen by depriving the animal of roughage for

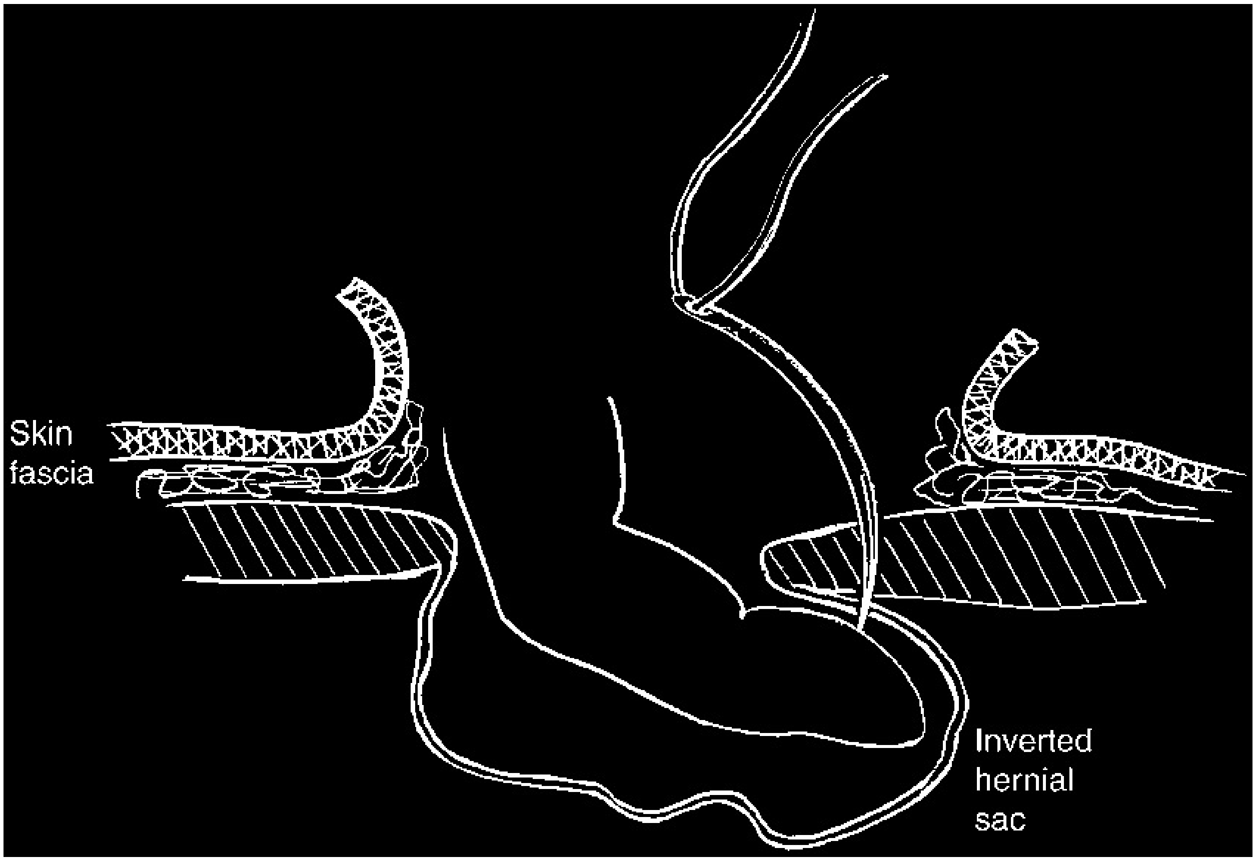


Fig. 66.10

Illustration of how the index finger

is used to guard the advancing needle tip

when laying sutures to close a hernial ring.

some 48 hours prior to surgery and then to carry out

if several animals are to be done, anaesthetize and

the repair as described above. Be sure to use strong

operate on them a batch at a time. Be sure to use an

suture material and to take good solid bites of the *anaesthetic solution containing adrenaline which has a*

fibrous aponeurotic tissue surrounding the ring. One

long duration of effect, and be sure that there is enough

modification which helps a great deal is to have an assis-

help available to persuade the animals to enter the

tant apply upwards traction equally and simultaneously

crush a second time!

on all the laid suture ends to bring the ring edges

Animals with very large horns and therefore a broad

together before the row is tied off, one suture at a time.

diameter at the skin–horn junction often require an

Using this technique and preoperative fasting, even the

additional ring block for full analgesia. If in doubt carry

largest hernias can be repaired satisfactorily.

out this procedure at the outset to avoid undue pain and

the consequent non cooperation of the patient. The skin

at the base of the horn is tightly applied to the skull and

Dehorning of an adult

infiltration can be difficult. Slide a long, relatively

In the past this procedure was commonplace; nowadays

narrow gauge needle (e.g. 19G) under the skin and *it is done less and less since most cattle are debudded*

inject the solution as the needle is withdrawn. Concen-

as calves. As a consequence, many students may not see

trate on the caudal aspect of the horn base as the 1st

the procedure performed at all.

and 2nd cervical nerves can innervate this area of

Dehorning should be done in the winter months

skin–horn junction and they will not have been affected

when the risk of fly-strike is at its lowest.

by the cornual block.

Anaesthesia: This is a technique which relies heavily on Surgical technique: There are many methods for remov-good restraint of the animal and the use of a 'crush' and

ing the horns; the commonest are shears, embryotomy

the help of a strong and competent assistant are essen-

wire and the butcher's saw. Shears can be used for young

tial if a rodeo is to be avoided.

stock where the horn and cornual process is soft, but

For most routine cases the standard cornual nerve

they are well nigh impossible to use if the horn is mature

block is sufficient. A common mistake is to use too little

or the horn base is very wide, as in the Welsh Black

anaesthetic solution: at least 10 ml should be infiltrated
breed. They allow very rapid removal of horns, though
across the path of the cornual nerve. Redirect the
if used carelessly they may not cut the horn low enough
needle several times during the injection to saturate a
and therefore not amputate a complete circle of the ker-
large volume of tissue and increase the chances of a suc-
atogenic tissue which lies at the skin–horn junction. In
cessful block. Bleeding from the injection site is normal
addition to the long term complication of horn regrowth
and a good indication that the needle was in the correct
which may result, there is the more immediate problem
place. Another error which can lead to problems is to
that a cut made too high amputates the cornual vessels
attempt surgery too soon after the injection was made.
after they have entered the bone of the cornual process,
Wait for at least 10 minutes before beginning to cut and,
making haemostasis extremely difficult.

Embryotomy wire is silent in operation, resulting in
of the remaining bleeding points stop or slow to a level

better patient cooperation; it allows for the direction

where they can be ignored.

of cut to be changed and provides good instrinsic

In those cases where the horn and cornual process

haemostasis. However, the push/pull action needed is

have been sectioned too high the vessels will continue

very tiring, the wire often jams in the cut, especially if

to bleed from the vascular canals within the bone. They

it is used too fiercely, and it is very prone to break.

cannot be picked up in artery forceps and are a nui-

The author's preference is for a heavy butcher's

sance. The time-honoured way of dealing with these is

saw which cuts with its own weight and whose use

to insert a sharpened matchstick point into the hole to

involves a more congenial action than the embryotomy

plug it. Although seemingly crude in these days of

wire.

modern technology, it works, and the presence of the

With the animal in the crush, the assistant should,

wood fragment does not appear materially to affect

using a 'nose lead' ('nose grip', 'bulldog'), bend the *healing in any way.*

animal's neck sharply to one side to move one horn

away from the crush door. This often causes the head

Post operative course: Treatment of the resultant

to tilt to one side and it should be straightened as much

wounds with antibacterial powders and aerosols is

as possible before cutting begins. At this stage check

widely practised. However, its effects are likely to be

that the anaesthetic has worked and that the whole of

cosmetic only and the author uses no wound dressing

the horn base is desensitized. If it has not been done

without apparently affecting the speed or course of

already, clip the hair from around the base of the horn

healing.

then position the saw blade some 2.5 cm from the

Post operative care must involve examining the

medial horn base. Angle the blade towards the point

animals every few hours for the first day or so in case

where the ear meets the head and begin sawing. Occa-

there is secondary haemorrhage; thereafter daily mon-

sional animals object violently even when the horn is *itoring will be sufficient. Advise the farmer to feed hay*

apparently completely desensitized and the blocks have

off the ground and not from overhead racks as this

been repeated or supplemented with a ring block. In

diminishes the amount of seed and dust contamination

these cases it is likely that they are reacting to the noise

of the exposed frontal sinus. In the normal course of

of the saw in their heads and a change to an embry-

events the hole will scab over within one or two weeks,

otomy wire will solve the problem.

with complete healing by skin contraction and epithe-

Saw swiftly through skin and bone to emerge just

lialization taking several months.

above the ear. Take care not to lift the skin from the ear

and, if this seems likely, cut the remaining skin tag with

Complications: Secondary haemorrhage is not

scissors.

common provided the largest vessels have been dealt

with properly. However, fighting or rubbing of the

Haemostasis: When the horn is finally detached from

wounds can occur as the analgesia wears off and bleed-

the head, haemorrhage can be impressive. However, it ing can be severe. Identification of the source of the is not life-threatening and can easily be temporarily haemorrhage is almost always impossible as the side of stopped by finger pressure. Many techniques of the head and the surgical site are covered with a mass haemostasis have been described and advocated but the of blood clot which effectively hides the bleeding point. simplest and most effective is torsion or twisting of the The area is now completely sensitive again and the bleeding vessels.

animal usually vigorously resents its handling. The With a robust pair of artery forceps, grasp the vessel quickest and least painful remedy is to apply pressure. ends firmly, apply gentle traction and spin them about Place a large pad of cotton wool directly over the horn six or so revolutions or until they break off. This will, in stump and bind it down tightly with several rolls of most cases, completely stop the bleeding or at worst 10 cm (3 inch) adhesive elastic tape wound around the reduce it to a small point of seepage. The largest vessels *head. Leave the ears protruding, as they help to prevent*

are always to be found at the ventral, rostral edge of the

the bandage slipping, and take care not to constrict the

skin wound and, if the cut is made low enough, will be

larynx or trachea. Although apparently crude, it is a

exposed for several centimetres of their length. If they

very effective method and avoids the need to re-

are not, grasp the bleeding, severed end of the artery

anaesthetize and explore the site in an often fractious

and, using gentle leverage over a finger, expose a suffi-

animal. Some individuals may be extremely anaemic

cient length to be twisted. Do not attempt occlusion by

after such haemorrhage and a small number may

snapping off the vessel end, as is occasionally recom-

require blood transfusion. As a rough guide, if the

mended; a high proportion break way below skin level

animal is able to stand and move around without being

and continue to bleed from inaccessible depths. If these

too ataxic it is not likely to require such measures.

large vessels are occluded in the manner described most

However, if in doubt, transfuse.

Long term complications are sinus empyema and fly-

dental rupture of the conjunctival sac and contamina-

strike. Farmers must be instructed to call for veterinary

tion of the wound.

attention if a recently dehorned animal becomes dull or

To penetrate into the orbital cavity, retract the upper

anorexic. In these cases the sinus should be examined,

eyelid skin and use a finger tip to locate the boney edge

if necessary by lifting the scab. If infected, or affected

of the mid upper orbit. With a scalpel cut just below

by fly strike, give systemic antibiotics and treat locally

the bone edge and parallel to it. Once an access hole

by irrigation with copious amounts of water to remove

has been created, use a curved-on-flat scissors to extend

the pus or larvae. Repeat the irrigation daily until the

the aperture laterally and medially, keeping close to

sinus is clean and healing is progressing well.

the orbit rim all the way round. Leave the medial

canthus until last as the largest vessels lie here and their

bleeding can be difficult to control. Up to this point

Eye enucleation *(see p. 922)*

haemorrhage is not usually a problem and it can be con-

The common indications for eye enucleation in cattle

trolled by conventional means. When the medial attach-

are panopthalmitis and conjunctival or scleral squa-

ments are severed the globe becomes free and

mous cell carcinoma. The presence of infected or

relatively mobile. If bleeding from the medial vessels is

tumour material within the conjunctival sacs in these

severe then hard finger pressure for a minute or so

cases precludes a subconjunctival approach through the

should reduce it to manageable proportions. These

palpebral fissure and so most large animal enucleations

vessels are often difficult to identify and even more dif-

are done by a transpalpebral technique. With this

ficult to grasp with artery forceps so if first attempts fail, method, the eyelids are sewn tightly together to trap

apply pressure to the area for a little longer and then

infection or neoplastic material with the conjunctival

proceed with freeing the globe from its deep attach-

sacs and the globe is removed intact to maintain a *ments. This is done by putting outward traction on the*

sterile wound.

globe, inserting a heavy pair of curved-on-flat scissors

into the gap between globe and orbit and cutting the

Anaesthesia: In tropical countries where occular squa-

taut tissue. As the globe becomes progressively looser

mous cell carcinoma is rife, enucleation is a common

it can be pulled further from the cavity and access

procedure and is usually done under retrobulbar block.

improves. Ideally the muscles should be detached close

This is a relatively simple technique which is described

to their insertion on the capsule so that as much tissue

in many textbooks but, if only the occasional enucle-

as possible is left within the orbit to minimize dead

ation is done, and facilities are available, then the lack

space. Practically, poor access, retrobulbar fat and the

of movement and relaxation of general anaesthesia

inevitable haemorrhage mean that cutting is usually

makes for much easier surgery!

done blind and the muscles, fat and optic nerve are sec-

tioned randomly. As soon as the globe is free lift it away

Technique: Prepare the eye by fine clipping of the eyeand attend to any haemorrhage. Unlike the dog and cat,

lashes, lids and periorbital region, followed by removal

bleeding from the optic artery is not dramatic, there is

of debris and discharge from the conjunctival sac. Sew

no need for ligation, and at worst blood wells up slowly

the shorn eyelids together tightly with an O or I non-within the cavity and can be contained by firm finger

absorbable suture, laying the sutures close to the eyelid

pressure maintained for four to five minutes. It is not

margins. The lids and surrounding area can now be

necessary to stop haemorrhage completely so as soon

prepared for surgery.

as it has slowed to manageable proportions suture the

Incise the skin of the upper lid in a line parallel to

remaining skin of the eyelids together with horizontal

the lid margins and some 4 mm outside the suture line.

mattress sutures of non-absorbable material. With the

Deepen the incision carefully to expose the subcuta-

suturing completed, squeeze out excess blood from the

neous fascia. Using Metzenbaum or other similar scis-

socket through the incision line and sew a stent bandage *sors blunt dissect under the skin of the eyelid, through*

(Fig. 66.1) firmly in place over the wound so as to exert

the circular muscle of the eye (orbicularis oculi), until

a firm inward pressure. This controls residual haemor-

a probing finger shows that the dissection plane has

rhage and protects the wound.

reached the boney rim of the orbit. Extend the skin inci-

If the conjunctival sacs and globe were removed

sion the length of the upper lid and the dissection plane

intact, healing is likely to be uncomplicated. Remove

to the remainder of the dorsal orbital rim. Repeat the

the 'Stent' at two to three days and the sutures at about

process on the lower eyelid so that the incisions above

10 days. Some authorities recommend instilling antibi-

and below the suture line meet beyond the medial and

otics into the orbital cavity before wound closure, but

lateral canthi in a fusiform shape. Make sure that the

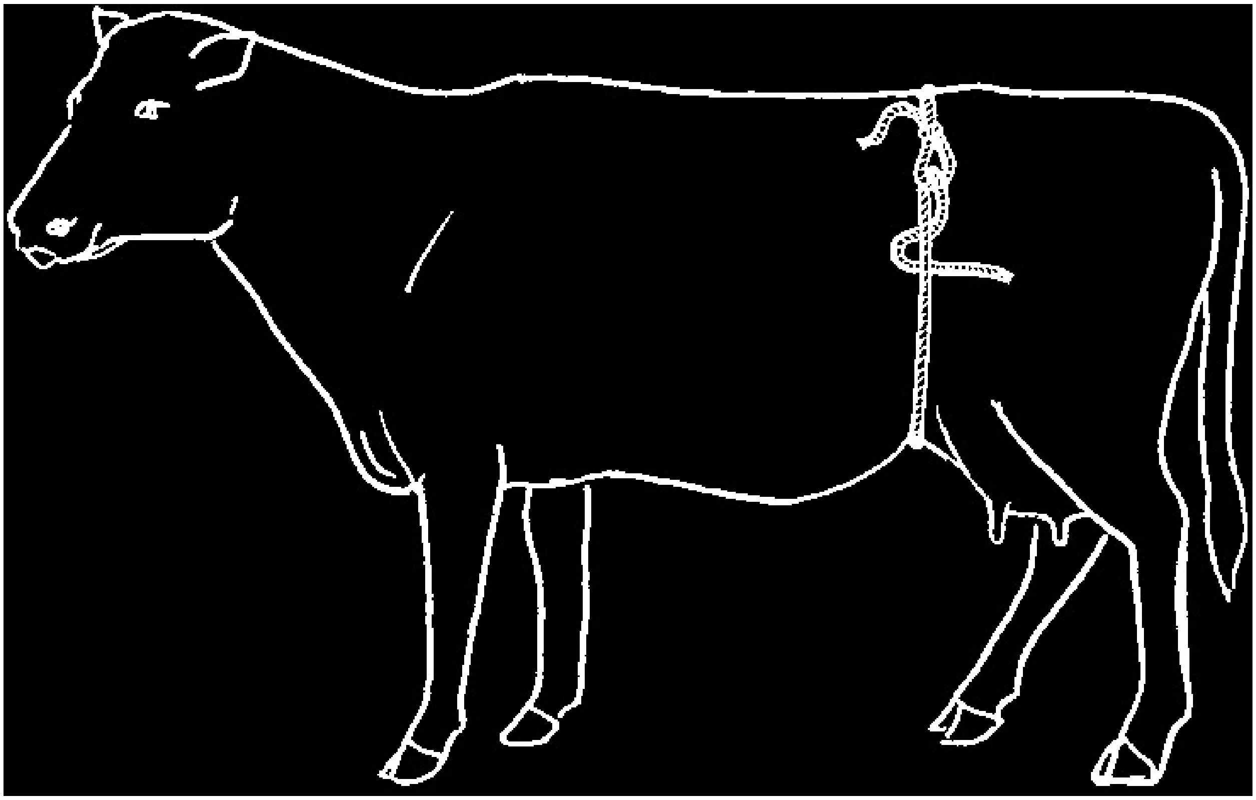
this is probably not indicated unless there is some con-

dissection planes within the lids remain superficial until

tamination and routine prophylactic and post operative

the orbital rim is reached; this will help prevent acci-

antibiotics normally suffice.



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Where there is known contamination of the wound,

In practice the former two requirements are met by

first intention healing may still occur with vigorous

using plastic indwelling cannulae, of which there are

antibiotic therapy, but an alternative method is to pack

many designs. Use them liberally; they are relatively

the cavity with sterile cotton bandage coated with anti-

cheap and work well. However, bear in mind that as

bacterial cream and layered concertina fashion. The *well as being a boon, they can also act as very efficient free end is laid in the medial commisure of the wound introducers of infection if used incorrectly. If they drop which is sutured in the usual way apart from its medial out, they must never be reintroduced, but must be 1–2 cm. The bandage is removed through this gap after replaced by a new one from the packet. Supply them in two to three days and the socket eventually fills with quantity with careful instructions as to their handling granulation tissue. There is a persistent discharge from and the cleansing of the teat before insertion.*

the drainage hole and routine management involves

To protect against infection be scrupulously clean maintaining the patency of the aperture and clearing up when introducing anything into a teat and use intra- the discharge. Irrigation of the cavity does not seem to mammary antibiotic preparations routinely after any materially affect the healing process. When the socket form of teat surgery or while a cannula is in place. Sys- is full the discharge dries up and the medial sinus closes. temic antibiotics too, although not often used, are indi-

This process can take several weeks.

cated in cases of trauma and surgery to aid successful

healing.

***Teat surgery** (see Chapter 27)*

Restraint: It is impossible to be clean and deft when the Milk production is the raison d'être of the modern dairy patient's hind legs are flying around the surgeon's head!

cow. Inefficiency in any of the factors involved leads to

Use restraint and lots of it! For simple examinations,

her becoming unprofitable. The care of teats and the

tail restraint, i.e. forcing the root of the tail vertically, is surgery that is frequently involved therefore deserve

often adequate; it discourages kicking, although it will

more attention than they often receive.

not stop a reaction if there is a sufficiently painful stim-

There are three enemies of successful teat surgery:

ulus. A second level of restraint is a 'nose lead' or

the 3 Ms! Milk, milking machines and mastitis must

'bulldog' clamp; again its effect is of discouragement

always be taken into account by the surgeon.

rather than prevention of reaction. A more effective

A simple way to avoid these problems in the small *method is the 'udder cinch'. This is a length of rope with*

proportion of surgery which is elective is to delay until

a loop in one end which is passed around the cow's

the cow's next dry period. Often this option is not open

abdomen just in front of her udder. The free end is

as the majority of surgical procedures are emergencies.

threaded through the loop and pulled against it to

In these cases the surgeon must take steps to ensure

tighten the cinch around the belly. Pull it tight enough

that milk pressure does not build up within the teat, that

to cause the cow to sway slightly then secure the free

the teat and surgical site do not have to bear the trauma

end by tucking it partially under the taut portion to

of being milked, either by machine or by hand, and that

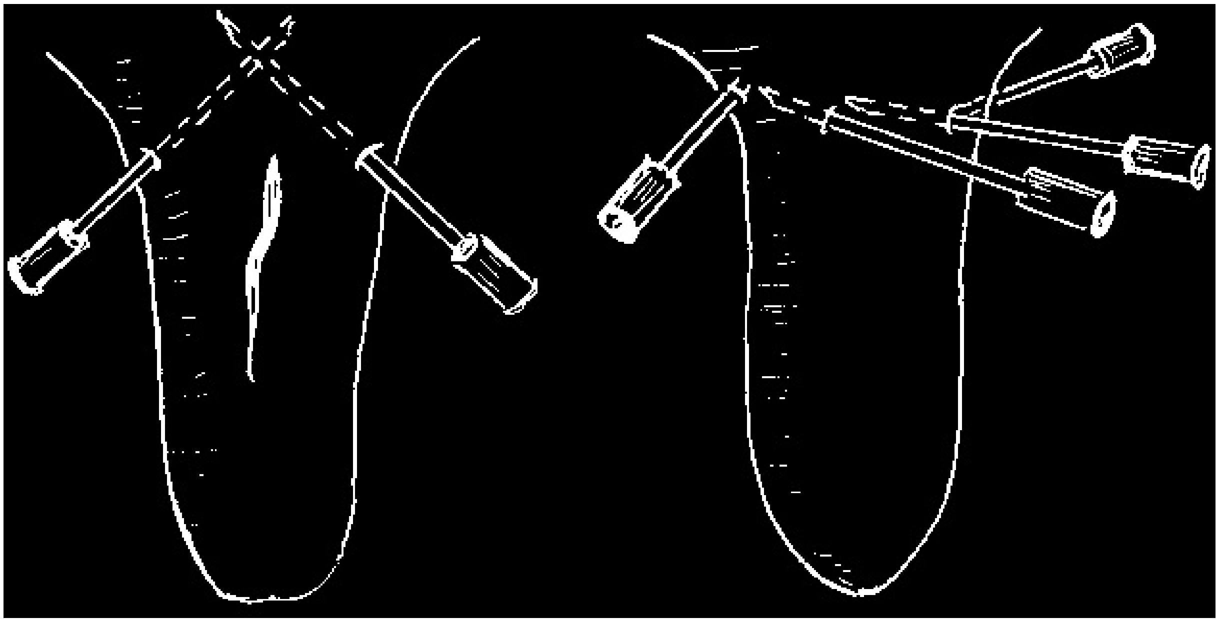
form a quick release (Fig. 66.11); do not pull too tightly

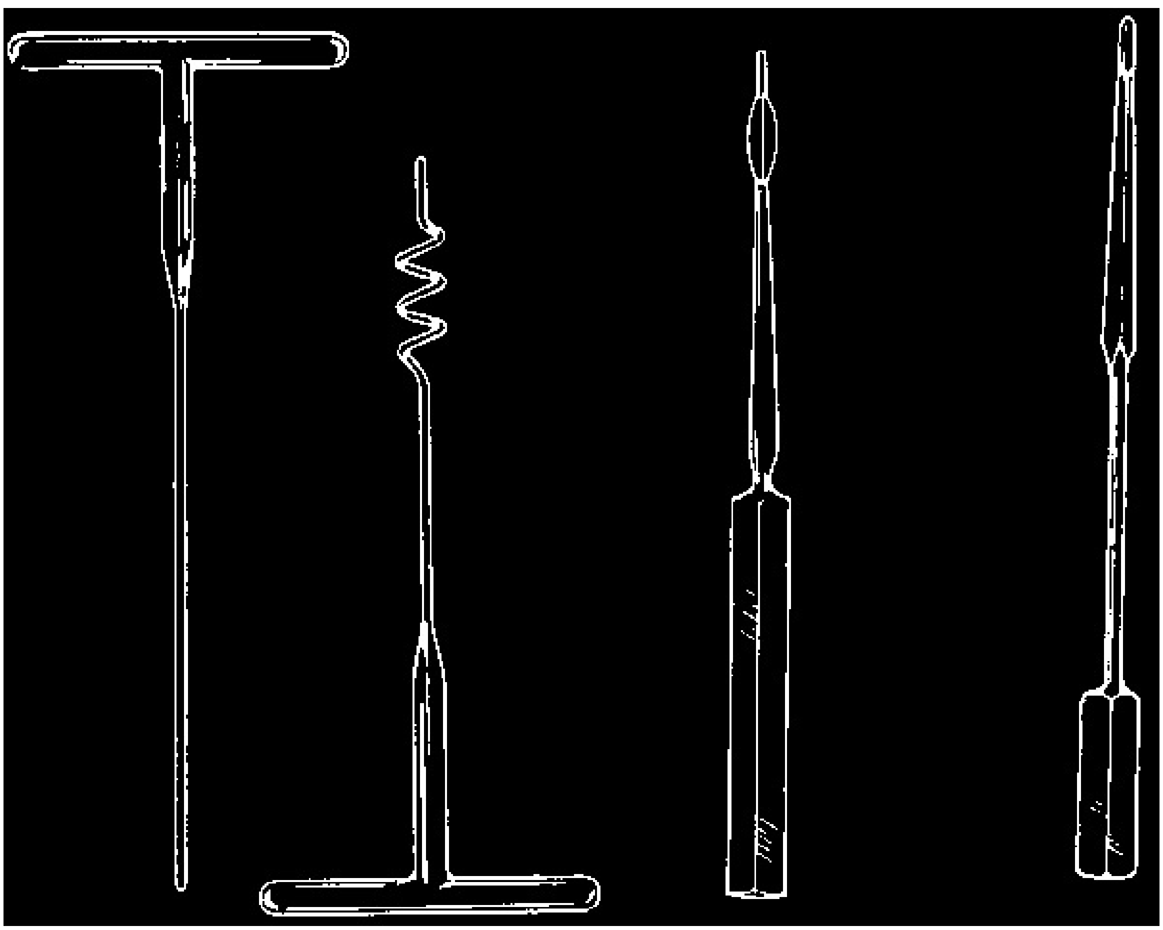
adequate antibiotic cover is given.

or the animal may go down! Used in combination these

Fig. 66.11

An udder cinch.





three techniques of restraint will dissuade the cow from

cerate. Also use the cerate to lubricate the cannula

kicking even in the face of a considerable pain stimu-

before inserting it gently into the canal and spiralling it

lus. Use them routinely as a cow's kick is quite capable

up into the teat. Once in place remove the cap and, after

of causing major injury!

a pause whilst the lubricant with which the cannula is

When there is a need to perform fine surgery, e.g. the

filled dissolves, the milk and some of the antibiotic will

closure of a lacerated wound, the success rate will be

run out.

much better if the cow is first cast, restrained and posi-

tioned to allow good access to the wound, better light-

Streak canal stenosis: This long-term sequel to teat

ing and a more comfortable position for the surgeon.

trauma is caused by fibrosis of the sphincter region. It

results in an increase in time needed to milk the quarter

Local anaesthesia: The usual method is a ring block at and is a nuisance in a parlour system which does not

the base of the teat or an inverted V block (Fig. 66.12).

tolerate delays.

In the former technique, the cow need only feel one

In the first instance, dilatation of the canal can be

needle prick, as the subsequent injections are made

tried, using a plastic teat cannula; this is inserted and

through the area of skin already desensitized. For

left in place for 7 to 10 days. If this is ineffective use a

streak canal and teat sinus surgery, more localized anal-

teat dilater. This device has two arms which, when the

gesia can be obtained by putting a tourniquet around

instrument is in a closed position, form a probe-like

the base of the teat and infusing local anaesthetic solu-

shape. After insertion into the canal a knurled knob is

tion up through the streak canal.

turned at the end of the instrument and the two arms

separate, stretching the lumen of the canal. These two

Crush injuries: In days gone by when cows were

methods are relatively atraumatic and should be used

shippen-housed, crush injuries were commonly caused

if possible; however, their effects are usually temporary.

by one cow swinging round to tread on her lying stall-

A more permanent result is obtained by incising the

partner's teat. Nowadays most cases are in older cows

canal walls with a McLean's knife or similar. This is flat,

who tread on the hind teats of their own pendulous

double-edged (Fig. 66.13) and is used with a push/pull

udders whilst getting up. These self-inflicted injuries

action. The teat is grasped firmly as if for hand milking,

usually consist of gross contusion to the teat walls

tensed and the probe end of the knife inserted into the

with much haemorrhage into the substance of the teat,

canal. A sharp push causes the leading edges to cut

swelling, pain and acute stenosis of the streak canal.

as the blades pass through the canal. Once inside the

If no major laceration has occurred, the treatment is

blades are rotated through 90° and pulled sharply out,

one of systemic antibiotics for several days and inser-

creating a cruciate incision. Use the narrowest blade size

tion of an indwelling cannula to ensure that milk can be

first and if after its single use the milk flow is good, insert released from the quarter and that milking is avoided.

a plastic cannula and allow the healing phase to take

Leave the cannula in place until the swelling and pain

place around it. If the milk still does not run out easily,

have subsided and the streak canal is functioning again;

repeat the procedure with a larger diameter knife.

this can take up to 14 days.

Inserting the cannula into the painful and swollen

teat can be difficult. After gentle cleansing of the teat

and the canal area, locate the latter with a blunt ended

probe. Insert the atraumatic end of a tube of intra-

mammary antibiotic and lubricate the canal with the

Fig. 66.13

Some common teat instruments; from left to right: a

Fig. 66.12

Ring block and field block techniques.

probe, a Hudson's spiral, a McLean's knife and a Hall's knife.

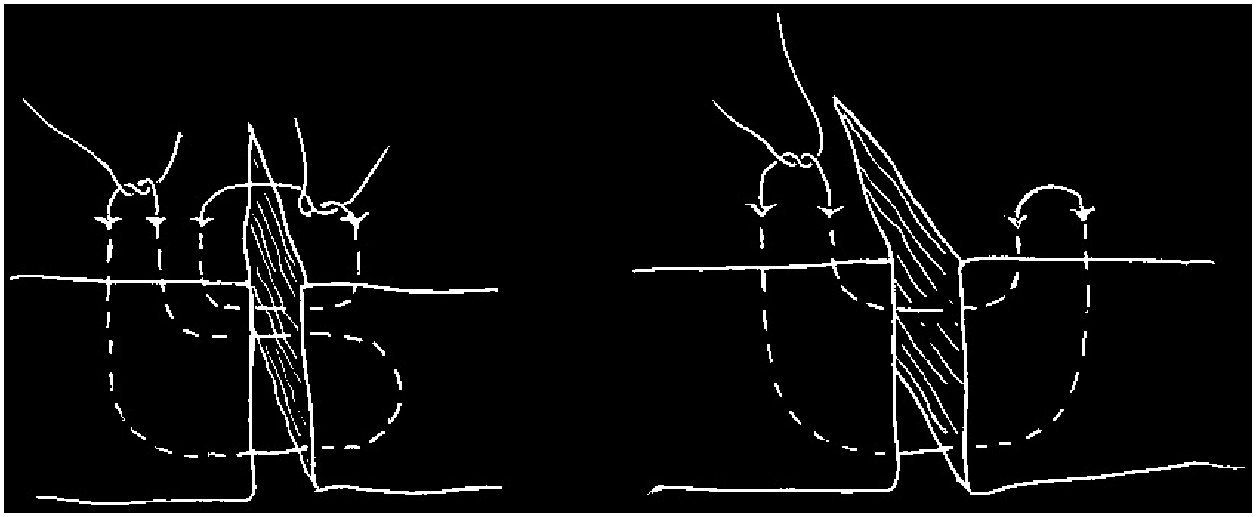


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Fig. 66.14

Two suture patterns which provide

apposition of both the deep and superficial

layers of the teat wall.

Although effective in the short term this is also traumatic

debridement of the wound margin. To achieve this, trim

to the canal and sphincter, and post operative fibrosis

a thin (0.5 mm) sliver of tissue off each wound edge

will usually result in a sphincter of varying competence,

along the whole of its length, extending the wound com-

with contraction of the scar tissue almost always causing

missures slightly at each end. This results in fresh bleed-

a recurrence of the problem at some later date.

ing tissue being apposed and a consequent rise in the chances of primary union.

Lacerations: For the purpose of deciding on the appro-
Use the suture patterns shown (Fig. 66.14) if possible
priate treatment, teat lacerations should be divided
as these compress both the superficial and deep layers, yet
into 'penetrating', i.e. those where the wound pene-
can be removed later. Sometimes the teat wall is excep-
trates into the lumen of the teat or canal, and 'non-
tionally thin and these more complicated patterns are dif-
penetrating', where the deep layer(s) are intact.
ficult to use; in these cases use simple interrupted sutures.
Using fine, non-absorbable material, lay sutures fairly
Non-penetrating wounds: Teats heal extremely well if
close to each other and do not penetrate the teat lumen.
given the opportunity. If it is certain that there is no
On completion, allow the cow to rise then apply a
penetration and no leakage of milk through the wound,
bandage to the teat. Degrease its surface carefully with
then allowing the wound to heal by second intention or
alcohol and allow it to dry. Place a small patch of

granulation is less risky than attempting to suture and

non-adhesive wound dressing over the incision line and,

possibly entrapping ischaemic tissue and infection.

using a 2.5 cm wide adhesive bandage, start at the

There is then the distinct possibility that enclosed sep-

sphincter end and layer it directly on to the teat skin.

sis will erode through the deep layers of the wound

Overlap each winding by about 30 per cent and secure

and create a fistula into the lumen. Only if a non-

the upper, free end of the bandage to the skin with a

penetrating wound is very fresh and exceptionally clean

single superficially placed suture. Insert a cannula into

should suturing be considered. If there is doubt, treat

the streak canal and remove the cap; this will prevent

by physical cleansing of the wound and by inserting a

any build-up of milk pressure within the teat. Give

cannula to remove the trauma of milking. Systemic and

systemic, broad-spectrum antibiotics. The use of

intramammary antibiotics are indicated and usually

intramammary cerates within the first few hours is

healing is rapid with minimal scarring.

questionable as their base is very pervasive and may

penetrate the suture line if they contact it before there

Penetrating wounds: Where the lacerations penetrate

is some adhesion between the wound edges. After the

into the lumen there is not the luxury of deciding

first 12–24 hours they are definitely indicated as a

whether to suture or not. The wound must be closed to

barrier to any infection entering the teat.

prevent the development of a fistula and inevitable

mastitis and, because the surgery involved is delicate

Special cases: Sometimes the teat is lacerated horizonand must be done carefully, there is every reason to cast

tally near its end so that the cut lies close to or enters the the patient and conduct the operation in a controlled

streak canal. To discover whether there has been pene-

and comfortable manner.

tration, hand milk the teat and look for milk emerging

In cases where the cut is recent and is minimally con-

from the cut.

taminated, simple cleansing and suturing may be all that

Where the streak canal has been spared, the decision

is needed. However, most wounds are much older when

to suture or not will be based on the criteria already laid
seen and are often badly contaminated. In these cir-
out. In these cases the laceration rarely extends even
cumstances a much better rate of healing is achieved if
180° around the teat circumference and so it usually
the cleansing of the wound is supplemented by surgical
does not gape too much. With a teat cannula in place

to minimize milking trauma, but otherwise left to their
dental amputation an inch or so remains it is worth-
own devices, teat lacerations usually heal extremely
while attempting some reconstruction. Trim the end of
well, being barely visible in a few months. This makes
the stump so that it lies roughly at right angles to the
the possible repercussions of suturing and the trapping
long axis of the teat, then insert a purse-string suture
of infection much less acceptable.
around its circumferance close to the cut end. Draw
On the other hand, when the streak canal has been
the purse-string tight to compress the sinus opening
cut its early closure is essential. However, before sutur-

snugly around a plastic cannula. Fashion two or three

ing begins, try to make some estimate of whether the

stay sutures to anchor the cannula in place and remove

distal tissue flap has an adequate blood supply for sur-

its cap or plug. With heavy antibiotic cover the teat

vival and healing; there is no point in trying to repair

end will heal around the cannula into a semblance

the defect if it has not! Sometimes it is obvious that the

of a streak canal. There will, of course, be no sphincter

attachment of the flap is too small for a good supply to

and milk leakage and bacterial ingress are major

be present and in these it is best to cut it off immedi-

hazards. However, as a salvage operation it will often

ately in the sure knowledge that it is not viable. With a

allow completion of the lactation and even a subse-

cannula inserted in the remaining streak canal while

quent one.

healing takes place, the resulting slightly truncated teat

is likely to be completely functional, although more

Repair of congenital and acquired teat fistulae: Con-

liable to bacterial ingress and mastitis.

genital fistulae are usually first noticed when a heifer

In other instances it is obvious that a good blood

calves and comes into milk. The most likely explanation

supply exists and repair can proceed; in yet others it is

for their presence is that they are the streak canals of

not so obvious and in these cases it is wise to give the

otherwise vestigial, supernumary teats. Acquired fistu-

tissues the benefit of the doubt.

lae are the result of wounds to the teat and failed repair

Before beginning to suture, debride the cut surfaces

of penetrating lacerations. They are a nuisance in that

carefully, if necessary cutting a thin sliver off both sur-

they leak milk, which causes bacterial multiplication on

faces of the entire wound. Also, and most importantly,

the teat surface and hence milking machine contami-

insert a teat cannula through both parts of the streak

nation. They also allow ingress of infection into the

canal so that they will be aligned during suturing and in

quarter and attract flies. To avoid the complications

subsequent healing. In the post operative period,

associated with open teat surgery, delay if possible until *examine the wound often and remove the sutures from*

the next dry period. Then with a cast, restrained cow

any part that looks as if it may dehisce. In this way pus

and the maximum cleanliness available, excise the

pressure is not allowed to build up and disrupt healing

fistula through all the wall layers by means of a fusiform

further.

incision. This shape causes the minimum of distortion

on closure of the wound. Use the suturing techniques

Transection of the teat: Milking machines need very

described above, apply a bandage post operatively and

little length of teat to hold on to, so if after the acci-

give systemic antibiotic cover for several days.

Adult Cattle

The Interaction of the Animal, Environment

and Management

Chapter 67

Stress and the Pathogenesis

of Disease

P.J. Hartigan

Introduction

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different occasions. Hence, when stress has adverse

The stress system

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effects on health, different patterns of disease may

The stress response

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emerge amongst animals exposed to the same stressors.

Coping with stressors

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Historically, biologists have formulated paradigms of

The biological costs of stress

1138

stress based on the concept of an integrated stress

The transition to pathology

1138

response jointly regulated by the sympathetic–adrenal

Concepts of allostasis and allostatic load

1139

medulla axis (Cannon's fight/flight response to threat)

Allostatic load and the veterinary practitioner

1140

Clinical implications

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and by the hypothalamic–pituitary–adrenal cortex axis

Concluding comments

1146

(the general adaptation syndrome described by Selye).

Glossary

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The two neuroendocrine axes have the capacity to alter

metabolism and to redistribute metabolites to help the

animal maintain homeostasis as it responds to stressors.

Introduction

While these feedback systems are capable of coping

with the many uncomplicated and discrete stressors

It is generally believed – and frequently repeated in the

that animals encounter every day, it has been realized

literature – that 'stress' is the major challenge to the

that the operating characteristics of typical feedback-

welfare, health and productivity of animals in intensive

controlled homeostatic systems are too narrow to *commercial cattle enterprises. However, when it comes account fully for the complexity of the interactive to drawing practical conclusions from the literature it responses that culminate in stress-related pathology. By becomes clear that scientists have been working with definition, homeostatic responses serve to maintain the paradigms of animal stress that have done little to help constancy of the internal environment; each strives to the industry to cope with the biological imperatives that return a regulated parameter to a set point that repre- it must address as it seeks to manage intensive units sents the central tendency of that activity. For instance, with the minimum of animal distress. There is a lack of a fall in serum calcium concentration elicits an imme- unanimity and clarity about which stimuli are so stress- diate increase in the secretion of parathyroid hormone, ful that, on occasion, they can undermine the dynamic which should promptly bring the calcium concentration equilibrium established and maintained by a battery of back to set point, its 'normal value'.*

homeostatic responses. Any stimulus that challenges

Many stress disorders may not be amenable to such homeostasis can be described as a stressor. It is a con- a straightforward resolution. Stressors may create per- dition of life that homeostasis is under constant turbations within several interacting organ systems and challenge by a multitude of stressors. Most of those they may require compensatory responses that elicit encountered by cattle in a well-managed enterprise are changes in the activities of other body systems that are amenable to the routine coping strategies of the governed by other regulatory actions. In those circum- animals; however, there are occasions when particular stances, the regulatory systems must have sufficient stressors seem to overwhelm the homeostatic flexibility to enable them to recalibrate operating set responses, to the detriment of welfare, health and points and to adjust the dynamic ranges of compensa- production. Apparently, the amount of stress an animal tory processes so that the interactions between the perceives depends on the intensity and duration of chal- brain, the autonomic nervous system and the endocrine *lenging stimuli and on the animal's physiological and*

system are geared to defend welfare, health and pro-

psychological state when challenged; as a consequence,

ductivity in the face of ongoing and evolving challenges.

the effects of a particular stressor may differ between

That type of construct is exemplified by the physiolog-

one animal and another or, indeed, the same stressor

ical adaptations of a mother during pregnancy: as ges-

may have different effects on an individual animal on

tation progresses the set points and operating ranges of

a plethora of homeostatic systems continually readjust

the core of the stress system consists of two axes that

in such a manner that the organ systems remain a har-

serve to integrate neural and neuroendocrine activities:

monious team.

in one, a neural pathway links the sympathetic division

In this chapter we provide a synoptic overview of the

of the autonomic nervous system with the adrenal

homeostatic components of the 'integrated stress

medulla (the SA or sympathoadrenal axis); in the other,
response' before proceeding to introduce a relatively
hormones link the hypothalamus with the adrenal
new paradigm of stress that recognizes that stressors
cortex (the HPA or hypothalamic–pituitary–adrenal
may activate multiple interactive mechanisms, that
axis). The stress system is on continuous service: in the
functional set points are subject to change, that distur-
absence of significant challenge it has a baseline, circa-
bances in one body system may elicit compensatory
dian pattern of activity that delivers homeostasis at rest;
changes in another and that compensatory changes
when challenged by perceived stressors it makes the
come at a biological cost which may make the animal
appropriate adaptive changes to maintain physiological
vulnerable to other unrelated stressors – which cost is
equilibrium, delivering what might be described as
a determinant of the clinical consequences of environ-
stress-related homeostasis.
mental stressors. We shall then examine the paradigm
Anatomically, three elements of the nervous system

in relation to aspects of the more common problems

interact to provide the regulatory core of the stress

encountered in intensive cattle enterprises: lameness,

system (Fig. 67.2):

mastitis, infertility, metabolic disorders, welfare, behav-

ioural problems and levels of production.

• Groups of noradrenergic neurones in the brainstem

(the locus coeruleus–noradrenaline system;

LC/NA);

The stress system

• Peptidergic neurones in the hypothalamus, mainly

in the paraventricular nuclei (PVN), that release

For didactic purposes, it is convenient to refer to the

corticotrophin-releasing hormone (CRH) and argi-

neuroendocrine responses evoked by stressors as the

nine vasopressin (AVP);

work of the 'stress system' (Fig. 67.1). As mentioned,

• Central neural projections that enable the LC/NA

neurones and the PVN neurones to innervate and

activate each other.

Mutual interactions between the two axes are not

Stress

restricted to local neurocircuits. They are regulated in

parallel by an extensive battery of humoral messengers:

hormones, opioid peptides, cytokines, growth factors,

metabolites – some stimulatory, some inhibitory and

CNS

HPA

SA

almost all counter-regulated by glucocorticoids

axis

axis

(Chrousos, 2000). For instance, the secretion of ACTH

(which can be stimulated by hypoglycaemia, social

CRH

CRH

PNS

CNS

stress, fear, physical stress, exercise, acute illness or

Sympathetic

Cerebral

inflammatory cytokines) is inhibited by oxytocin, *Pituitary*

Brain

nervous

catecholamine

gland

somatostatin and opiates, and is modulated by negative

system

systems

feedback by glucocorticoids. We shall have occasion to

return to the importance of counter-regulation again,

ACTH

and again.

Noradrenaline

Adrenal

Adrenal

Adrenaline

cortex

medulla

The stress response

Noradrenaline

Glucocorticoids Adrenaline

The principal function of the stress system is to release

Noradrenaline

appropriate amounts of glucocorticoids and cate-

cholamines from the adrenal glands and of noradrena-

Hormonal response

Neural response

line at peripheral nerve terminals, specifically to assist

the animal to cope with the demands of metabolic,

Fig. 67.1

Schematic overview of the stress system. CRH,

corticotrophin-releasing hormone; HPA axis, hypothalamic-

physical, social or psychological stressors. The SA axis

pituitary-adrenal axis; PNS, peripheral nervous system; SA axis, elicits
responses much more rapidly than does the HPA

sympathoadrenal axis; ACTH, adrenocorticotrophic hormone.

axis; that is largely because it releases catecholamines

HPA axis

SA axis

Humoral messengers

Brain

Hypothalamus

Brain stem

Neural projections

PVN

LC/NA

CRH

AVP

Cytokines

Spinal cord

Anterior

Lymphoid

pituitary

tissue

gland

Negative

ACTH

feedback

Adrenal gland

Cortex Medulla

Peripheral

sympathetic

system

Adrenaline

Glucocorticoids

Systemic circulation

Noradrenaline

Fig. 67.2

A schematic representation of cross-talk between the neural, endocrine, and immune systems when challenged by stressors. The cell bodies of the peptidergic neurones that govern the hypothalamic-pituitary-adrenal (HPA) axis are located principally in the paired paraventricular nuclei (PVN) within the hypothalamus. They secrete corticotrophin-releasing hormone (CRH) and arginine vasopressin (AVP; also known as ADH), both of which stimulate the release of adrenocorticotrophic hormone (ACTH) from the anterior pituitary gland. ACTH stimulates the adrenal cortex to release glucocorticoids (principally cortisol). The glucocorticoids exert negative feedback at hypothalamic and pituitary levels of the HPA axis and they counter-regulate the activities of both the sympathoadrenal (SA) neurones in the brain stem (locus coeruleus-noradrenaline: LC/NA) and (but not shown) the central humoral messengers that modulate the stress response. Neurones in the PVN and in LC/NA mutually innervate and activate each other. The SA axis releases noradrenaline within the brain (not shown), adrenaline and noradrenaline from the adrenal medulla and noradrenaline from peripheral sympathetic nerves. The cells of the lymphoid tissues release various cytokines that interact extensively with the neural and endocrine systems (see Fig. 67.6). Solid lines represent activation; dashed lines represent inhibition.

that can achieve their objectives by modifying pre-

Response of the SA axis

existing substrates within their target cells, whereas the

HPA axis releases steroids – hormones that direct the

When activated by stressors, the SA axis releases

synthesis of new proteins that the target cells must

noradrenaline from neurones within the brain and

manufacture before they can proceed to do the busi-

from peripheral sympathetic nerve endings; in addi-

ness. When the stress system is being aroused, the pep-

tion, it releases both adrenaline and noradrenaline

tidergic neurones at the PVN and the noradrenergic

from the adrenal medulla. The noradrenaline released

neurones of the LC/NA activate each other and both

centrally results in greater mental acuity ('arousal'),

contribute to the adaptive behavioural and physiologi-

whilst the catecholamines released peripherally

cal changes that ensue.

promote changes in metabolism and in the activities of

Noradrenaline

Box 67.1

Metabolic responses to stress.

• Initially, insulin secretion is suppressed

CRH

LC

decreased uptake of glucose by cells: hyperglycaemia

CRH

breakdown of stored triglycerides: increased fatty acids

in blood

Spinal

cord

• *Raised concentration of plasma catecholamines*

breakdown of stored glycogen:

in liver Æ increased blood glucose

in skeletal muscle Æ increased blood lactate

breakdown of stored triglycerides Æ increased fatty

acids in blood

Pituitary

increased secretion of glucagon

gland

Adrenaline/noradrenaline

decreased secretion of insulin

increased gluconeogenesis (from glycerol, lactate,

amino acids)

• *Increased secretion of glucagon*

ACTH

breakdown of stored glycogen

Glucocorticoids

breakdown of stored triglycerides

increased gluconeogenesis

• Rapid rise in secretion of glucocorticoids

breakdown of skeletal muscle

Adrenal

breakdown of stored triglycerides

glands

inhibition of uptake of glucose by tissues (other than

brain)

Fig. 67.3

Schematic diagram of the functional inter-relations

increased gluconeogenesis

between corticotrophin-releasing hormone (CRH) and the locus

• Increased release of arginine vasopressin (AVP, ADH)

coeruleus–noradrenaline (LC/NA) system. ACTH, adrenocorti-

retention of water

cotrophic hormone. Adapted from E.O. Johnson et al. (1992).

• Increased release of renin

Solid lines represent stimulatory effects; dashed lines represent activation of angiotensin–aldosterone system

inhibitory effects.

retention of water and sodium ions,

loss of potassium ions

the cardiovascular and respiratory systems to increase

cardiac output, to facilitate oxygenation of blood, to

raise blood glucose concentration and to deliver the

enriched blood selectively to the tissues upon which the

The secretion of adrenaline is the more rapid response

stressors are making the greatest demands.

that underpins the flight/fight reaction, whereas the glu-

cocorticoids give a slower response that helps to real-

locate resources to meet the challenges to homeostasis

Response of the HPA axis

and, equally important, to curtail the potentially

The paraventricular nuclei secrete CRH and AVP in

harmful effects on health and welfare that could be

response to stressors. In cattle, the two peptides appear

exercised by exaggerated or unregulated autonomic

to be equipotent in stimulating the pituitary gland to *responses. The importance of counter-regulation of the*

secrete adrenocorticotrophic hormone (ACTH) which,

autonomic component of the stress response is brought

in turn, stimulates the adrenal cortex to secrete gluco-

into sharp focus by the conviction of our medical col-

corticoids. As the final effectors of the HPA axis, glu-

leagues that the risk of myocardial infarction is signifi-

cocorticoids (chiefly, cortisol) participate in a multitude

cantly increased in individuals in whom sustained high

of activities that maintain whole-body homeostasis,

catecholamine levels cause hypertension by sustained

including feedback regulation of both axes of the stress

contraction of arterial smooth muscle and at the same

system (Fig. 67.3) and the metabolic readjustments

time induce metabolic changes (insulin resistance,

(Box 67.1) required to sustain the physiological adap-

hypercholesterolaemia, hyperlipidaemia) that predis-

tations invoked to cope with stressors.

pose to arterial damage and the formation of athero-

matous plaques in the coronary arteries.

Counter-regulation of the SA response is a key

Counter-regulation

element in an animal's ability to cope with environ-

The stress response can increase the concentrations of

mental stressors without incurring a residual physio-

adrenaline and/or glucocorticoids in the circulation.

logical toll of inordinate proportions.

Coping with stressors

tract. Another consequence of general activation of the

sympathetic system is the release of renin, leading to

Animals may employ active coping strategies to reduce

activation of the angiotensin–aldosterone system, and

the aversive effects of stressors or they may use passive

consequent conservation of sodium and water, accom-

coping strategies to minimize the biological cost of the

panied by excretion of potassium ions.

stress response evoked by the stressors. Moberg (2000)

identified four general types of biological responses

Neuroendocrine responses

available to an animal to cope with stress: behavioural,

autonomic, neuroendocrine and immunological (Fig.

Within minutes of the LC/NA response, the HPA axis

67.4). Although all four biological defence systems are

is called to arms but, because steroids take longer than

available to respond to a stressor, an animal does not

amines to elicit responses, there is a time lag before the

always call on each of them to deal with each stressor:

glucocorticoids begin to exercise dominant control –

different stressors elicit very different types of biologi-

with adrenaline, growth hormone and thyroid hor-

cal responses. Nevertheless, in the vast majority of

mones in supporting roles. The combined activities of

instances the response will contain some element of all

these hormones result in metabolic adjustments (Box

four.

1) while the animal continues to resist the stressor(s) or

until its reserves of energy have been exhausted. The

first priority is to maintain blood glucose concentration

Behavioural responses

and to conserve the glucose for utilization by the neural

Behaviour offers the animal choices: to confront the

system. The liver can liberate glucose from stored *stressor aggressively, to remove itself from the stressor glycogen. Skeletal muscles do not possess the full com- or to engage in displacement activity that ameliorates plement of enzymes necessary to do this; there the impact of the stressor. In many instances a behav- glycogenolysis yields lactate, which the liver can use to ioural response is the simplest and most biologically produce new glucose (gluconeogenesis). Metabolic economic reaction to a stressor; for instance, simply processes are altered so that peripheral tissues use walking away. However, some displacement activities lipids rather than glucose as the prime source of energy; (e.g. stereotypies such as compulsive walking) may glucocorticoids and growth hormone (GH) act in expend an enormous amount of energy to no produc- consort to facilitate that switch by inducing the break- tive purpose.*

down of triglycerides stored in adipose tissues to yield the required fatty acids plus glycerol. These glucose- sparing actions are augmented by the synthesis of new

Autonomic (LC/NA) responses

glucose from endogenous substrates: the glycerol

When the situation is not immediately resolved by a

released from adipose tissues is made available for the

behavioural response, the reaction is directed by a gen-

synthesis of glucose in the liver (gluconeogenesis), as is

eralized activation of the sympathetic nervous system

the lactate released from muscle glycogen. Concur-

including the release of adrenaline from the adrenal

rently, the same hormones induce proteolysis in skele-

medulla. The preparation for 'fight or flight' is manifest

tal muscle, releasing amino acids that the liver also uses

by a heightened state of arousal, by increases in blood

to manufacture glucose. The process of gluconeogene-

pressure, heart rate, respiratory rate, blood flow to

sis is regulated by glucocorticoids (HPA axis), by

skeletal muscles and consumption of energy and by

glucagon and by adrenaline from the adrenal medulla

decreased blood flow to skin, kidneys and digestive

(SA axis).

Behavioural

response

Autonomic

response

(SA axis)

Stressor

Host perception

Arousal

Allostatic load

Neuroendocrine

response

(HPA axis)

Fig. 67.4

Coping with stressors. SA axis,

sympathoadrenal axis; HPA axis, hypothal-

Immune

response

amic–pituitary–adrenal axis.

Immunological responses

ish the body's metabolic reserves and how does this

impact on health and welfare?

The two axes of the stress system are at all times

In the first instance, the biological cost of stress is met
engaged in bidirectional communication between
from the body’s reserves of energy. For many short-
the central nervous system and the immune system. The
lived stressors that cost is negligible: it is met from
cross-talk is intensified during the stress response. The
reserves without any impact on other biological func-
brain issues messages through the SA and HPA axes
tions. As an example, catecholamines secreted during
that affect the activities of the cells of the immune
stress stimulate the conversion of stored glycogen into
system, while products elaborated by various immuno-
glucose; once the stress has been alleviated, the glyco-
cytes affect the functions of the neurones at the centre
gen stores are quickly replenished by gluconeogenesis;
of both axes. In brief, the corticosteroids and the cate-
there is no lasting deficit. On the other hand, when
cholamines down-regulate the activities of the immune
there are insufficient biological reserves to meet the
system: they inhibit many of the functions of leucocytes,
costs, resources must be diverted from other biological

macrophages and lymphocytes, and they decrease the functions: for example, if a young heifer reared under production of many cytokines and mediators of inflam- very stressful conditions has to divert a significant frac- mation. Also, it is believed that the endogenous opiates tion of the energy normally expended on growth and released in response to stress are, in general, immuno- reproduction it is likely that her growth will be retarded suppressive. Early in the response to stress there is and puberty will be delayed. In other words, for some increased release of growth hormone and prolactin, persistent or intense stressors the cost is high, a signifi- both of which enhance the immune response; however, cant burden on the body that places the animal ‘at risk the circulating levels of both hormones are decreased of developing pathologies’ (Moberg, 2000). The gap later in the stress response and, also, when there is between those two extremes is filled by examples in recurrent or chronic stress. Thus, the net effect of stress which the hidden costs of coping strategies so deplete is immunosuppression and increased susceptibility to *biological reserves that the animals develop 'patholo-*

some infectious diseases, particularly those that target

gies' when challenged by what might otherwise be

the respiratory system or the digestive system. There is

considered to be rather minor, inconsequential factors.

convincing circumstantial evidence that some bacterial,

Such are the cases that raise the questions that need to

viral and parasitic pathogens themselves act as stressors

be addressed by the clinician in the field: how does

that attenuate the immune response.

stress influence the pathogenesis of disease and what

accounts for the variation in susceptibility to stress-

Physiological toll

related diseases amongst animals in the same, or

similar, environmental circumstances?

If stress is intense and prolonged, the coping strategies

may become part of the problem. Rapid production of

glucocorticoids in response to a stressor is beneficial,

The transition to pathology

provided an efficient shut-off can occur; chronic eleva-

tion of glucocorticoids persisting after the stressor has

There are several routes by which coping strategies can

gone indicates poor adjustment and is detrimental to

progress into pathology.

health. Prolonged elevation of glucocorticoids in the

circulation can cause excessive breakdown of muscle

• *If stress is intense and long-lived, the coping strate-*

protein, depletion of energy reserves, hyperglycaemia,

gies may become part of the problem. The poten-

immune suppression, attenuation of the inflammatory

tial pathological consequences of prolonged

reaction, increased susceptibility to infection and

elevation of glucocorticoid concentrations have

delayed healing of wounds. The principal mechanism by

been mentioned above. Persistent activation of the

which the body is protected from these deleterious

SA axis, which stimulates the renin–angiotensin–

effects is feedback inhibition of the HPA axis by the

aldosterone system, may also translate into pathol-

corticosteroids themselves.

ogy: initially, by progressively increasing blood

volume and raising blood pressure; later, as a consequence of the alterations in neuromuscular

The biological costs of stress

excitability due to hypokalaemia.

• Obviously, whenever coping strategies have

All stressors, no matter how innocuous, have some

exhausted the biological reserves of the animal it is

biological costs. There is a price to pay, even when the

to be expected that further challenge(s), even by

homeostatic balance is restored promptly. The real

inconsequential stressors,

may translate into

questions are: to what extent does the challenge dimin-

pathology.

• A coping strategy may increase the animal's expo-

parameter(s) can be returned to the fixed set point(s).

sure to environmental factors that damage its health

A simple example: if, for whatever reason, blood

(e.g. the housed subordinate cow that copes with

glucose concentration falls, the neuroendocrine axes

dominant cows by standing and lying at a distance in *will set about correcting the deficit by typical homeo-*

damp, dirty, unsheltered locations) or it may deny

static responses that implement glucose-sparing meas-

the animal the opportunity to participate in activi-

ures augmented by gluconeogenesis.

ties that promote its health and welfare (e.g. limit its

It is entirely appropriate that those components of

access to feed or, in the extreme, an animal exposed

the internal milieu that are absolutely essential for life

to chronic, unavoidable stress may develop 'learned

(for instance, oxygen tension, pH, body temperature)

helplessness', become recumbent and stop eating).

should be governed according to strict homeostatic

• *A coping strategy may involve a physiological*

principles that operate within narrow ranges about

response that directly contributes to a pathological

fixed set points. However, life expects the body to be

process (e.g. a very thirsty, salt-deprived animal

capable of adapting to marked variations in its natural

consumes excess water and develops haemolysis

environment and that is possible only if the animal can *and cerebral oedema: water intoxication).*

continuously readjust a number of parameters toward

• A coping response may attenuate or suppress an

new set points and wider operating ranges that are

important component of the animal's normal

appropriate to the challenging circumstances in which

defence system and leave it vulnerable to a disease

it finds itself. Put very simply, different circumstances

unrelated to the original stressor (e.g. attenuation

demand that the several interacting systems vary their

of the immune response by transportation stress

homeostatic set points to ensure that their activities

renders an animal susceptible to respiratory

remain in synchromesh. Allostasis enables the SA axis,

disease).

the HPA axis and the cardiovascular, metabolic and

immune systems to effect the changes in the internal

In each scenario the transition to pathology is pred-

milieu that make the most beneficial use of the animal's

icated on a changed (or changing) internal milieu that

biological resources; in brief, they induce a new steady *cannot be explained in terms of strict homeostatic*

state based on a panel of readjusted set points in

dogma. The principle of homeostasis is that the body

counter-balancing systems.

must hold all its regulated parameters within very

Allostasis is a useful concept but, as McEwen and

narrow operating ranges centred on the relevant

Stellar (1993) pointed out, it does not take into consid-

'normal' set points. Students of stress are well aware

eration the strain on the body produced by the activi-

that that is not how things are in the real world. It is

ties of physiological systems adjusting to repeated

recognized that an animal exposed to intense or per-

challenges, the consequent changes in metabolism or

sistent stressors may have to vary many parameters of

the impact of wear and tear on a number of organs and

its internal milieu and match them appropriately to

tissues that can predispose an individual to disease.

environmental demands. Sterling and Eyer (1988)

They introduced the term allostatic load to describe the

referred to this principle as allostasis, meaning 'stability *aggregate biological costs that result from chronic over-*

through change'.

activity or underactivity of allostatic systems.

As McEwen (1998) perceived it, there are three

phases in the body's response to challenge: it must

Concepts of allostasis and

mount an adequate allostatic response, it must maintain

allostatic load

that response until the stress ceases and it must shut off

the response when the threat has passed. Thus, allosta-

When an animal perceives a situation as stressful it

tic load can accrue when:

makes the behavioural and physiological responses that

it considers most appropriate. Experience will help the

• There is an inadequate response that leads to

compensatory hyperactivity of other regulatory

animal assess how much of a threat is posed and what

systems;

it requires to do to ward off that threat. If a particular

stressor has been encountered previously and been

• The body is subjected to repeated challenges from

multiple stressors;

found to be easily controlled, the response will be meas-

ured accordingly; habituation will ameliorate the

• There is failure of habituation to repeated chal-

lenges of the same type;

physiological perturbation and the biological cost will

be reduced. The responses are mediated by the SA and

• Delayed shut-down prolongs the response after the

threat has passed.

HPA axes and, if the stressor is mild and short-lived,

homeostatic regulation will modulate the perturbations

When circumstances improve, with enviromental

within tolerable operating ranges until the regulated

stress consistently at a low level, the animal may

discharge much of the allostatic load, to the benefit of

parameters persistently outside their normal operating

its health and production.

ranges – whether because of many significant chal-

On the other hand, if life remains stressful the load

lenges or because the allostatic responses remain

will accumulate and the animal will find it progressively
turned on when no longer required – the body incurs
more difficult to make effective readjustments in
a cumulative biological burden that constitutes its
response to further challenges: in a figure of speech, a
allostatic load.
point may be reached at which all the slack in biologi-
The biological costs of each challenge to homeosta-
cal reserves has been taken up and the next coping
sis are influenced by the genetic background of the
strategy will propel the animal into overt dysfunction.
animal, its previous history, the magnitude of the allo-
In many instances, the final challenge that breaches the
static load it has accumulated already and the func-
boundary between the compensated state and ‘pathol-
tional priorities of the current phase of its life cycle, as
ogy’ may be relatively minor and, if it is identified, it
well by the nature of the stressor, its novelty, its inten-
may be assigned an exaggerated degree of causal
sity, its frequency, its duration and the types of
importance that is an impediment to the exploration of

responses it elicits.

the real sources of allostatic load within the herd, which

Thus, when clinical disease is manifest the cascade of

must be the ultimate target for the dedicated clinician.

environmental factors that have contributed to the

More immediately, failure to see the ‘big picture’ may

current state of the sick animal will have operated at

militate against the efficacy of treatment of the diag-

two levels: the proximate and the ultimate. The proxi-

nosed ailment – it is unlikely that targeting what, in

mate factors (infectious, metabolic, toxic or whatever)

essence, may be just the tip of a dyshomeostatic iceberg

have made the immediate challenges that caused the

will successfully restore the animal to full health and

presenting signs. The ultimate factors have been

production. Recognition of the bases from which the

responsible for the allostatic load, for the depletion of

allostatic load has accrued should enable the clinician

energy reserves and the cumulative wear and tear of

to implement a more holistic, more successful, approach

vital organs and their regulatory controls that have *to the problem.*

predisposed the animal to the ravages of the proximate

In summary, the concept of allostatic load provides a

stressors. In brief, allostatic load is the burden of costs

rational hypothesis to account for the contribution of

that have been paid at several toll-bridges on the road

environmental stress to the pathogenesis of dyshome-

to clinical disease. Increasingly, trends in intensive

ostasis, a sometimes precarious state of readjusted

systems of animal production will force us to bring that

parameters that, when propelled into decompensation,

toll into sharper focus in our deliberations on the patho-

can be manifest as any of a range of different ailments

genesis and treatment of ailments and on the husbandry

in individual animals within a herd.

and welfare of farm animals.

The stress response can be mobilized in response to

physical or physiological stimuli, and also in expecta-

Allostatic load and the

tion of them. As is evident from the early part of this

veterinary practitioner

chapter, the brain is the coordinator of the body's

responses to the stimuli: it decides whether or not a

How should the concept of allostatic load inform the

potential stressor poses a threat, and how the animal

veterinary practitioner in the field? How does it relate

should cope with it. The cognitive appraisal of the envi-

to the major problems encountered in intensive cattle

ronmental stimulus determines the response: if it is not

enterprises: lameness, mastitis, infertility, metabolic dis-

perceived as a threat, it does not elicit a stress response.

orders, welfare, behavioural problems and levels of

On the other hand, novel stimuli will be perceived as

production?

threats ipso facto, even though they may not be par-

ticularly aversive in character; the intensity of the

responses will decline as the novelty wears off. It is

'Life is stress, stress is life'

neither possible nor desirable to isolate livestock from

Life is a minefield of potential stressors that each crea-

the aversive stimuli that are a feature of the complex,

ture has to negotiate by recourse to its repertoire of *dynamic environment of the modern intensive cattle*

cognitive, behavioural, neural, endocrine and immuno-

enterprise. Some types of mild stimuli are beneficial; for

logical modalities. The ability to adapt successfully to

instance, they induce a state of arousal in which meta-

the multifarious challenges of life – or, in the words of

bolic processes are adjusted for rapid expenditure of

Sterling and Eyer (1988), the ability of the 'organism to

energy and they 'tune' the cognitive and motor mecha-

vary parameters of its internal milieu and match them

nisms that the animal will call upon whenever it is chal-

appropriately to environmental demands' – is called

lenged by a significant stressor. Furthermore, there is

allostasis. When the adaptive responses put those

convincing experimental evidence that when the stress

system is activated in that manner, productivity is

Partitioning of metabolic fuel

improved and some immune functions are enhanced, at

Each organism has a limited energy budget from which

least in the short term.

it must allocate resources prudently if it is to maintain

the body and perpetuate the species. When the supply

Practical considerations

of energy falls below total requirement, the available

metabolic fuels are partitioned according to priorities

The scientific literature, particularly the medical litera-

set to ensure the survival of the organism (Fig. 67.5).

ture, has concentrated unduly on the negative aspects

The energy equation can go into negative balance

of stress, on its role in the pathogenesis of disease; in

either because the intake has been reduced below

reality, the stress system has evolved as an essential

normal expenditure, or because the expenditure has

defence mechanism that plays a very positive role in the

been increased to meet special needs, as happens in

survival of organisms beset by stressors. The task is to

early lactation or when the animal has to cope with

manage the sources of environmental stimuli to the

major stressors. In the trade-off between competing

mutual benefit of the animal and of the commercial

energetic requirements, environmental stressors can

imperative; that requires attention to the structure
exercise a defining role. Top priority is given to main-
and hygiene of the physical facilities, and to the social
tenance of basic cellular functions, thermoregulation
contexts, metabolism, physiology, vulnerabilities and
and locomotion for foraging (not a problem in a
coping strategies of the animals. Several of those topics
modern cattle enterprise). When the short-fall is severe,
are dealt with in some detail elsewhere in this book;
less and less of the intake goes to growth, fat storage or
here, under several subheadings, we cherry pick some
reproduction; in extreme circumstances these activities
clinical conditions that illuminate the central thesis: that
will be suspended until they can be resumed when the
allostatic load is a significant factor in the pathogenesis
energy balance has been restored.
of many ailments, that sick animals should be seen as
sentinels of stress within the herd and that the thera-
Counter-regulation by glucocorticoids
peutic, prophylactic and managerial measures are
unlikely to be entirely satisfactory unless that fact is

As mentioned, negative feedback by glucocorticoids

taken into consideration. Although the vast literature

plays a significant role in protecting the organism

on the stress response has yet to generate a unitary par-

against 'overshoot' by either limb of the stress system

adigm that would inform the clinical judgement of a

(Fig. 67.3). In addition, they contribute to the effort to

veterinary surgeon in relation to those decisions, there

conserve energy whenever stressors threaten home-

are two less ambitious constructs, mentioned above,

ostasis: they exert inhibitory effects at more than one

that are relevant to the message of this essay: the par-

point in each of the endocrine axes that regulate

titioning of metabolic fuels and the counter-regulatory

growth, thyroid function, reproduction and immune

activity of the corticosteroids.

function (Fig. 67.6).

Procurement

Metabolism

and ingestion

and partitioning

Expenditure

Liver

Reproduction

Thermoregulation

Oxidizable

FOOD

metabolic

Cellular maintenance

Fig. 67.5

Partitioning of metabolic fuels. When

fuels

the supply of energy is insufficient to meet

demands, non-essential processes such as repro-

Locomotion

duction and growth are deferred, and fat stores are

mobilized to ensure that the essential processes

Growth

of basic cellular metabolism, thermoregulation and

Adipose tissue

locomotion are maintained. (After G.N. Wade &

fat stores

J.E. Schneider, 1992).

(a) Reproduction

(b) Growth and thyroid function

(c) Immune function

b-endorphin

GHRH

CRH

TRH

CRH

GnRH

CRH

STS

STS

GH

ACTH

TSH

Cytokines

ACTH

(IL-1, IL-6, TNF)

LH, FSH

ACTH

Cortisol

T4

Mediators of

inflammation

Glucocorticoids

SmC

T3

(eicosanoids,

Oestradiol

PAF, serotonin)

Cortisol

Testosterone

Target tissues

Target tissues

Target tissues

Target tissues

ACTH: Adrenocorticotrophic hormone

SmC: Somatomedin C

CRH: Corticotrophin-releasing hormone

STS: somatostatin

FSH: Follicle-stimulating hormone

T3 and T4: thyroid hormones

GH: Growth hormone

TNF: Tumour necrosis factor

GHRH: Growth hormone-releasing hormone

TRH: Thyrotrophin-releasing hormone

IL-1: Interleukin-1

TSH: Thyroid-stimulating hormone

IL-6: Interleukin-6

Fig. 67.6

Interactions of the HPA axis with the systems that subserve (a) reproduction, (b) growth and metabolism, and (c) immune function. Solid lines represent direct or indirect activation; dashed lines represent direct or indirect inhibition. (After Stratakis & Chrousos, 1997.) ***Clinical implications***

Social stress may be a source of significant allosta-

tic load.

Social context (see Chapter 55)

Foot lameness (see Chapter 31)

Each herd of cattle develops its own social structure, a

hierarchy in which social rank is held at a price. Social

It is accepted that poor quality horn is a significant

interactions within the group can be stressful: deter-

factor in the pathogenesis of foot lameness in lactating mined subdominant animals challenge the dominant dairy cows. The defect in the horn is associated with animals; in turn, dominant animals bully subordinate impaired keratinization in the epidermis of the horn, a animals. Several lines of evidence suggest that the mag- process that is known to be influenced by the dominant nitude of the allostatic responses to social stressors is hormones in late pregnancy and early lactation. Particu- influenced greatly by the social rank of the animal: the larly relevant to the present discussion is the evidence biological costs are greatest at the two extremes of the from hoof explants in organ culture that glucocorticoids hierarchy. The allostatic load – and the loss in produc- inhibit the synthesis of hoof protein. It has been sug- tivity – depends on the animal's perception of the threat gested that the elevated systemic concentrations of to its well-being and on its coping strategy. The active glucocorticoids during lactation could contribute to the coping strategy of the dominant animal can be as costly deterioration in horn quality in the lactating cow. It is

as the passive coping style of the subordinate animal.
conceivable that other stressors that induce the release
When an animal is exposed repeatedly to the same
of more glucocorticoids would exacerbate that deterio-
predictable stressors, the intensity of the stress reaction
ration. For instance, poor quality horn that predisposes
tends to decline progressively. This process of habitua-
to foot lameness is not uncommon in recently-calved
tion appears to be stressor-specific; the animal retains
heifers joining the milking herd for the first time; in
the capacity to make an acute response to a novel stres-
those circumstances, horn is being produced by an
sor. Therefore, within a settled herd the toll of social
immature animal whose endocrine organs are secreting
stress can be attenuated by good stockmanship that
unprecedented quantities of lactogenic hormones aug-
seeks to shield the animals from all that they will per-
mented by the hormones released in response to the
ceive as novel, frightening, painful, unpredictable,
social stress – and whose metabolic stability is being
frustrating or uncontrollable.

challenged by the unaccustomed demands of her first

lactation. Thus, the presenting ailment may be a mani-

reproduction is suppressed while the animals are in

festation of a 'big picture' that incorporates a number

negative energy balance: that the hypothalamic–

of elements of systemic dyshomeostasis – abrupt expo-

pituitary–gonadal (HPG) axis is inhibited while the cow

sure to a novel hormonal milieu, unrelenting demand

'milks off her back'. Most high-producing dairy cows

for an unprecedented quantity of energy, and social

enter the breeding season in a negative energy balance;

stress.

some will not have achieved a positive balance before

Allostatic load may find expression in a presenting

the end of the third month after calving, at which time

ailment that has no obvious anatomical link to the

they are expected to be in-calf again. From an energetic

systemic dyshomeostasis that has made the host

perspective, this means that the biological costs of reac-

animal vulnerable to 'pathologies'.

tivating cyclic activity of the HPG axis and its associ-
ated organs have to be abstracted from a budget that is
in negative balance because it has to support, either in
Infertility (see Chapters 33–37)
sequence or in parallel, the extensive hormonal changes
Reproductive functions in the female are more suscep-
(qualitative, quantitative and temporal) that accom-
tible to the effects of stress than are those of the male,
pany the transition from pregnancy to lactation; the bio-
for two reasons: firstly, because she has to budget for a
logical costs of uterine involution; the extraordinary
vastly greater investment of metabolic resources over a
nutrient demands of lactation and the regulation of the
much longer time; secondly, because stressors are prone
associated metabolic adaptations; the extensive adapta-
to disrupt the precision with which a number of hor-
tions in cardiovascular and digestive physiology; the
mones must be secreted in appropriate quantities and
biological costs of immune defence of organs newly
in a delicately ordered and exquisitely timed sequence
opened to ascending infection (uterus, mammary

in order to establish a pregnancy. It is known that short-

gland); the transition from housing to pasture and the

term stressors (such as fear engendered during herding,

associated meteorological and nutritional changes;

handling or transport, electric prods or stray voltage)

together with any number of contingency costs. Despite

can interfere with fertility if they challenge the cow at

all that massive drain on body reserves, approximately

a critical juncture. To a considerable degree, the

half of the mated cows conceive to first service. It is

response of the female to stressors is predicated by a

clear that although the energetic perspective provides

desire to conserve energy until the threat is past; clearly,

a rational account of the drain on body resources, it

that is the case when she falls into a negative energy

does not provide a comprehensive explanation for

balance and suspends her reproductive activities pro

either the infertility of a sizeable number of clinically

tem. Fortunately, the suspension leaves the regulatory normal cows or for the relatively poor response to

neuroendocrine apparatus intact and normal business *hormone therapy in those animals.*

should be resumed when the energy balance has been

It is likely that much of the infertility reported in

restored. In reality, spontaneous resumption often takes

clinically normal cows is due to unrecognized allostatic

longer than is ideal for the commercial enterprise; this

load; in other words, it is not a disease in the traditional

is particularly significant in relation to the low calving

sense, rather a suspension of service due to a fault in

rates achieved in the early post partum period – which

the signalling system. Therefore, the protocol for clini-

can be a cause of considerable economic loss, especially

cal assessment of cows being prepared for the breeding

in a herd where a seasonal breeding programme is in

season should include a check-list of potential stressors

operation.

to which the animals due for examination are most

Over the past 20 years, the dairy industry in the UK

likely to have been exposed; the prophylactic manage-

has switched from a predominantly British Friesian cow

ment of the breeding herd should take account of the *population to predominantly North American Holstein*

findings.

cows and, further, it has engaged in intense selection for

The effects of stress on reproductive functions are

milk yield. The records show that over that period the

complex; however, it is reasonably close to the truth to

pregnancy rate to first service has declined at an

say that most of the adverse effects are mediated by

average rate of approximately 1 per cent per annum,

interactions between the HPA axis and the HPG axis

and that atypical ovarian hormone patterns have been

(Fig. 67.6(a)). Corticotrophin-releasing hormore (CRH)

contributing factors to that reduction (Royal et al. , can suppress the secretion of gonadotrophin-releasing

2000). The response to hormonal therapy has not been

hormone (GnRH) via an opioid-mediated mecha-

consistently good; it has fallen considerably short of

nism, supranormal levels of androgens from the adrenal

that which current knowledge of reproductive biology

glands can distort the negative feedback regulation at

would lead us to expect.

the hypothalamus and pituitary gland and glu-

A plausable hypothesis advanced to account for the

cocorticoids can exercise inhibitory effects at all critical

decline in fertility in high-producing cows was that

points in the HPG axis (and even as far as the target

tissues for gonadal steroids). It is probable that the most

logical defences. When the stored fat is mobilized, some

important factor in the suspension of reproductive activ-

is deposited in liver, kidneys, adrenal glands and muscle.

ity is interference with the pulsatile release of GnRH by

The fatty infiltration of the liver can be severe in cows

the hypothalamus, which alters the pulsatile release of

that are overfat at calving and in cows that mobilize fat

LH by the pituitary gland that, in turn, regulates ovarian

faster than it can be utilized. Subclinical fatty liver has

activity. However, in practice, inhibition at other points

been linked to increased susceptibility to ketosis, milk

in the HPG axis may be just as significant if it reduces

fever, mastitis, lameness and infertility.

the prospects of success when exogenous hormones are

The important features here are that metabolic per-

used to 'kick start' the inactive axis. For instance, exoge-

turbation can be a significant primary cause of allosta-

nous GnRH may be an adequate stimulus to provide a

tic load borne by a cow as she enters the transition

functional pulsatile release of LH, but its ability to

period and that the magnitude of that load can be a sig-

improve calving rates may be constrained if it does not

nificant factor in determining how she copes with the

lead to the removal of inhibition or to the acquisition of

subclinical metabolic problems that invariably arise in

essential receptors at other points around the HPG axis

the early weeks after calving. Failure to cope renders

or in the peripheral target organs.

her vulnerable to a plethora of stressors that are rife at

A plausible alternative hypothesis is that the counter-

that time and act as proximal factors in the pathogene-

regulatory components of stress responses to various

sis of several clinical diseases, metabolic or infectious.

challenges experienced during early lactation exert a

Inappropriate nutrition can be a significant factor

residual inhibition on the biochemical activities of the

in the pathogenesis of a variety of metabolic and infec-

HPG axis and that this inhibition can be of varying

tious diseases.

duration depending on the magnitude of the allostatic

load and the ability of individual animals to cope with

Coping with pathogens

it.

Allostatic load may find expression as a bio-

By definition, pathogens are stressors. The magnitude

chemical lesion.

of the biological costs they impose on their hosts is

determined by the virulence, infective dose and novelty

of the pathogen and by the nature, location, intensity

Metabolic diseases (see Chapters 46, 47)

and duration of the host response, together with the

The peripartum period is a stressful time in the life of

pre-existing allostatic load of the host. In turn, stress is

a cow. During the 'transition period' (the last four

a risk factor for a variety of infectious diseases, partic-

weeks of gestation and the first four weeks of lactation)

ularly in the periparturient period and especially in
cows experience enormous changes in the hormonal
individual cows who enter the transition period with
milieu, a negative energy balance and a plethora of
appreciable allostatic loads, and in cows that are geneti-
stressors that arise from changes in feeding and man-
cally predisposed to exaggerated responses of the HPA
agement regimes. Not surprisingly, a considerable pro-
and SA systems to stressors.
portion of the metabolic and infectious diseases to
Risk of infection can be increased when the stress
which cows are subject occurs during the transition
response leads to behavioural changes that increase
phase, many of them having metabolic perturbation as
exposure to pathogens, when it impairs the immune
the ultimate source of allostatic load. Metabolic per-
response (whether to an invading pathogen or to a
turbations can both induce and be induced by allosta-
latent resident), when it contributes to the progression
tic load.
of an existing pathological process or when it is

It is recognized that absorption of glucose by the prolonged unnecessarily. intestine contributes little to the energy homeostasis of It is accepted that stress has a negative effect on the lactating cows. The large and immediate requirement of immune response and it is often said that the effect is the lactating mammary gland for glucose is met by a largely due to the corticosteroids released during the reduction in utilization by several other tissues and by stress response. The reality is a very much more an increase in synthesis from fats and proteins by the complex scenario that involves the nervous, the liver (gluconeogenesis). The key role is played by lipid endocrine and the immune systems. The different types metabolism that provides a rich supply of substrate for of immune cells possess receptors for the signals issued gluconeogenesis. The amount of energy reserves upon by the HPA and SA axes; in turn, immunocytes release which the postparturient cow can draw is a product of cytokines that modulate the activities of the stress the feeding regime during the recent dry period. At the system.

onset of lactation there is extensive mobilization of

Recent research indicates that stress may boost

body fat and in many cows this gives rise to a state of

humoral immunity as it suppresses cellular immunity –

subclinical ketosis, a condition that impairs immuno-

a response that is due to the effects of glucocorticoids

and catecholamines on the differentiation of T helper

future challenges. This strategy is used in dealing with

cells. The stress hormones modulate the secretion of

a range of microbes and parasites and, in addition to

different types of cytokines by antigen-presenting

enhancing the host's immune repertoire, it represents

cells (macrophages and other phagocytic cells); those

prudent use of energy reserves since the likelihood is

cytokines influence the differentiation of antigen-naïve

that the biological cost of total elimination would be far

T helper cells (Th0) into two subsets (Th1 and Th2)

greater than the net cost of maintaining a resident

that, in turn, secrete cytokines that are involved in the *population to which the host becomes habituated – and*

acute phase response, in sickness behaviour and in the

which brings such benefits as on-going priming of local

differential regulation of cellular and humoral immu-

immunity to the pathogen and competitive inhibition

nity. The cytokines secreted by Th1 cells promote

of other pathogens that might attempt to invade the

cellular immunity, those secreted by Th2 cells promote

location.

humoral immunity. The Th1 and Th2 responses are

Given that infectious agents impose an increased

mutually inhibitory; it is thought that the Th2 shift that

metabolic and nutritional load on their hosts, it is aston-

accompanies a vigorous stress response might have

ishing that voluntary reduction in food intake appears

important implications for the course and outcome of

to be a beneficial coping strategy in some viral, bacter-

infectious, allergic, autoimmune and neoplastic dis-

ial and parasitic diseases. For instance, there is experi-

eases. Some immunocytes secrete hormones: for

mental evidence that when mice infected with Listeria *instance, lymphocytes can synthesize ACTH, growth monocytogenes were force fed to the same energy hormone and prolactin – messengers that probably act intake as their uninfected controls, they had a higher locally in a paracrine fashion. In addition, there are mortality rate and a shorter survival time than did the functional contacts between nerve fibres and immuno- infected mice that were anorexic. Clearly, in this cytes: for instance, lymphoid organs are innervated by instance, force feeding nullified the benefits of a natural nerve fibres that release noradrenaline or neuropep- coping strategy and became an iatrogenic instrument of tides which interact with the immunocytes to cause death. It is legitimate to question the wisdom of force changes in cellular trafficking, lymphocyte prolifera- feeding sick animals.*

tion, antibody production and cell lysis. The physio- The two coping strategies just discussed – subclinical logical and pathophysiological consequences of all this infection and anorexia – are somewhat at variance with cross-talk are most evident to the veterinarian in the

the thrust of conventional wisdom; nevertheless, their

periparturient cow.

adoption by diverse species indicates that they bring

The transition period is recognized as a time of rela-

significant benefit to the host. Therapeutic interventions

tive immunosuppression and increased susceptibility to

should not run counter to the way of nature.

infectious diseases – whether viral, bacterial or para-

Therapeutic interventions in infectious diseases

sitic. The periparturient cow is at serious risk of infec-

should be consonant with coping strategies, including

tion because, at parturition, the uterus and the udder

those that appear to be contrary to conventional

lose the physical barriers that have protected them

wisdom and expectation.

from ascending infections; thus, bacterial pathogens

may enter while the defences are at their weakest.

Altered behaviour

Leukocytes play key roles in the defence of both

organs: prompt migration of neutrophils (PMNL) is

Changes in behaviour may be evoked as coping strate-

essential to overcome the bacteria; however, the activ-

gies (confrontational, submissive or socially neutral) or

ities of the leucocytes are depressed as a consequence

they may emerge in the course of stress-induced illness

of the negative energy balance, the subclinical ketosis,

– in the form of listlessness, exaggerated sleepiness,

the fatty liver and the raised circulating concentrations

weakness, depressed locomotor activity, shivering,

of glucocorticoids. Some recently-calved cows develop

diminished social interaction, anorexia, decreased

a severe systemic illness when the influx of PMNL does

foraging and absence of body-care activities. Current

not materialize in response to invasion of the udder by

opinion amongst those who study infectious diseases is

Escherichia coli. However, in most instances the cellu-that those behavioural changes are an integral part of

lar and humoral responses control the proliferation of

an adaptive response to antigenic challenge and that

the invading bacteria without achieving total elimina-

they are elicited by the pro-inflammatory cytokines that

tion; for instance, Staphylococcus aureus frequently is are released from immunocytes to mediate both the *relegated to subclinical residence in the udder. This is*

local (inflammatory) and the systemic (febrile and

an important adaptive strategy: its immediate effect is

behavioural) components of the reaction to foreign

to protect the organ from serious tissue damage, while

antigens. In that interpretation, sickness behaviour and

it sets up a mechanism by which the organ can main-

fever share two significant attributes that are of funda-

tain a satisfactory level of local immunity to cope with

mental concern to the therapist: each is an important

component of the natural defence system; in excess,

Quite often the downer cow syndrome is seen as an

each can be detrimental to the host.

incomplete response to treatment for milk fever: it is

Cytokine-induced anorexia can be interpreted as a

said that the longer the interval between the time the

way to reduce the availability of some nutrients (e.g.

cow becomes recumbent and treatment for milk fever,

iron, zinc) necessary for multiplication of the

the greater the incidence of the downer cow syndrome.

pathogens. Sleepiness and reduced activity can be inter-

One has to entertain another possibility: that some

preted as ways in which to conserve energy that the sick

recently-calved cows, already burdened with substantial

animal will re-allocate to new priorities geared toward

allostatic loads and with the added stress of acute

victory over the pathogens (e.g. inflammatory and

hypocalcaemia, may find rapid intravenous injection of immunological responses). Therefore, as far as is possi-essential ions to be a stressor too many – sufficiently

ble, our treatment modalities should not nullify the

stressful to necessitate a period of recumbency in which

natural benefits of sickness behaviour – as force feeding

to recover the will and the confidence to resume normal

did to the Listeria-infected mice.

activities. When management fails to recognize the

The behavioural changes evoked by the stressors

cow's immediate need for a period of relative in-

may be transient (e.g. failure to groom during illness),

activity she will be subjected to repeated premature

persistent (e.g. stereotypies) or life-threatening (e.g.

attempts to force her to stand; this will increase the risk

learned helplessness). Learned helplessness is an
of physical damage and, by the same token, it is likely
unmotivated state in which an animal gives up trying to
to reinforce the state of helplessness that now is at the
cope with the exigencies of life, is indifferent to its own
core of her problem.
well-being and is unresponsive to therapeutic or puni-
It is tempting to speculate that the dispirited state
tive interventions. Originally, the term was used by
may have a morphological basis somewhat analogous
scientists who assessed the coping abilities of dogs
to the neuronal damage seen in the hippocampus of
exposed to repeated electric shocks. They found that
chronically stressed humans, shrews and rodents. If that
dogs that had been subjected to unavoidable shock
were the case, the evidence from the other species
treatments in a preliminary experiment just sat and
would be reassuring: the neuronal damage is neither
took the shocks when the experiment was repeated in
terminal nor irreversible. Most of the affected cattle
a situation from which there was a fairly obvious means

should respond to standard treatment, always provided

of escape. Subsequently, it has been recognized that

the clinical problem is not compounded by muscu-

chronic stress can lead to learned helplessness in other

loskeletal damage incurred during ineffectual attempts

species (including humans), notably when they have

to get the cow on her feet before she is ready to do so

endured repeated failed attempts to achieve an

of her own volition or by complications arising from

objective.

prolonged recumbency.

The author believes that he has encountered this

These observations on altered behaviour highlight

cognitive aberration in cattle originally thought to

two significant aspects of animal health: firstly, sickness

be suffering from metritis, mastitis, acetonaemia or

behaviour is an adaptive response to infectious or non-

hypocalcaemia, but most convincingly in a subset of

infectious stressors; it provides the allostatic base from

downer cows that did not have the physical or biochem-

which the recuperative process develops and it is instru-

ical defects to account for their predicament (pp. 439,

mental in setting the endogenous rhythm for that

797). From clinical experience, he suspected that some

process; secondly, any therapeutic intervention that

of the underlying allostatic load in the helpless downer

jolts the periodicity of the process becomes an addi-

cow had been brought forward from the dry period and,

tional stressor that is likely to delay or distort

perhaps, from previous lactation(s). If the conjecture is

resolution.

correct, it follows that a comprehensive record of health

Sickness behaviour is a strategy that may be invoked

and production parameters should reveal more about

to cope with either infectious and non-infectious stres-

the bases from which the load accrued than would the

sors; interventions that target the behaviour rather

most recent metabolic profile. Learned helplessness may

than the stressors are liable to delay, distort or prevent

be associated with either infectious or non-infectious

the recuperative process.

conditions; it is regarded as a putative animal model of *depression. The pathophysiological mechanisms have*

not been elucidated but some evidence from animal

Concluding comments

experiments hints at an imbalance between the activities

of the two limbs of the stress system, with the HPA axis

The primary aim of this chapter is to draw attention to

in the ascendant. It would not be prudent to treat such

the concept of allostatic load and to encourage practi-

animals with corticosteroids, as is often advocated for

tioners to appreciate how important a role it plays

the downer cow syndrome.

in the pathogenesis of most of the ailments they

encounter. More often than not, clinical disease is the

Habituation: extinction of a conditioned response by repeti-

product of a cascade of environmental stressors: some

tion of the conditioned stimulus; perceived threat dimi-

can be designated as ultimate factors that have been

nishes as novelty wears off.

responsible for the allostatic load that has made the

Hypothalamic–pituitary–adrenal (HPA) axis: the hormonal

animal vulnerable to the proximate stressors (infec-
interplay between those three organs; the principal
hormones involved are corticotrophin-releasing hormone
tious, metabolic, toxic) that are the immediate causes of
(CRH) and arginine vasopressin (AVP; formerly ADH)
the ailment. If we wish to keep pace with current trends
from the hypothalamus, adrenocorticotrophic hormone
in intensive systems of animal production we will have
(ACTH) from the pituitary gland and cortisol from the
to take greater stock of ultimate stressors than has been
adrenal cortex.
our wont. Increasingly, our task will be to devise and
Hypothalamic–pituitary–gonadal (HPG) axis: the hor-
monitor herd health programmes that manage the
monal linkage between the hypothalamus (releases
sources of environmental stimuli to the mutual benefit
GnRH), the pituitary gland (releases the gonadotrophins,
of the livestock and the profit-and-loss account. In that
FSH and LH) and the gonads (secrete testosterone, oestro-
context, it does not require great insight to realize that
gens, progesterone).

curtailment of allostatic load is the key to improvement

Locus coeruleus: a small pigmented cluster of noradrenergic

neurones in the dorsal brain stem on the floor of the

in the overall health and productivity of the herd.

fourth ventricle. It contains more than half of the nora-

When the accumulated allostatic load attenuates the

drenergic neurones in the brain; they project widely

animal's ability to cope with further challenges, the host

throughout the CNS and they are highly responsive to

becomes vulnerable to all sorts of stressors, even those

alerting/stressful stimuli, including those that activate the

that are only mildly aversive. In that situation, a rela-

HPA axis.

tively minor proximate stressor may propel the host

Paracrine: hormone (or cytokine) acts on a different cell type into clinical disease, particularly one that reflects the

which lies in close proximity to the producer cells.

functional priorities of the current phase of the animal's

Proximate cause: an environmental factor that acts as

annual life cycle. For that reason, the differences in pre-

an immediate stimulus for a biological event (e.g. a *senting signs shown by herd mates should not obscure*

disease).

the fact that each sick animal has had a significant allo-

Sympathoadrenal (SA) axis: consists of two components: the

sympathetic nervous system and the adrenal medulla. The

static load and, in that sense, each clinical case should

major biologically active products, the catecholamines

be seen as a sentinel of stress within the herd.

(adrenaline and noradrenaline), serve both as neurotrans-

Allostatic load is not something that can be measured

mitters and as hormones. Within the CNS they act as neuro-

by standard biochemical or physiological techniques.

transmitters; outside the CNS, adrenaline acts principally as

Research scientists use hormone assays and heart rates

a hormone, while noradrenaline acts principally as a neuro-

to monitor responses to acute stressors, but those

transmitter at sympathetic post ganglionic terminals.

parameters are not indicative of allostatic load. The best

Ultimate cause: an environmental factor that increases

sources of the required information are comprehensive

the probability that a particular biological event will be *life-time records of health and production parameters.*

elicited by another factor that is seen as the immediate

The onus is on the herd veterinarian to ensure that the

stimulus.

appropriate records are compiled, that they are used to

identify both ultimate and proximate stressors and

References

that the information so gained is taken into account

whenever therapeutic or prophylactic interventions are

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contemplated.

tion: clinical implications. Annals of the New York Academy of Science, ***917****, 38–67.*

Johnson, E.O., Kamilaris, T.C., Chrousos, G.P. & Gold, P.W.

Glossary

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behavioural homeostasis. Neuroscience and Biobehavioral

Arousal: the state of general alertness. It is reflected in

Reviews, ***16****, 115–30.*

conscious state, in cognitive activity, and in behaviour.

McEwen, B.S. (1998) Protective and damaging effects of stress

Autocrine: hormone (or cytokine) acts on the cells that

*mediators. New England Journal of Medicine, **338**, 171–9.*

produce it.

McEwen, B.S. & Stellar, E. (1993) Stress and the individual: Brainstem: the stem-like region that links the cerebrum with

mechanisms leading to disease. Archives of Internal Medi-

the spinal cord; consists of the midbrain, pons and medulla

*cine, **153**, 2093–101.*

oblongata.

Moberg, G.P. (2000) Biological response to stress: implications Cytokine: protein or glycoprotein (produced by one or more

for animal welfare. In The Biology of Animal Stress, pp.

cell types) that regulates the activity of other cells.

1–21. CABI Publishing, Wallingford.

Endocrine: hormone is secreted directly into blood stream

Royal, M.D., Darwash,A.O., Flint,A.P.F.,Webb, R.,Woolliams,

and acts on target cells elsewhere in the body.

J.A. & Lamming, G.E. (2000) Declining fertility in dairy

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*Stratakis, C.A. & Chrousos, G.P. (1997) In Endocrinology: fertility. Animal Science, **70**, 487–501.*

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Sterling, P. & Eyer, J. (1988) Allostasis: a new paradigm to Melmed), p. 205. Humana Press, Totowa, NJ.

explain arousal pathology. In Handbook of Life Stress,

Wade, G.N. & Schneider, J.E. (1992) Metabolic fuels and

Cognition, and Health (ed. by S. Fisher & H.S. Reason), reproduction in female mammals. Neuroscience and Biobe-pp. 629–49. Wiley, New York.

*havioral Reviews, **16**, 235–72.*

Adult Cattle

Global Variation in Cattle Practice

Chapter 68

Diseases Related to Management in

Europe

G.H. Wentink and A. de Kruif

European dairy farming trends

1151

per hectare may be as high as or even higher than in

Infectious diseases

1152

The Netherlands and Belgium.

Metabolic diseases

1153

Total milk production in Europe is fixed by the quota system introduced in 1983. Placing a ceiling on milk production per country puts a limit on the number of

European dairy farming trends

dairy cows. As a result of fruitful breeding programmes and efficient feeding regimes the annual milk yield per Europe stretches from the 70th degree of latitude cow increased during the last decades. The number of (north of the polar circle) to the 40th degree of latitude dairy farms and dairy cows will be reduced even more into subtropical regions. Many different climatic condi-during the next decade, with an increase in the number tions and huge differences in landscape exist. These of cows per farm.

differences work out in very variable disease problems The diets of dairy cows in The Netherlands and and different husbandry systems. In Denmark, northern Belgium contain substantial levels of concentrates. The Germany, The Netherlands, northern Belgium, north constituents of these concentrates are partly grown in west France and in Italy at the borders of the river Po,

Europe, but for the larger part, in particular protein,
flat land with fertile pastures is located. These areas are
they are imported into Europe. Nitrogen, phosphate
suited for dairy farming. Annual milk production is high
and other minerals are actually imported into these
and may reach 8000 kg with 4 per cent fat corrected
countries, but a limited amount of minerals is exported
milk (The Netherlands). However, in Sweden, southern
as milk and meat. Therefore, an imbalance exists
Germany, southern Belgium, eastern France and
between the amount of minerals imported into these
Austria a hilly or mountainous landscape exists. These
areas and the amount exported to other areas of
areas are less suited for dairy cows, but more suited for
Europe or to other parts of the world. The mineral
suckler cows and beef production. Traditionally, in these
surplus is applied into the ground as manure. This
areas dairy herds with limited numbers of cows occur.
causes an accumulation of elements (nitrogen) and puts
Italy, Spain, Portugal and Greece have a rather hot
a further stress on the reduction of the number of cows

climate during summer time; dairy farming is difficult

on environmental grounds, especially in The Nether-

and of reduced extension. The average annual milk

lands and Belgium.

production is 3000 kg (Greece), although exceptionally

During the last decades, the average education level

dairy farms with a high production level occur (Portu-

of the farmers increased sharply and as a consequence

gal). In this chapter attention will be focused mainly on

veterinarians must take another role. The veterinarian

dairy cattle management in north west Europe.

will be called in to take their part in prevention of dis-

In 1998 just over 82 million cattle, including 21

eases and to sustain the milk production level on dairy

million dairy cows over 2 years old, were present in

farms rather than to cure sick animals. Therefore a shift

Europe. In Table 68.1 the number of cows and the agri-

in the veterinary skills is inevitable: the veterinarian has

cultural area per country are given. In The Netherlands

to support the management system of the client, mainly

and northern Belgium the ratio of cattle to agricultural *by doing the thinking for prevention of diseases and to*

area is more than two animals per hectare, in Ireland

optimize production levels.

1.5, while the other countries have less than one cow

In the past, much attention was paid to certain

per hectare agricultural surface. This quotient applies to

aspects of food quality, e.g. the cell count in milk,

the agricultural area and gives an indication of animal

but nowadays the consumer's attention is even more

density in a country. In countries with a low quotient

focused on food safety. Although the quality of prod-

cows may be kept on a limited part of the agricultural

ucts for human consumption increased during the last

area and in some areas the actual number of animals

decade, the confidence of the consumer in these prod-

Table 68.1

Cattle population and agricultural area in Europe 15 (source FAO).

Country

Agricultural area ¥ 1 000 000 ha

Number of cattle ¥ 1000 Cattle/agricultural

ha

(1999 data)

(2000 data)

EU 15

143.018

82.332

0.58

Austria

3.419

2.150

0.63

Belgium-Luxembourg

1.521

3.085

2.03

Denmark

2.644

1.850

0.70

Finland

2.272

1.086

0.48

France

29.900

20.572

0.69

Germany

17.031

14.658

0.86

Greece

9.020

590

0.07

Ireland

4.418

6.708

1.52

Italy

16.268

7.184

0.44

Netherlands

1.967

4.200

2.14

Portugal

4.142

1.245

0.31

Spain

29.980

6.203

0.21

Sweden

3.235

1.713

0.53

UK

17.219

11.133

ucts continuously declined. The latter aspect is empha-

infectious diseases and of diseases that are indigenous

sized by BSE. The supposition that BSE prions might

in all cattle populations, such as mastitis and lameness.

have caused the vCJD in man (see p. 909) and the

possibility that prions entered the human food chain

without appropriate check on the source of the animals

Infectious diseases

for food production caused a shift in public opinion.

The threat of disease caused by products of animal

In north west Europe a number of major infectious

origin and the threat of antibiotic resistance in human

diseases have been eradicated, e.g. rinderpest, BCPP,

bacteria due to the application of antibiotics in food

tuberculosis, brucellosis and EBL. In 2001, FMD re-

animals increase the attention paid by the consumer to

emerged in north west Europe and caused severe (UK),

the chain in which human food is produced. The chain

moderate (Netherlands) or mild (France) epizootics,

must be completely transparent and the methods to *focusing attention on this disease again. Until this out-*

control the processes must be supervised by independ-

break attention was mainly focused on the eradication

ent people.

of BSE, IBR, BVD and on a limited scale of paratu-

Furthermore, increasing attention is paid by the

berculosis (Johne’s disease) (see p. 857).

public to animal welfare. The consumer demands food

Veterinarians must be fully aware of the agents and

from animals that are kept under conditions that allow

their epizootiology. The Achilles heel in the infection

them to function more or less naturally. Reducing

chain must be found for each individual pathogen to

the frequency of microtraumata by comfortable barns

develop effective eradication strategies.

beyond doubt increases the durability of dairy cows. In

the future veterinarians may participate in the supervi-

FMD (see Chapter 43c)

sion of the production of food from cows by paying

attention to their comfort.

As long as FMD exists somewhere in the world, the

Knowledge of diseases, and especially knowledge of their cause and aetiology, the consequent knowledge to prevent problems and the skills to prevent a decline of milk production and disasters on dairy farms must be an essential characteristic of veterinarians in the next decade. Veterinarians may also contribute to the achievements of dairy farmers by increasing the quotient milk production versus manure per surface unit. Two aspects for veterinary prevention programmes must be considered: prevention of the introduction of

risk of introduction of the virus into Western Europe by food products from infected animals remains real. Intensive traffic movements of people over the world increase the risk of accidental introduction of contaminated food products. When the FMD virus is introduced into a West European country, the risk of an epizootic depends on the time lapse between introduction of the virus and the diagnosis, and of the number of animal movements over the country or to other countries during that period (see p. 705).

IBR (see p. 289)

in life. In the last phases of the disease bacteraemia

develops and as a consequence milk and meat might be

In the 1980s, voluntary eradication programmes

infected with the bacterium.

for IBR were started in the Scandinavian countries.

In man, Crohn’s disease has a pathology that is very

However, there was no thorough economic basis for the

similar to paratuberculosis in the bovine. M. avium ssp.

eradication of IBR. IBR is also not a threat for human

paratuberculosis was isolated from the intestines of

health, the economic damage is limited and clinical

patients with Crohn’s disease, but not from the

disease can be prevented by an appropriate vaccination

intestines of humans suffering from other intestinal

programme. However, as Scandinavian countries

disorders. The PCR for M. avium sp. paratuberculosis became officially free of IBR several other European

is significantly more often positive in patients suffering

countries were forced to achieve IBR negativity as well.

from Crohn’s disease than in those suffering from

It was mainly a political decision to eradicate IBR.

other gastrointestinal disorders. This does not prove,

Eradication programmes were successful in Switzer-

however, that M. avium ssp. paratuberculosis is the land, Denmark, Sweden, Finland and Austria. The basis

causative organism for Crohn's disease. The agent

for the success of these programmes was that all sero-

might take advantage of the pathological changes in

logically positive cows, which might be latently infected,

the intestines of human patients with Crohn's disease

were eliminated. The percentages of animals found

to colonize the bowel. It demonstrates, however, that

serologically positive for IBR in these countries did not

the agent must be present in the human environment

exceed 20 per cent of the dairy cows.

and probably in human food. Actually, about 6 per cent

However, percentages of serologically positive

of milk for human consumption in the UK was

animals turned out to be as high as 50–60 per cent in

contaminated with M. avium ssp. paratuberculosis, The Netherlands and Belgium, and therefore the above

although it is unclear whether the bacteria in milk are *mentioned method was not applicable. Vaccination*

viable.

programmes using gene deleted vaccine virus, but with

It is, however, important to ensure that the human

a serological response distinguishable from field virus

food chain is free from this bacterium and veterinari-

infections, are applied to all cattle herds that are not

ans are obliged to pay attention to the eradication

proven negative for BHV1. These programmes started

of the agent from the cattle population. On the other

recently (1998), so there is no evidence that these

hand, efforts to eradicate paratuberculosis (Johne's

schedules will turn out to be completely successful.

disease) in all countries are limited.

BVD (see p. 853)

BSE (see p. 909)

Bovine virus diarrhoea virus (BVDV) has a real

Bovine spongiform encephalitis prions are suspected

economic impact on infected farms and the disease

to be the cause of the [new] variant Creutzfeldt Jacob

deserves full attention for eradication. Although some

Disease ([n]vCJD). These prions are present in tissues Scandinavian countries have voluntary eradication pro- from the central nervous system and jejunum of grammes, the efforts to eradicate this virus are far less cattle with overt clinical signs of the disease. Cows are intensive than the efforts to eradicate IBR. In Sweden believed to contract the disease by consuming ruminant and in Denmark voluntary programmes for the eradi- proteins produced from infected ruminants. The major cation of BVDV have been in progress since 1993. The breakthrough was the total elimination of animal backbone for the eradication programme is the detec- proteins (except fish and poultry proteins) from the tion and destruction of all persistently infected animals. ruminant food chain. The consumer requires a guar- A herd has to start with a virulogical search for the antee that animals for human consumption have never presence of persistently infected animals. After the consumed animal protein and puts emphasis on the elimination of these animals a regular serological source of the meat and its control chain.

survey of the animals between 6 and 12 months is

performed, and later on by testing for the absence of

antibodies against BVDV in bulk milk samples.

Metabolic diseases *(see Chapter 46)*

The increased capacity for milk production necessitated

Paratuberculosis (Johne's disease) (see p. 857)

improved feeding regimes. The quality of grass silage

Johne's disease is caused by Mycobacterium avium

and corn silage increased and facilitated higher pro-

paratuberculosis. After infection by the oral route

duction levels. Next to roughage a substantial amount

during the first months of life, clinical disease charac-

of concentrates are fed. Concentrates are added in the

terized by diarrhoea and emaciation may develop later

milking parlour or in concentrate stations, where each

Table 68.2

Prevalence of disease problems in 8272 cow years

(roughage). In experimental farms in The Netherlands

in nine dairy farms in The Netherlands during a 10-year period.

with a management above average the incidence of this *disease was limited to 1 per cent of the cows.*

Fertility problems

34.9%

A disease biochemically very similar to acetonaemia

including 19.0% irregular heat periods

may develop within two weeks after parturition. In the

Udder problems

24.6%

peripheral blood high levels of non-esterified fatty acids

including 22.5% mastitis cases

(NEFAs), high levels of b-hydroxybutyrate and low

Locomotory

36.7%

levels of glucose are found, indicating severe energy

problems

including 6.8% laminitis

including 17.7% solar ulcers

deficit, but with very high levels of triacylglycerol in the

Metabolic problems

19.7%

liver. This phenomenon is known as fatty liver, a *including 5.5% acetonaemia*

very peculiar phenomenon in that the peripheral body

including 14.4% milk fever

is deficient in energy supply, while in the liver high

levels of energy (up to 25 per cent of triacylglycerol of

wet liver tissue) are available (see p. 801). The cow is ill

and may die from energy depletion while abundant

individual cow can obtain an amount relative to milk

energy is present but is not made available for the

production, or a total mixed ration is provided.

metabolism. The origin of the disease is considered to

Indications for a causal relationship between food,

be a sequel of excess of energy supplementation in the

feeding and diseases are increasing and substantiated

last part of the lactation period and during the dry

by experimental work. Metabolic disturbances also

period. About 10 to 12 weeks after parturition, the

significantly influence the health of claws and may

initial decrease in body weight due to the physiological

exacerbate the consequences of external forces (mini-

negative energy balance turns and becomes positive.

trauma) on claws, causing lameness (see Table 68.2).

The body weight increases until drying off.

Veterinarians should be fully aware of the relation-

During the dry period the body weight must be kept

ships between food, metabolism and disease, and must

constant. However, the increasing energy value of the

be able to translate food changes into possible devia-

roughage produces an energy surplus during the dry

tions of the health of the animals in a herd. Thus the

period and as a result many cows increase their body

veterinarian involved in cattle herd health management

weight and are fat at calving. Although exact mecha-

must be familiar with food constituents and compo-

nisms are poorly understood, many cows in a fat body

nents and their digestion and metabolism.

condition at calving (BCS 4 or higher on a 5 point scale)

Large quantities of rapidly fermentable starches in

suffer from a decreased appetite after calving. This

the diet may cause disturbances of rumen fermentation,

reduced appetite may be related to or caused by leptins,

resulting in low milk fat percentages, off feed syndrome,

by high levels of NEFAs, by a combination of these
laminitis and ruminal acidosis consecutively, depending
factors or by other not yet described causes. In these
on the grade and the period of acidosis. These phe-
fat animals with often high milk production the energy
nomena are mainly observed in herds with high milk
intake is short in comparison to the energy demand.
production levels being fed high amounts of concen-
Increased lipolysis, in order to compensate for energy
trates in the diet. Although there are no exact data
demand, results in the accumulation of triacylglycerol
on the incidence of these diseases in Europe, in The
in the liver, i.e. fatty liver. In the short term this
Netherlands and Belgium these disturbances have
metabolic disease may result in emaciation and death;
occurred rather frequently in the past, but are now
in the long term it may cause reduced reactivity of the
decreasing due to the lower percentage of easily
immune system, making the cow more vulnerable to
fermentable starches in the concentrates.
common bacterial infections. There may be a high

If the energy in food is maintained in accordance prevalence of mastitis in the post partum period in with the milk production level, cows lose body weight animals suffering from fatty liver. Ova mature during moderately during the first few weeks of lactation. The an eight-week period and the first ovulation after negative energy balance during the first weeks after parturition in these cows produces an ovum matured parturition is physiological (energy intake by food and during the period with high levels of NEFAs in the energy from reserve fat equals energy demand). If this blood. These ova are less fertile and may result in equilibrium is disturbed by low energy content of the lowered conception rates. This metabolic disturbance food acetonaemia some three weeks after parturition causes decreased ovarian activity with prolonged develops, characterized by high levels of b-hydroxybu- intervals from calving to heat, resulting in prolonged tyrate and low glucose levels in the peripheral blood. intervals from calving to conception. The incidence of This problem is still known but occurs less frequently *fatty liver is not known, but it is suspected to occur*

than previously due to increased quality of the diet

more frequently than anticipated.

Dietary deficiencies are rarely diagnosed in dairy

in management which result in reduced fertility,

herds in areas with a high milk production. The diet

reduced immunoreactivity or in lameness .

receives adequate levels of minerals and vitamins from

the addition of concentrates, the composition of which

Further reading

is monitored by the manufacturer. However, as many

farms start to feed home-produced diets composed

FAOSTAT Database Collections; http://apps.fao.org/

from basic substances there is a risk of miscalculation

Smolders, G. In Annual Reports of the Research Station for and thus excesses or deficiencies may occur. The

Cattle-, Sheep-, and Horsehusbandry 1990-1999, Institute veterinarian will be asked to support management

edn. Research Institute for Animal Husbandry, Lelystad,

decisions taken by the owner and to diagnose failures

The Netherlands.

Chapter 69

Cattle Disease in Africa

R.S. Windsor

Introduction

1156

868), foot-and-mouth disease (p. 700), rabies (pp.

Epizootic diseases

1156

908, 1164), tuberculosis (p. 862) and brucellosis (p.

Rinderpest

1156

280).

Foot-and-mouth disease

1157

• Parasitic diseases caused by either by helminths, e.g.

Tuberculosis and brucellosis

1157

Haemonchus contortus (p. 275), or Fasciola gigan-

Parasitic diseases

1157

tica (p. 276), or by tick-borne protozoa, e.g. Theile-Trypanosomosis

1159

ria parva (p. 750) or Anaplasma marginale (p. 761), East Coast fever

1160

Plant poisonings

1161

or by the biting flies (p. 747) (Glossinia spp.), or the various species of Trypanosoma (p. 756).

• *Plant poisonings caused by the varied and extensive* ***Introduction***

flora of Africa. Among such a profusion only a few

examples can be given.

The purpose of this chapter is to indicate some of the

differences between cattle problems in Africa and the

rest of the world and to highlight some of the condi-

Epizootic diseases

tions that are of major importance to livestock produc-

tion. North Africa is part of the Mediterranean area and

Rinderpest *(see p. 707)*

it is separated from the rest of Africa by the Sahara

First among cattle diseases is rinderpest, the greatest

Desert, where there are few cattle. SubSaharan Africa

scourge of cattle, and indeed their owners, that the world *has a variety of climatic conditions, from almost no rain-*

has ever seen. When rinderpest was imported into

fall to heavy, regular and seasonal rainfall areas, and in

Britain in the mid nineteenth century it ruined farmers,

consequence there is a variety of environmental types

bankrupted insurance companies and was directly

and eco-systems. This in turn has led to many different

responsible for the foundation of what is today the State

lifestyles from the sedentary agriculturist to the

Veterinary Service. The Royal Agricultural Society

nomadic pastoralist who moves his herds as conditions

considered that rinderpest was responsible for the death

dictate, e.g. the Fulani in west Africa would prefer to

of more than 400 000 head of cattle in Britain in six

graze their animals in the south where there is more

months of 1866 at a cost in 1866 figures of £8 million. It

rain and the grass is better for the cattle. However,

was introduced into Egypt in 1890 and in five years it had

during the rainy season the tsetse flies are active, so the

travelled to South Africa, killing not just cattle but also

cattle are moved north to escape their bites. When the *huge numbers of game animals as it passed.*

dry weather returns and the pastures in the north

Following Macmillan's famous 'winds of change'

become depleted of grass they return their animals

speech to the South African parliament in 1960, African

south. In large measure the distribution of the human

countries raced towards independence. The cold war

population has been governed by this fly (Glossinia

was beginning to push America and Russia: both wished

spp.). To many African people, the well-being of their

to develop spheres of influence in Africa and so they

animals governs their lifestyle. The differences in the

poured money into the continent. Joint Project 15 was

ecology of the continent govern the behaviour of

set up, with almost limitless funding, to eradicate rinder-

disease agents, parasites and vectors: therefore, cattle

pest from Africa. A vaccination campaign, using the

diseases to be considered here fall into three main

Muguga tissue culture vaccine, almost succeeded in

categories:

eradicating the infection. Unfortunately pockets of

• Epizootic diseases that have mostly been intro-
virus persisted in Chad and Ethiopia and from these the
duced into the continent from Europe – rinderpest
disease ‘recolonized’ Africa. The Pan African Rinder-
(p. 707), contagious bovine pleuropneumonia (p.
pest Campaign (PARC) was set up with the aim of erad-

icating rinderpest within a period of 10 years. PARC has
parasites. Unlike the Amazon Jungle the tropical
the advantage of superior immunological tests and it
forests of Africa are not so large as to make huge tracts
would seem that the goal may be achieved. Similar proj-
of land uninhabitable. Africa has probably more species
ects in the Middle East and southern Asia also seem
of tick than any other continent and because of the
to be achieving success: it is possible that early in the
extensive savannah areas these creatures have had
new millennium global eradication of rinderpest may
plenty of hosts and time, so that a reasonable equilib-
become a reality.

rium has built up between animals (including indige-

nous domestic cattle), ticks and the parasites that they

carry. This equilibrium was destroyed when the

***Foot-and-mouth disease** (see p. 700)*

Europeans imported exotic cattle in an attempt to

In Africa, foot-and-mouth disease (FMD) is more

increase productivity of the native cattle. For some

important for its political impact than for the disease

unknown reason cattle, and indeed humans, have failed

that it actually causes. It is endemic throughout much

to build up resistance to the parasites carried by the

of the continent and the African buffalo (Syncerus

tsetse flies (Glossinia species) (see p. 747) – the try-caffer) has been shown to be a carrier of the SAT

panosome (Trypanosoma species) (see p. 756). In large strains. This makes the eradication of the virus from the

measure it has been the trypanosome that has deter-

continent problematical. Control measures follow

mined the distribution of cattle in Africa and conse-

the normal international pattern, with the exception of

quently it has played a part in the distribution of the

Botswana, which has developed its own technique of *human population. Tsetse fly are recorded in 37 African*

control. The country is divided by cordon fences (some

countries and more than 10 million square kilometres

hundreds of kilometres in length) into different areas

of land are infested. There are few breeds of cattle that

of 'infected', 'clean but vaccinated' (buffer) and 'unvac-

have developed a trypanotolerance and these are

cinated' areas. Movement of cattle from one area to

mostly confined to west Africa.

another is strictly controlled, including physical exami-

The reason for the difference in resistance may well

nation of every animal by the Veterinary Department.

be associated with the feeding habits of the parasites.

At each biannual vaccination the animal is branded and

Hard ticks (and these are the only ones of importance

only branded animals are allowed into the abattoirs. As

to cattle) are sedentary and remain on the host, or at

a result of this control, Botswana is permitted to export

least each stage of the parasite remains on the hosts and

meat into the European Union from the 'unvaccinated'

feeds by sucking blood. There are three types of hard *areas.*

tick: one-, two- and three-host ticks, depending upon

For many years Kenya was allowed to export meat

whether or not at the completion of each stage of life

into the European Economic Community. Movement

the tick remains on the host to moult or whether it

controls broke down, the disease spread and Kenya is

drops off. A one-host tick spends its life on one animal:

no longer able to export its meat to Europe. Other coun-

the larvae moult to nymphs, the nymphs to adults on

tries with no export trade outside the continent make

the same animal. The gravid female drops off to lay her

little or no official attempts to control the infection.

eggs on the ground. The two-host tick usually moults

from larva to nymph on one animal but the nymph

drops and moults to an adult on the pasture. The three-

***Tuberculosis and brucellosis** (see pp. 280, 862) host tick drops off at each moult. It is obvious that*

Bovine tuberculosis in Africa is complicated by the

three-host ticks are more efficient at spreading infec-

presence of a large number of 'cold blooded' or atypi-

tions than the one-host variety. By contrast, the tsetse

cal strains of Mycobacterium. These make the interprefly takes each meal where it finds it and moves from

tation of the tuberculin test more difficult and today

animal to animal: there is no time for a host–parasite

outside South Africa there is little done to control the

interaction and the parasite moving from host to

disease at the official level. In most countries with a

host has accustomed itself to varying host immune

commercial dairying industry (e.g. Kenya, Ivory Coast)

mechanisms.

the industry itself tries to ensure freedom from both

Each species and genus of tick has a different distri-

tuberculosis and brucellosis, thus enabling producers to

bution, a different life cycle and differing host prefer-

market 'attested' milk.

ences and site predilections. Specific ticks transmit

specific infections: e.g. Rhipicephalus appendiculatus

(the brown ear tick) transmits East Coast fever (ECF)

Parasitic diseases

(theileriosis) (p. 750) and other theilerial parasites,

whereas Boophilus decoloratus (the African blue tick)

The African continent has the climate, soils and hence

transmits Babesia bigemina (the cause of bovine

ecology to support a great diversity of animals and their

babesiosis) (p. 748) and Anaplasma marginale (the

cause of anaplasmosis) (p. 761). By the same token,

tions in order to reduce the dipping and work towards

there are different species of Glossinia that inhabit dif-endemic stability; the second is to try and control the

ferent ecological niches and that transmit different

ticks by intensive dipping.

species of Trypanosoma. The demonstration by Bruce,

Over the years there has been a different approach

at the end of the 19th century, that it was the tsetse fly

to the control of tsetse flies. Perhaps the greatest

that transmitted pathogenic trypanosomes to livestock

natural control of the fly was the epidemic of rinderpest

led the way to understanding the role of arthropod

that started in Egypt and moved south at the end of

vectors in animal disease. The tsetse fly has been a *the nineteenth century. Not only were cattle killed, but*

major impediment to the development of a large part

there was a massive destruction of game animals and

of the continent and environmentalists would say that

hence a lack of food for the tsetse flies: e.g. rinderpest

this has been a good thing! With the rapidly increasing

eliminated the tsetse fly from the Limpopo valley

population in Africa and the need for more food it is

between Botswana and South Africa and in almost 100

essential that tsetse flies and ticks be controlled.

years the valley has not been recolonized. Human activ-

It has been known for many years that some animals

ity has an effect:

in a herd are more resistant to a specific disease than

• Clearing forests for timber or settlement destroys

others, and some more susceptible. Breeders have used

the habitat of the fusca group of flies (G. brevipalpis these characteristics and, as mentioned above, trypan-in particular).

otolerant breeds of cattle are found in west Africa. It

• Clearing the savanna has made the greatest impact

has been demonstrated recently that some cattle *on the morsitans group (G. morsitans and G.*

have an increased resistance to tick infestation. This

pallidipes). These primarily feed on game animals

increased resistance is associated with immune mecha-

and clearing the bush results in destruction of the

nisms. It has been said that the trypanotolerant Ndama

wildlife. At levels of human habitation in excess of

breed is more resistant because the animals are better

40 per square kilometre, the morsitans group dies

able to control the parasitaemia, although the mecha-

out completely.

nism by which this occurs has not yet been demon-

• *The palpalis group may be beneficially affected by*

strated. Resistance to Babesia bigemina (p. 748) has

human activity, as these are the flies of the river-

been shown to have more to do with resistance to the

bank, and it is rare for human activity to clear the

tick, than to the parasite itself. Resistance to tick infes-

bush by the side of rivers. Cattle graze on the

tation was first demonstrated in Australia. It was also

cleared land but pass through the riverine bush to *noted in Africa that indigenous breeds kept with exotic*

get to the river. The establishment of game parks

animals often showed much lower (down to 1/6) tick

has provided breeding grounds for tsetse flies and

burdens. It has been possible to breed cattle with

food for them to eat!

increased resistance to the one-host tick, but so far not

to the multi-host ticks.

Pesticides have been used to control the flies, by knap-

It is unlikely that tick resistance can be developed to

sack spraying the area of the flies' resting sites.

the point where there is no transmission of the proto-

Organochlorine compounds such as DDT and dieldrin

zoal diseases. Consequently a combination of resistance

were widely used and effective, with synthetic

with acaricide treatment will probably always be

pyrethroids taking over when the organochlorines were

required. Before deciding upon a programme of tick

banned. A more efficient form of spraying was from the

control by acaricides it is essential to know which ticks

air. Today with the rotary atomizers and night flying *are to be controlled, and when. For many years Malawi*

equipment, the spraying is much more efficient and in

had a policy of strategic dipping of cattle: in the north

the Okavango Swamp in Botswana, the use of endo-

of the country it was confined to the wet season when

sulphan has reduced the environmental contamination

the number of ticks increased dramatically. In the dry

– only 8 g per square kilometre are used and the drug

winter the tick burden was at a minimum and so the

targets the tsetse fly rather than other insects; so far as

gain was less than the cost. In areas of Africa where

is known, the only detrimental environmental effect

ECF is not a problem it is often not necessary to

that it has is to inhibit fish reproduction for a season.

attempt acaricide dipping or spraying of cattle. In areas

Tsetse flies can be caught in traps and although this

of Africa where ECF has been introduced, there may

was not successful at eliminating flies from an area,

be a mortality rate approaching 100 per cent, and then

work with traps led to the discovery that the flies are

it may be necessary to use chemicals to keep the tick *attracted by the colour blue. The use of odour to attract*

burden to a minimum. In the absence of ECF, there are

the flies only had limited success, but the development

two options: the first is to control the remaining tick-

of targets impregnated with insecticides has had a strik-

borne diseases by chemotherapy and vaccination and to

ing success. As the fly lands on the blue cloth it receives

ensure that the young animals are exposed to the infec-

a dose of insecticide.

Trypanosomosis

as the nutritional state of the host. Tissue lesions vary

with the species: T. vivax and T. congolense are mainly This disease occurs in humans, cattle (where it is known

intravascular parasites inducing changes in the

as nagana), camels, horses and pigs, but the infection

endothelium of the capillaries, wheareas T. brucei has occurs in most wild mammals. Trypanosomes are pro-an affinity for tissues. The anaemia seen in trypanoso-

tozoa that possess a kinetoplast and a flagellum and

mosis is caused by a multiplicity of factors including

require two hosts to complete their life cycle: a mammal *haemolysins and enzymes such as proteinases or phos-*

and an insect (in South America, chaggas the human

pholipases. The trypanosome attaching to the erythro-

disease is transmitted by blood sucking bugs). The try-

cyte makes it a target for the body defence mechanisms.

panosomes multiply in the mammalian host and, with

If the animal does not die in the acute stages it becomes

the exception of T. equiperdum which is venereally

progressively emaciated. Mixed infections tend to cause

transmitted, they are ingested by blood sucking insects:

more severe disease.

in Africa normally by tsetse flies. Multiplication within

In endemic areas the disease causes huge economic

the fly varies with the Trypanosoma species, but the

losses. Clinical disease is more commonly caused by T.

infective stage ends up either in the salivary gland or in

vivax and T. congolense; T. brucei causes much less the faeces. Other biting flies are able mechanically to

serious disease. However, there are no specific signs for

transmit the parasite to a new host.

trypanosomosis and they are dependent upon the

There are three major species that infect cattle: T.
degree of damage to specific organs and the severity of
brucei (p. 759), T. congolense (p. 758) and T. vivax (p.
the anaemia. Acute disease with death within two to six
758). The last has become established in South America
weeks is seen in animals introduced into an endemic
where there are no tsetse flies and so transmission is by
area, but chronic disease with the animal surviving
means of other haematogenous flies, and it is assumed
months or even years is more common. Acutely
that no development of the parasite occurs in these flies.
affected animals rapidly lose weight and all the classic
Trypanosomes multiply by longitudinal binary fission
signs of fever may be seen. In the chronic form the
in the fly and the mammalian host, although sexual
animals show periods of weakness and lethargy fol-
processes occur only in the fly. Mature trypanosomes
lowed by a recovery; the animal becomes pale with
are ingested by feeding flies and they undergo devel-
raised pulse and respiratory rates. Good nutrition may
opment in the salivary gland or gut. Development and

help an animal to throw off this chronic infection, but

maturation occur in the vector, after which the parasite

the more normal outcome is for the animal to become

is transferred to another mammalian host. Transmission

thinner and thinner. The infection induces immunosup-

is either by the presence of the trypanosome in the

pression, which can allow other infections such as

saliva or by contamination of the host's skin by try-

anaplasmosis to take over.

panosomes in the faeces of the fly.

It can be very difficult to diagnose this disease

A critical factor in the epidemiology of trypanoso-

because the parasites are not always present in the

mosis is that, once infected, a tsetse fly remains infected

blood and there are no specific clinical signs. Moreover

for life. The development of the parasite in the fly varies

there is no relationship between the number of parasites

from a few days in the case of T. vivax up to 45 days in and the severity of the disease. Trypanosomosis must be

the case of T. brucei. The role of game animals cannot considered to be a herd problem and so the presence of

be overemphasized; the present policy of game ranch-

parasites in the blood of a 'normal' animal should be ing in conjunction with rearing cattle and the increas- taken as significant. In many endemic areas there are ing numbers of game parks has increased the risk of inadequate laboratory services to assist in making the disease in cattle. Another significant factor in the epi- diagnosis and so many veterinarians consider that demiology of the disease is the use of trypanocidal response to treatment is a good way to confirm the diag- drugs, which may in turn lead to the development of nosis. Serological tests have until recently suffered from resistant trypanosomes.

an inability to produce specific antigens. However, the The pathogenesis is not completely understood: the indirect fluorescent antibody test and the enzyme- trypanosome multiplies at the site of infection and local linked immunosorbent assay have recently been intro- lymph nodes become enlarged, before the parasite is duced into the arsenal of tests used for making a herd found in the blood. Then the classic intermittent para- diagnosis, and monoclonal antibodies have been pro-

sitaemia ensues. As the parasites increase in number, so

duced to identify the three bovine species of try-

does the febrile response: as they decrease, so does the

panosome. The main problems in the differential

fever. The body mounts an immunological defence

diagnosis are with the other protozoan infections, i.e.

against the parasite and the trypanosome changes its

anaplasmosis (p. 761), babesiosis (p. 748) and East Coast

external antigens to defeat the host. The outcome of

fever (p. 750), however, in these diseases it is usually a

this battle often depends upon extraneous factors such

simple procedure to demonstrate the parasite.

The control of the infection by the use of drugs pres-

As with trypanosomes, so T. parva alternates

ents a continuing problem and the Veterinary Depart-

between its mammalian and invertebrate hosts. The

ments in many African countries control the use of

piroplasms in the erythrocytes of an infected bovine are

them to prevent the development of resistant strains of

ingested by the tick in its blood meal and these develop *trypanosomes. There is more to treatment than drugs via a sexual stage to a stage that invades the gut cells of and a good plan of nutrition is essential; all animals, and the tick. Further development results in a motile stage particularly work oxen, must be rested during conva- that invades the body cavity and migrates from there to lescence. One of the major problems facing trypanoso- the salivary gland, where large numbers of sporozoites mosis control is that today there are only four drugs are produced; these are the infective stage for the effective in treating the condition, the most recent of bovine, being injected when the tick feeds. Because which (isometamidium) was introduced in 1961; more- the vector is a three-host tick and because there is no over, no pharmaceutical company is working on this transovarial transmission the infection is transmitted by problem. Care must be exercised in using a combina- nymphs infected as larvae, or adults infected as nymphs. tion of drugs because some of the drugs have a com- Should an infected larva feed on a non-susceptible host bined toxicity greater than that of the individual drugs.*

there will be no transmission from the larva to the adult.

Because of the problems of drug resistance it is essen-

The disease affects only cattle, the African buffalo

tial that optimum use must be made of them, that is to

(Syncerus caffer) and the Asian water buffalo (Bubalis say they should be used in a strategic way whenever

bubalis). No other ungulates are infected and the par-possible to coincide with the local rainfall and hence

asite depends upon Rhipicephalus appendiculatus for

fly patterns. However, the most important factor is to

transmission. This tick is widespread in the warm humid

reduce the fly population and hence the parasite chal-

areas of Africa, and were the parasite to be introduced

lenge. The Zimbabwe Veterinary Department has made

to these areas the infection would be rapidly dissemi-

great strides in vector control going back over a period

nated. The peak incidence of the disease is just after the

of more than 50 years. This is well described by Connor

rainy season. Zebu cattle which carry low burdens of

(1994). Many countries in Africa have units within their

ticks rarely show clinical disease: they are infected as

Veterinary Departments (e.g. Botswana, Kenya, Ghana *calves and may show a febrile reaction with complete*

and Zimbabwe) devoted to testse fly control. However,

recovery; mortality is low. However, if susceptible

Basil Parsons, the Kenyan parasitologist, was of the

animals are introduced into this endemic area and

opinion that ‘when the last man leaves the African con-

become infested with ticks, acute disease will follow.

tinent, he will be bitten on the backside by a tsetse fly’.

The disease can be introduced into a clean area if an

infected animal is brought in or if conditions are

such that an area can be colonized by the tick. In the

East Coast fever *(see p. 750)*

absence of control measures, the mortality can reach 90

In 1965, the owner of a ‘high grade’ (mostly Jersey cross

per cent.

indigenous Kenyan cattle) herd of cattle went on

The disease is primarily one of the lymphatic tissue.

holiday leaving his manager in charge. Because they

The sporozoite enters lymph cells at the place of entry

were ‘high grade’ they had to be dipped in acaricide

and within a few days schizonts can be seen in the cyto-

every five days to prevent ticks introducing Theileria plasm of the cells. Lymphocyte proliferation occurs at parva parva (T. parva). Unfortunately the manager the site and within five days infected cells can be found allowed the fences to be cut and the neighbour's indige- in the drainage lymph node. Massive proliferation of nous cattle were able to mix. The farmer returned to lymphoblasts ensues and more distant lymph nodes, find 75 of his best heifers dead from East Coast fever spleen and thymus become affected. Finally all the (ECF). The infection is transmitted by the three-host parenchymatous organs become involved. Within a few tick Rhipicephalus appendiculatus and the disease is days lymphocyte proliferation is replaced by lympho- characterized by the multiplication of the lymphoblasts cyte destruction, resulting in immunosuppression. The infected with theilerial schizonts throughout the body. outcome of the disease depends upon the survival of The disease was first recognized in 1897 by Robert sufficient lymphocytes to effect an adequate immune Koch, who called it African Coast fever. Following the

response. Release of piroplasms which then invade the
ravages of rinderpest and the introduction of European
erythrocytes appears to have no specific pathogenic
stock in an effort to replace the dead animals, ECF
effects.
spread south from East Africa down to Cape Province
East Coast fever is characterized by fever with all its
in South Africa, killing more than one and a quarter
complications – lethargy, constipation or diarrhoea, res-
million cattle. The disease was eradicated by a process
piratory signs and abortion, together with enlargement
of dipping in acaricide, movement controls and destock-
of the superficial lymph nodes. Auscultation of the lungs
ing of infected pastures.
indicates severe pulmonary oedema. Because the ticks

live in the ears it is often the parotid lymph nodes that
in different places and so the famous ‘Muguga cocktail’
first show enlargement. Death occurs from five days to
was developed. This in turn has its problems, in that
three weeks after the onset. Exotic animals that recover

Directors of Veterinary Services are not happy to use

often become emaciated and can remain unproductive

live, virulent strains of Theileria parva from foreign for months.

countries and this means that it is not possible to

On post-mortem examination the three classic find-

produce the vaccine on a large, regional scale. The

ings are severe lymph node enlargement, a massive

vaccine is expensive and not without its problems and

pulmonary oedema and splenomegaly. Congestion

so it is only used by commercial farmers. Work to

and oedema can be found in any of the internal organs.

improve the vaccine using molecular techniques is in

Numerous small white foci may be present in the

progress.

kidneys, indicating lymphoid hyperplasia in the cortex.

Because of the behaviour of the tick and the parasite

There may be emaciation and subcutaneous oedema.

it is possible to control the infection by isolation of sus-

Diagnosis is confirmed by the examination of smears

ceptible cattle, but they must not be fed purchased hay

stained with Giemsa stain, of lymph node, spleen, blood

which might contain ticks. Tick control can keep ECF
or almost any organ. The presence of large lym-
at bay providing that mistakes are not made in dip
phoblasts is strongly suspicious: the presence of
strength or dipping interval. Leaving the pasture free
schizonts is conclusive.
from cattle for 18 months or more will 'sterilize' the
In some cases it is possible to observe lymphocytes
pasture because the parasite cannot survive that long:
containing schizonts in blood smears. It may not be pos-
the ticks will feed on other animals, but there will be no
sible to demonstrate schizonts in zebu cattle and so
transmission of the parasite and so it will die out. The
demonstration of rising titres of antibodies should
control of cattle movement is also a good way to halt
be made, using the immunofluorescence techniques.
the spread of the parasite. Because ECF control
Among the conditions to be considered in the differ-
requires a comprehensive infrastructure many coun-
ential diagnosis are rinderpest (p. 707), bovine virus
tries have employed communal dipping as a means of

diarrhoea (p. 853), contagious bovine pleuropneumonia

bringing the cost within the grasp of the smallholder. To

(Chapter 49(b)) and trypanosomosis (p. 750); the pres-

be effective, control measures for ECF need to be long

ence of the schizonts is conclusive. At the Veterinary

term, take into account the whole management of the

Research Laboratory, Kabete, Kenya, in the mid 1960s,

herd and the farmer must be eternally vigilant.

each morning the staff were confronted by a line of men

This account has concentrated on the disease caused

with bicycles, in the baskets of which were a selection

by Theileria parva parva; however, this is not the only of viscera from a dead animal. The farmers were only

theilerial disease. Corridor disease caused by Theileria

interested to know whether or not the animal had died

parva lawrencei was first seen in Zimbabwe and is an

from anthrax (if not, then they could eat the meat!);

infection transmitted by ticks from the African buffalo.

most animals had died from ECF.

It is indistinguishable from ECF. Zimbabe theileriosis,

Although tetracyclines have some effect against T.

caused by Theileria parva bovis, is also clinically indis-parva they are only consistently effective during the tinguishable from ECF, but is treatable with tetracy-incubation period. The development of parvaquone,

clines and shows differences in its epidemiology. The

napthoquinone and febrifugene has resulted in success

cause of 'turning sickness' (p. 752) is a theilerial para-

rates for treatment of over 90 per cent. However, some

site but its identity is in doubt. The disease is manifested

animals may remain carriers following treatment.

by nervous signs and infected lymphocytes can be found

Because immunity to the natural disease persists for

in the brain. None of these conditions has the economic

more than five years, there has been a massive search

importance of ECF.

for a vaccine and millions of pounds have been invested

in this work at the Veterinary Research Laboratory,

Kabete, the Kenya Agricultural Research Institute (for-

Plant poisonings

merly East African Veterinary Research Organisation),

Muguga, and latterly at the International Laboratory

The foreword to Plant Poisonings and Mycotoxicoses of

for Research on Animal Diseases (now ILRE), all in

Livestock of Southern Africa (Kellerman et al., 1990) Kenya. The vaccine consists of injecting a controlled

says it all!

number of sporozoites obtained from schizonts, origi-

nally from infected ticks but now from tissue culture,

'Southern Africa is well known for the diversity and

and then following this with treatment; initially a tetra-

beauty of its flora. It is perhaps ironical, but not entirely

cycline was used but today the newer drugs have taken

unexpected that the sub-continent should be "blessed"

its place. Because the vaccine is only effective against

with a possibly unequalled variety of poisonous plants

homologous strains different preparations must be used

and toxic fungi.'

'About 600 indigenous poisonous plants are known to

Massive losses occur from this plant; in the Maun

occur.'

District of Botswana in 1984 one farmer lost 34 animals

'In this part of the world, where livestock are tradi-

(10 per cent of his herd) and more than 700 cattle

tionally kept under extensive conditions on veld that is

deaths were reported in the District. At the same time

frequently denuded by droughts, overstocking and

in the Chobe Game Park more than 70 buffalo were

uncontrolled fires, the animals are often forced to eat

found dead by the side of the Chobe River. If the

poisonous plants which they would normally avoid.

farmer sees his animals eating mogau he can save

Devastating outbreaks have been reported under such

them by restricting their access to water for 24 hours.

conditions, for instance, during 1926–27 about 600,000

Because of its nature Dichapetulum cymosum is even

sheep died of plant-induced photo-sensitization in the

more difficult to eliminate from the pasture than

north western Cape Province and during 1929–30 over

Pavetta.

one million were killed by Geigeria spp., in Griqualand A plant that is found throughout Africa and beyond

West.'

is the castor oil shrub Ricinus communis (Euphor-

biaceae). It has been grown as both a crop plant and as It is only possible to give a few examples with a view *an ornamental plant in gardens because of the striking to stimulating the reader to carry out his own leaves and its red stems. The toxic principle is ricin, a researches. Among many strange poisonings, perhaps toxalbumen, that is immunogenic and so repeated the most odd is that caused by Pavetta harbori ingestion of small doses produces immunity. Ricin is (Rubiaceae) (gousiekte). The original report concerned found in all parts of the plant, but particularly in the a mob of fat cattle waiting in the holding pens at the seeds. Pure ricin is one of the deadliest substances railside of Mahalapye Station, Botswana. The train known to man (Georgi Markov, the Bulgarian refugee, came into the station, sounded its horn and 18 beasts was murdered by this poison being injected from an dropped dead. The author found it hard to believe until umbrella on London Bridge!). The toxin is not so he had a similar experience (on a much smaller scale): potent when ingested and the author remembers seeing when he was investigating an outbreak of this disease, an outbreak in Kenya in which 25 yearling dairy heifers* *he drove into a kraal, shut the door of his truck and a*

were involved. All recovered, but the moment they

fat bullock in excellent condition dropped dead. A post-

were turned back into the field they went straight back

mortem examination revealed no gross abnormalities.

to the plant and started eating it: they were removed

There had been a severe drought and the only green

from the field. The classic signs of the disease are a

plant on the range was Pavetta harborii and the animals profuse watery, haemorrhagic diarrhoea, accompanied

had been eating it for several months. The lesions pro-

by inappetence, pain and bellowing. The normal post-

duced by this plant are caused by one or more cardiac

mortem picture is of a severe haemorrhagic gastroen-

glycosides and produce a diffuse hyaline degeneration

teritis. Since there is no way to demonstrate ricin, it is

and necrosis of heart muscle, with the muscles being

essential that a careful examination of the rumen con-

replaced by fibrotic tissue. There is no treatment for this

tents be made for the seed or leaves. The best means of

condition and the only control is by preventing access *control is to keep the animal away from the plant.*

to the plant. Since there are few farm fences in

This is just a small sample of the 'unequalled variety

Botswana the only remedy is to dig up the plants – a

of poisonous plants' that are found in Africa. For those

forlorn hope.

whose interest has been stimulated, the books by

A second plant which kills by means of a cardiac

Kellermann et al. (1990) and Watt and Breyer-Brand-

poison is Dichapetulum cymosum (Dichapetalaceae)

wijk (1968) make excellent and entertaining reading.

(Mogau [Tswana] or gibflaar [Afrikaans]),

the

toxic principle of which is monofluoroacetate. In

the rumen this is converted into fluorocitrate which

Conclusion

interferes with the Krebs cycle. The plant has been

likened to an underground tree: the tips of the branches

In conclusion it must be said that only a small number

protrude above the soil while the vast majority of

of diseases have been discussed from a continent of infi-

the plant is underground, making it very difficult to

nite varieties. There are virus diseases such as lumpy

eliminate. Unlike Pavetta, mogau is an acute poison

skin disease (p. 887) or bovine malignant catarrh (p.

which acts within four to 24 hours of ingestion, but as

935); there are protozoal diseases such as elephant skin

with Pavetta the animal drops dead without any pre-

disease or Ondiri disease (p. 763), rickettsial diseases

monitory signs. There are no post-mortem lesions and

such as heartwater (p. 765). There are many, many prob-

there are often no histological lesions. The only way to

lems and the governments have no money to control

confirm the diagnosis is to demonstrate the leaves in the

the major diseases, how much less these minor infec-

rumen.

tions. Africa is in need of our help.

Further reading

Koch, R. (1903) Interim report on Rhodesian redwater or

'African coast fever'. Journal of Comparative Pathology and

Parasitic diseases

Therapeutics, ***16***, *273–80.*

Theiler, A. (1904) East Coast fever. Transvaal Agricultural An excellent text covering all aspects of disease vectors with Journal, ***2***, *421–38.*

good diagrams and maps is:

Modern papers on various topics are given below:

Coetzer, J.A.W., Thomson, G.R. & Tustin, R.C. (ed.) (1994) Brown, C.G.D., Malmquist, W.A., Cunningham, M.P., Radley,

Infectious Diseases of Livestock with Special Reference

D.E. & Burridge, M.J. (1971) Immunization against East

to Southern Africa. Vol. 1, Section 1, 3–163, Oxford Univer-Coast fever. Inoculation of cattle with Theileria parva

sity Press, Cape Town. various authors and topics on this

schizonts grown in cell culture. Journal of Parasitology, theme.

57, *59–60.*

Chema, S., Chuomo, R.S., Dolan, T.T., Gathuma, J.M., Irvin,

Trypanosomiasis

A.D., James, A.D. & Young, A.S. (1987) Clinical trial of

halofuginone lactate for treatment of East Coast fever in

Connor R.J. (1994) African animal trypanosomiasis . In Infec-Kenya. Veterinary Record, ***120***, *575–7.*

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ern Africa (ed. by J.A.W. Coetzer, G.R. Thomson & R.C.

Africa. International Laboratory for Research on Animal

Tustin), Vol. 1, pp. 493–552. Oxford University Press, Cape

Diseases, Nairobi, Kenya.

Town.

Murray, M., Morrison, W.L., Murray, P.K., Clifford, D.J. & Trail, J.C.M. (1979) Trypanotolerance – a review. World Animal

Plant poisonings

*Review, **31**, 2–12.*

Murray, M. and Dexter, T.M. (1988) Anaemia in bovine

The classic modern text, which is brilliantly written and

*African trypanosomiasis . Acta Tropica, **45**, 389–432.*

superbly illustrated, is:

Nantylya, V.M. (1990) Trypanosomiasis in domestic animals.

Kellerman, T.S., Coetzer, J.A.W. & Naudé, T.W. (1990) Plant The problems of diagnosis. Revue Scientifique et Technique Poisonings and Mycotoxicoses of Livestock of Southern

*de l'Office International des Epizooties, **9**, 357–67.*

Africa. Oxford University Press, Cape Town.

Apart from this the only book required is a good flora and the

East Coast fever

finest, although old, is:

Watt, J.M. & Breyer-Brandwijk, M.G. (1968) The Medicinal For an early description of the disease see the reports of Koch and Poisonous Plants of

Southern and Eastern Africa, 2nd or Theiler:

edn., E. & E. Livingstone, Edinburgh.

Chapter 70

Rabies

R.S. Windsor

Introduction

1164

***Aetiology** (see p. 908)*

Aetiology

1164

Epidemiology

1165

Europe

1165

Rabies virus belongs to the family Rhabdoviridae and

Africa

1165

is classified as a lyssavirus, from the Greek word for

North America

1165

rage. In recent years the rabies-related viruses have

The Caribbean, Central and South America

1166

been added to this genus. Today the rabies virus is

Asia

1166

Transmission

1166

referred to as lyssavirus serogroup 1: the Lagos bat,

Pathogenesis

1167

Mokola and Duvenhage viruses are serogroups 2, 3 and

Clinical signs

1167

4, respectively. What previously was thought to be a

Necropsy and pathological findings

1168

single, simple agent has been shown to belong to a

Diagnosis

1168

complex grouping. Studies using monoclonal antibod-

Differential diagnosis

1169

ies have shown that within a given geographical area

Vaccination

1169

the virus adapts to its environment, resulting in distinct

Control

1170

biotypes. Despite this, the antigenic structure of rabies

virus has remained stable, which is a boon for diagnos-

tic workers.

This is not the place to discuss the structure of

Introduction

the virus: suffice it to say that it is bullet shaped, and

contains a single-stranded genome of RNA and five

Rabies is the most feared of all diseases. Once humans

structural proteins. Following attachment to a cell the

show signs of disease, they die. This virus disease affects

ribonucleoproteins are released and act as a template

all warm-blooded vertebrates and is usually transmit-

for replication in the cytoplasm. These accumulations

ted by the bite of a carnivore. The virus enters the *of viral proteins in the cytoplasm give rise to the bodies*

peripheral nerves and spreads to the spinal cord and

described by Negri.

brain, a process that might take several months. The

The rabies virus is delicate and is destroyed by

nervous disease that ensues may last from a few days

sun and ultraviolet light, heat and many of the common

to several weeks before the animal dies. In humans one

disinfectants, e.g. 0.2 per cent quaternary ammonium

of the characteristic signs is a fear of water – hence its

compounds. However, it remains viable in nerve tissue,

alternative name of hydrophobia.

the length of viability depending upon temperature

The disease appears to have had a wide distribution

and storage conditions.

since time immemorial, but it was Louis Pasteur

Because of the work of Pasteur, rabbits were used as

who demonstrated the association between the causal

laboratory hosts for experimental work up to the

agent and nervous tissue. By serial passage in

Second World War, since which time the mouse has laboratory animals he transformed the field ('street')

been the principal experimental animal. At the same

agent into a 'fixed' agent with a shortened reproducible

time the virus was adapted to grow in embryonated

incubation period. Not until the twentieth century

eggs; these were later used to produce very successful

was it shown that the agent of rabies was a virus which

vaccines for use in animals. In 1958 the virus was first

could pass filters that retained bacteria. And in the

grown in tissue culture and there is a multiplicity of cells

same year, 1903, Negri demonstrated the intracytoplas-

in which the virus will grow. The rabies-related viruses

mic inclusions in the nerve cells of infected animals.

will also grow in tissue culture. Recently the human

These Negri bodies form the basis of diagnosis even

diploid cell line has been used for the production of a

today.

very successful human and animal vaccine.

Epidemiology

(1)

The urban dog cycle: in the towns dogs spread the

disease which can spill over into other species,

It is mostly island countries that are reported to be free

most commonly man. Cattle are not involved in

from rabies infection – Great Britain, Ireland, Malta,

this cycle.

Cyprus, New Zealand, Australia, Japan, Fiji and certain

(2)

The jackal cycle: this is the rural cycle with the

Caribbean islands. Some mainland countries are also

disease spreading between the black backed

free from the infection – Denmark Portugal, Spain,

jackal (Canis mesomelas) and being transmitted to

Sweden, United Arab Emirates and South Korea. These

cattle, small ruminants, wild ungulates and man. It

are not exhaustive lists but the majority of the countries

is jackals that infect most cattle.

in the world have endemic rabies.

(3)

The mongoose cycle: this is seen in the yellow *mongoose in south eastern Botswana. The disease*

mostly cycles within the burrows of these animals

Europe

but can affect wild and domestic cat populations.

Rabies has been known and feared here since time

The domestic cat is responsible for most human

immemorial. Dogs, foxes and wolves have all played

infections in this part of Botswana. Cattle are not

their part in the spread of the disease. From the end of

involved in this cycle.

the second world war rabies in foxes has become a

(4)

The kudu cycle: this is really a Namibian problem

serious problem with the disease moving westwards and

but may involve Botswana. The kudu (Tragela-

eastwards from Poland, reaching France in 1968. Vacci-

phus strepsisteros) outbreak was responsible for

nation and rigorous control of urban dogs has reduced

the death of more than 30 000 kudu between 1975

the disease dramatically in the past 30 years. The

and 1985, but still continues. The disease spreads *upsurge of rabies in foxes has resulted in an increase in*

from kudu to kudu: herbivores are normally

the disease in cattle; until today cattle rabies is more

thought to be 'dead end' hosts because they do not

common than dog rabies. However, human rabies has

spread the disease. Kudu groom each other, which

been on the decline for many years and today it is a

may account for this atypical spread.

rarity in Western Europe. The move to reintroduce the

In East Africa the disease was first confirmed in 1912,

wolf into Scotland has been halted for the time being

with intermittent outbreaks until the 1960s. The war

by the fear of rabies.

with Somali insurgents after Kenya's independence

resulted in wholesale destruction of the herbivores in

Africa

the northern districts of Kenya. The jackals and hyenas,

being deprived of their prey, moved into the villages

It is likely that far more rabies occurs in Africa than is

and there was an upsurge in human and dog cases.

reported. In the 1960s rabies was mostly controlled

Jackal and urban dog cycles remain a problem to this

throughout the continent. War, strife and the break-

day throughout east Africa. However, disease in cattle

down of veterinary services have resulted in an upsurge

is not a major problem. In central southern Africa,

of the disease, but less disease is being reported from

rabies is a problem in cattle when the jackal population

many countries. There is some debate about whether

is allowed to increase.

rabies existed in subSaharan Africa or whether it

Non-fatal rabies-like disease is seen in west Africa and

was introduced by the European colonists. The answer

classical rabies does occur. The author will never forget

is probably both: as will be seen below there is some

walking into a house in northern Nigeria to find a mother

evidence of virus modification in west Africa.

protecting her children from a rabid dog that had

The first outbreak of rabies confirmed on the African

entered the house. After dogs, cattle are the animals

continent was in the Cape Province of South Africa

most commonly seen with rabies in West Africa.

in 1892 in a dog imported from England that spread

In the countries bordering the Mediterranean, rabies

the infection to dogs, cats and cattle. The outbreak was

has been known since time immemorial: it is primarily

controlled and the disease was not confirmed again

a disease of urban dogs, but it spills over into herbi-

for more than 30 years. A rabies-like disease affecting

vores, including cattle, and humans. The Saharan coun-

mongeese and humans on the western side of the

tries are sparsely populated by animals and man and in

country was known and, in 1928, rabies was confirmed

consequence rabies is not a major problem in countries

in two children bitten by a yellow mongoose (Cynictis

such as Mali, Niger or Somalia.

penicillata). Since then rabies has been regularly

diagnosed throughout South Africa.

North America

Although suspected for many years, rabies was not

confirmed in Botswana until 1938. Workers in Botswana

Was rabies endemic in America or was it brought by the

believe that there are four manifestations of rabies:

Europeans? The latter may hold good because the

disease was not seen until the middle of the eighteenth
animals occur from Mexico to Perú and are responsible
century. It is also possible that the disease came across
for huge losses in the cattle population: some authori-
the Arctic at the time of the human and animal migra-
ties quote annual losses of half a million for South
tion when the Baring land bridge existed. The disease
America alone. It has been thought for many years that
is well reported in Eskimo folklore. It was not common
vampire bats are 'true carriers' of the disease, in that
in the USA until the civil war, after which it increased
they can be infected without being affected and yet
in dogs on a regular basis until the end of the second
still be capable of transmitting the infection. Recent
world war. With increasing vaccination of dogs and con-
work suggests that this is not so and that the bats have
sequent decrease in the number of cases there has been
a variable length of incubation period before they
a concomitant increase in the amount of sylvatic rabies.

succumb. The urban dog cycle is seen in the large South

Today there are approximately 4000 cases of rabies a

American cities, but it is not important to cattle rabies.

year in the USA, of which almost 90 per cent is in wild

animals (bats, foxes, raccoons and skunks being the

Asia

animals principally affected); domestic cats and herbi-

vores (including cattle) make up the remaining 10 per

There are many Asian countries with huge cities as in

cent of cases. The number of cases of rabies in cattle has

South America, and again urban dog rabies is a serious

remained static over the past 30 years, during which

problem. As a result, India has an enormous human

time the disease in dogs and cats has been decreasing,

death toll: some authorities put it as high as 25 000 a

thus demonstrating that it is not the urban dog cycle

year, although this figure is disputed. There is little hard

that involves cattle. Cattle rabies occurs most fre-

evidence of the level of infection in the dog population

quently in those states that have the highest levels of

in any of these poor Asian countries; there is even less *skunk rabies (Iowa, Texas and Minnesota), indicating*

information on the incidence of the disease in the cattle

that it is this sylvatic cycle that involves cattle. The

populations. More is known about the disease in India

decrease in urban dog rabies with an increase in the

than in other Asian countries and jackal and mongoose

sylvatic cycle has also been seen in Canada.

cycles are known to occur.

It has been said that some wild species of mammal

are natural or 'reservoir' hosts for the virus and that the

rabies virus persists in these animals without inflicting

Transmission

harm until the virus is transferred to a different mam-

malian host. The extension of this theory is that the

Rabies is normally transmitted by a bite, but not all

infection will not be controlled in domestic animals

animals bitten contract the infection. Although the

until it is controlled or eliminated from these hosts.

virus is present in the salivary glands of infected carni-

Bats present another problem. In addition to the role

vores for several days before the animal shows signs *of vampire bats in the spread of rabies (an important*

of disease, it is not normally secreted in the saliva

cause of the disease in cattle), 30 of the insectivorous

until clinical signs are apparent. There is no convincing

species of bats have been shown in the Americas to be

evidence of a species' susceptibility to rabies other

infected with the true rabies virus (lyssavirus 1). It was

than epidemiological data. Despite this animals have

originally thought that all true rabies viruses belonged

had their susceptibilities rated, as in Table 70.1.

to a single strain. However, recent work has suggested

The site and severity of the bite is also important: the

that there are species-specific biotypes of the virus.

nearer the brain, the more rapid the onset. Non-bite

transmission is not common. Transplacental transmis-

sion has been demonstrated in cattle, dogs and humans.

The Caribbean, Central and South America

There are reports of oral transmission from dam to

The introduction, from India, of the grey mongoose

offspring in humans and sheep via the milk. The only

(Herpestes auropunctatus) in an attempt to control rats and snakes in the sugar

plantations has not been an

unequivocal blessing. It soon became the principal car-

Table 70.1

Susceptibility to rabies.

nivore on the islands. Today almost 50 per cent of the

mongoose population has antibody to rabies virus in its

Very high

High

Moderate

Poor

blood. Rabies has been eradicated from many of the

islands but the mongoose population presents a serious

Foxes

Cattle

Humans

Opossum

Jackal

Cats

Primates

threat should the virus be reintroduced. In Mexico the

Coyotes

Skunks

Dogs

major problems are urban dog rabies and vampire bat

Rodents

Sheep/goats

rabies. The vampire bats are of several different genera

Mongoose

Horses

but the most important is Desmodus rotondus. These

Rabies • 1167

species in which this is a significant route of transmis-

cation has commenced there is transport of particles of

sion is the kudu, which transmits the infection by

the genome along the axon to the central nervous

licking. There has been a report of aerosol transmission

system. Viraemia can occur but it is thought to be of

of rabies virus to two humans in a bat-infested cave in

importance only in animals with damaged immune

Texas, which was confirmed by placing animals in

systems or pregnant animals. The mechanism of spread

insect-proof cages in the cave. Transplantation of *from neuron to neuron is not properly understood, but*

corneas from cadavers to patients has resulted in the

the genomic material may complete its maturation or

transmission of the disease.

there could be direct transmission of the genomic mate-

The study of the outbreak in foxes in Western Europe

rial at the synaptic junctions. Once it reaches the brain

over the past 30 years has shown that normally the

the spread there is rapid, although adjacent structures

infection spreads from one family group to its neigh-

are thought to be the first affected. The accumulation

bour, with the occasional jumping of a group. Because

of virus in particular parts of the brain is thought to be

fox ranges are much larger in Canada than in Europe,

responsible for the clinical signs. Once the virus reaches

the disease spreads more rapidly there – up to 100 km

a particular site in the cord the virus can travel in a cen-

a year compared with 20–60 km here. Within a wild

trifugal direction out to the tissues. Thus the virus can

animal species it is thought that the disease spreads at

be found in a range of tissues and organs. However, it *a rate related to the number of animals available. As*

is thought that the spread to the salivary glands occurs

the disease kills them so there is less opportunity for

once the virus spreads within the brain.

spread and the disease becomes quiescent. The number

Emaciation or failure to thrive is often seen and this

of cases in cattle can indicate the weight of infection in

is caused by damage to the hypothalamus and interfer-

the predator.

ence with the production of growth hormone. Cell

The level of urban rabies in a population is controlled

mediated immunity is suppressed. Post exposure vacci-

by the size of the city and the numbers of dog, the socio-

nation is known to be effective, but the mechanism is

economic status of the people and the efforts of gov-

still not definitely understood. However, the production

ernment to control the disease. Rabies was a serious

of virus neutralizing antibody correlates with resistance.

problem in Lima until the Veterinary Department sup-

Passive antibody has been shown to be effective in

ported by the World Health Organization instituted *animals that have been infected, if given in large*

effective vaccination campaigns.

enough doses. While it is in the nervous system it

The understanding of the pathogenicity and spread

seems that the virus does not stimulate the immune

of rabies-related viruses is as yet incomplete and any-

mechanisms but once it has passed into the non-

thing that muddies the waters of rabies control needs

nervous tissues, antibody production is stimulated. It is

investigation. One of the problems is that rabies-related

then too late to help the animal.

viruses have been isolated from domestic animals vac-

Recent workers have suggested that the pathogenic-

cinated against rabies. There have also been cases of

ity of rabies is eminently suitable for the persistence of

rabies-related viruses in humans that have no history of

the virus and the spread of the disease. The virus is

a bite by a wild animal. Rabies-related viruses have

hidden from the immune system until it is too late. The

been demonstrated in bats in Australia, where rabies

distribution in the brain spares the neocortex and *has never occurred. Recently, bats infected with these*

results in behavioural changes that promote confronta-

viruses have been found in Britain; they are thought to

tion between rabid and healthy animals and these

have come from Europe.

changes coincide with the arrival of the virus in the sali-

vary glands. The high mortality ensures that there is a

minimal accumulation of immune individuals in the

Pathogenesis

population and the occasional long incubation period

ensures that the virus survives until there are sufficient

A skin wound following a bite from an infected animal

susceptible individuals present in the population!

is the common route of entry of the infection, hence the

common route of entry of the virus is the sensory nerve

endings in the affected area. With deep bites the virus

Clinical signs

enters the stretch proprioceptors of the muscle or the

motor nerve endings in the muscle. The virus is thought

Man

not to enter through the cut surface of damaged nerves.

Both sensory and motor nerves may be infected. Exper-

The incubation period in humans varies from a week to

imental work has shown that the virus multiplies at the

a reported 19 years. However, only 15 per cent of cases

site of infection and that it remains there for some time

have incubation periods in excess of 90 days. Non-

(more than two weeks in some cases). Once viral repli-

specific signs are the first to develop: malaise, headache,

anorexia, nausea or diarrhoea. Some patients experi-

anorexia and docility. Usually there is a drop in milk

ence pain or itching at the site of the wound. This is

production and bulls become more sexually active.

followed after a few days by the acute, agitated form

After a few days the aggressive phase may begin with

of the disease: the patients are excitable, rush about and

the animal attacking anything. A fixed stare may be

undergo convulsive seizures which occur at random or

seen and the animal grinds its teeth. Inability to swallow

following stimulation. They become unable to swallow

in many African animals results in saliva running from

and this is followed by hydrophobia. Death may super-
the mouth and you put your arm down the throat to
vene in about 10 days or the patient may slowly develop
relieve the choke at your own risk! Salivation occurs in
paralysis and pass into a coma before death. A small
less than half the bovine cases in the USA. As the
percentage of patients develop signs similar to the
disease continues, paralysis of the tail is seen, posterior
dumb form of dog rabies. There is a gradual onset of
paresis and a swaying gait are noted and the animal
paralysis; once the respiratory muscles are affected the
bellows. Loss of condition ensues and the animals go off
patient dies. There are only three recorded cases of
their legs, develop paralysis and between bouts of
humans recovering from clinical rabies, all from the
convulsions go into a coma and die. In north west
New World.
Argentina a completely dumb form of the disease is
seen in cattle, with the animal showing progressive
paralysis. Other domestic animals show variations on
Dog

the pictures described above.

In the dog the incubation period is commonly two to

The classic sign of rabies in wild animals is the loss of

eight weeks, although there is a record of a dog

fear of humans. This was very dramatically seen in the

imported into Britain that developed rabies eight

kudu outbreak in Namibia in which the animals would

months after it arrived. It is likely that the prodromal

walk into houses. Jackals become very friendly but have

period seen in humans occurs in dogs but is recognized

sudden mood swings. Wild cats become more aggres-

by few owners, after which the dog passes into the

sive with rabies, although even some of these animals

classic 'furious' phase, showing nervousness, restless-

become docile. Most humans bitten by rabid mongeese

ness and exaggerated response to stimuli. Self-infliction

are bitten while handling these animals, thinking that

of injury at the site of bite is not uncommon. They may

they are tame.

attack anything – human, animal or inanimate objects

– and some will eat anything, including stones and

lumps of wood. There is no forgetting the look in the

Necropsy and

dog's eyes: a fixed stare or a far-away look which is dif-

pathological findings

ficult to describe. They may howl between the convul-

sive seizures and they often die during a seizure, or

No consistent macroscopic lesions are seen. There may

paralysis ensues, the animal passes into a coma and dies.

be emaciation and self-mutilation. The histological find-

Dogs that develop the dumb form of the disease may

ings are, however, consistent in the central nervous

show periods of furious activity. The muscles of the jaw

system. There is perivascular cuffing, focal and diffuse

are often the first to be affected and so the dog lies with

gliosis, neuronal degeneration and intracytoplasmis

its mouth open. The dog is unable to eat and many

inclusion bodies from 2 to 8 mm in diameter: these are

owners suspect that the dog has a bone in its throat.

the acidophilic Negri bodies. There is a marked species

Argentine veterinarians believe that the disease is

difference in the presence and distribution of these *caused by two different strains of the virus: the furious*

bodies. In the Ammon's horn (the usual place to look

form by the strain involved in the urban dog cycle and

for such bodies) the number of bodies in humans and

the dumb form by animals involved in the fox cycle.

dogs is variable. In herbivores, particularly goats and

donkeys and to a lesser extent cattle, large numbers of

Cattle

Negri bodies of variable size are found. In cats,

Ammon's horn is a poor source of Negri bodies and

Much less is known about rabies in cattle than in either

so it is more common to make the smears from the

humans or dogs. The incubation period is said to be

cerebellum.

between two and 12 weeks (three to 21 weeks in the

USA). Where the disease is transmitted by jackals it

is not uncommon to find several animals affected at

Diagnosis

one time (although this was not the experience when

the infection was introduced into Ghanzi District in

The history and origin of the animal will suggest the

Botswana, where the single animal was the norm). The

possibility of rabies and abnormal behaviour of any sort

affected animal separates itself from the herd, shows

should lead the clinician to suspect rabies. In most

countries rabies has to be reported to the state or

carried out on samples that were negative to the FAT.

national veterinary authorities. If they suspect rabies as

Histological examination was abandoned. Recently an

the cause of the problem the normal action is to keep

ELISA test has been developed which apparently gives

the animal under observation for up to 10 days and to

similar results to the FAT. The results can be read with

kill it for laboratory diagnosis if the disease is sus-

the naked eye and thus an accurate diagnosis can be

pected. With the advent of the fluorescent antibody test

achieved without the need for expensive equipment.

it is no longer necessary to wait for clinical disease to

Viral tissue culture, the detection of viral nucleic acid

progress before the animal is killed for examination.

and serological tests are not used in diagnostic labora-

This is particularly so with wild animals or animals of

tories but are restricted to research and investigation

unknown ownership.

laboratories. Monoclonal antibodies have been used in

The animal should be killed in such a manner that the

the identification of the rabies-related viruses.

brain is not damaged; it should be divided sagittally into

two halves, one half should be immersed in a large

quantity of 10 per cent formol saline (histological exam-

Differential diagnosis

ination) and the other half should be put into a large

jar of glycerol-saline (viral examination). Both jars are

There are many diseases that can be confused with

placed in a special container with sufficient absorbent

rabies in different animals. Distemper and canine

material to soak up the liquids should the bottle break;

hepatitis are the most common infections in dogs,

the parcel should be sealed and all should be sent to

heartwater (p. 765), cerebral babesiosis (p. 748),

the laboratory. In Botswana, where there were daily

cerebral theileriosis (p. 750), meningoencephalitis *temperatures of up to 40°C, samples that were delayed*

caused by Haemophilus somnus (p. 907) and BSE in

for a week en route could still be examined with a good cattle and parasites and toxic plants and chemicals in all

chance of success.

species. One should first eliminate rabies and BSE and

The tissue in formalin is used for making histological

then proceed to the differential diagnosis.

sections and, in negative cases, may often help to

confirm a differential diagnosis, e.g. babesiosis in cattle

and distemper in dogs. Smears are made from the

***Vaccination** (see p. 1018)*

Ammon's horn and can be stained by Seller's stain

(a Romanovsky stain) in which the eosinophilic bodies

Pasteur produced the first vaccine by suspending spinal

stain pink. This technique is rarely used today because

cords from infected rabbits in an atmosphere of sodium

it has been replaced by the use of the fluorescent

hydroxide for various periods of time. The drawback to

stained antibody test in which the smears along with

this vaccine (used for many years) was that the patient *control positive and negative smears are stained and*

had to receive 14 injections on a daily basis. There was

examined under the ultraviolet light micoscope. A

also the possibility of the patient developing a neu-

definitive test is to make a suspension of the brain and

ropathy (paralytic neuritis) following vaccination. The

inject this into the cranium of sucking mice. If rabies

next vaccine was produced in sucking mice because

virus is present, the mice will die within 30 days and

these immature creatures have less myelin, so reducing

Negri bodies can be demonstrated in their brains.

the risks of auto-antigenicity. Hen (for animals) and

Unpublished results from Botswana show the relative

duck (for human) eggs were the next vaccines produced

value of these tests (Table 70.2).

and both were used extensively for upwards of 20 years.

Complete comparability between the fluorescent

In some African countries the Flury strains are used to

antibody test (FAT) and the biological tests was demon-

this day and they work well – high passage for cats and

strated. Following this work, biological tests were only *cattle and low passage for dogs. Today the vaccine most*

Table 70.2

Results of all brains examined over a period of three years.

Positive

Negative

FAT

Biological

Histological

FAT

Biological

Histological

207

207

156

235

235

286

FAT, fluorescent antibody test.

commonly used in man and animals is the human

lation such slaughter may be counterproductive: rapid *diploid vaccine. Post exposure treatment of humans in*

reproduction will soon increase the numbers and all the

Botswana is given on days 0, 4, 7, 11, 17 and 84.

increase will be susceptible. Cats are not usually vacci-

Oral vaccines have been developed for use in the

nated because they play less part in the disease cycle.

control of the disease in wildlife, particularly for foxes

In countries where there is movement of animals then

in western Europe. It has been shown that foxes will

some form of permanent marking or certification is

take chicken head bait laced with the vaccine in a

required. Although the modern vaccines produce

capsule. This has proved very successful in controlling

immunity that lasts for three years it is normal practice

the disease in foxes. So far it has not been extended to

to mount a vaccine campaign on a yearly basis. Move-

other species of wild animal. Future research will

ment control from the affected areas is practised and

undoubtedly be into the production of recombinant

only vaccinated dogs are permitted to leave the area. It

vaccines using harmless viruses: in this way it might be *is considered that an area can be considered rabies-free*

possible to vaccinate all species of wild animals that

if there has been no case of the disease in the last two

carry the rabies virus.

years.

In Botswana, cattle owners are not permitted to vac-

cinate their cattle against rabies. A susceptible cattle

Control

population acted as a marker for the infection of

jackals. The economics of vaccinating cattle in Africa

In Britain, as in many other islands free from infection,

are such that the farmer would not recoup the cost of

the perfect control measure was in place, namely the

the vaccine as it is cheaper to let the odd bovine die.

prohibition of importation of carnivorous animals

This is not the case in South America where the

unless they underwent six months' quarantine. This was

vampire bat can wreak havoc in a herd. The author

changed in 2000 to a system of movement controls and

knows of no country in South America that has a policy

vaccination. It is interesting to speculate when the first *of cattle vaccination: it is left to the individual owner.*

case of rabies will be diagnosed in Britain. Most coun-

The presence of rabies-related viruses in a country

tries in the world have laws in place to control this

complicates the control of rabies. It is known that with

disease. These vary from the strictest in Australia, where

some viruses the rabies vaccine provides some protec-

carnivores may only be imported from countries free

tion and so this has been used in human patients bitten

from infection and they are still required to be kept in

by bats. In the National Veterinary Laboratory,

quarantine for six months, to poor countries such as

Botswana, it was the policy that staff were not routinely

Tanzania where almost nothing is done (there were 400

vaccinated against rabies. It was thought that confi-

human deaths in the Mwanza region a few years ago

dence would breed carelessness. It was known that

because there was no money to buy vaccine!).

pre-exposure vaccination even with the tissue culture

What is needed to control the disease is an efficient

vaccine would not give adequate protection, if it were *laboratory to diagnose the infection and an efficient*

not followed up with post exposure vaccination. Over

veterinary service to undertake field studies to deter-

the years several staff members received the treatment

mine the areas of the country in which the infection

course of rabies vaccination.

is most prevalent, the various species of animal that

With rabies eternal vigilance is required.

are involved and the populations of these animals. It is

necessary to determine whether there are wild-life

Further reading

reservoirs of infection or whether it is purely a

problem of urban dogs.

With this information it is possible to plan the cam-

A modern text with a bent towards southern Africa is:

Swanepoel, R. (1994) Rabies. In Infectious Diseases of

paign of control and budget for its costs. In most Third

Livestock with Special Reference to Southern Africa (ed.

World countries rabies vaccination is supplied free to

by J.A.W. Coetzer, G.R. Thomson & R.C. Tustin), Vol. 1,

dog owners during the campaign, either at predeter-

pp. 493–552. Oxford University Press, Cape Town.

mined vaccination sites or on house to house visits.

Owners who require their animal to be vaccinated

An older text on rabies in the tropics including vaccination:

Kuwert, E., Mérieux, C., Koprowski, H. & Bogel, K. (eds)

outside this time usually have to go to a private veteri-

(1985). Rabies in the Tropics. Springer-Verlag, Berlin.

nary surgeon. In Botswana, at the time of vaccination,

the dog is painted on the head. Once the vaccinations

An older text concerning South America:

are completed then control teams go into the area and

Anon (1984) Septimo Informe. Comité de expertos de la OMS

capture or shoot all dogs without the paintmark. Other

sobre Rabia. World Health Organization, Geneva. (Control

countries do not have such draconian measures. In

in cities, pp. 39–41; vampire bats, pp. 71–5.)

countries where there is little control of the dog popu-

Rabies in cattle in the USA:

Baer, G.M. (1986) Rabies in cattle . In Current Veterinary Steck, F., Wandeler, A., Biochel, P., Capt, S., Hafliger, U. & Therapy 2: Food Animal Practice (ed. by J.L. Howard), *Schneider, L. (1982) Oral immunisation of foxes against*

pp. 501–504. W.B. Saunders, Philadelphia.

rabies: laboratory and field studies. Comparative Immunol-

*ogy, Microbiology and Infectious Diseases, **5**, 165–71.*

Oral vaccination of wildlife against rabies:

Chapter 71

Dairy Farming in Saudi Arabia

J.C. Fishwick

Introduction

1172

nies, both privately and state owned. In addition to

Cattle industry

1172

farming activities most dairy companies have their own

Dairy farming

1172

processing plants and distribution systems.

Role of the veterinary surgeon

1174

The full range of pasteurized fresh dairy products

Function of the health team

1176

that would be found in any Western country is readily

Summary

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available. The largest selling product is a traditional

Middle Eastern fresh natural drinking yoghurt called

Introduction

laban. About 60 per cent of fresh milk production is

fermented into laban while approximately 25 per cent

With an area of approximately 2.1 million square kilo-

is processed as fresh milk. The retail price of a litre of

metres and an estimated population of over 19 million

milk has fallen rapidly due to competition pressures

people, the Kingdom of Saudi Arabia dominates the

from the equivalent of 75 pence (US$1.05) in 2000 to

Arabian Peninsula. Within its boundaries, the country

about 53 pence (US$0.80) in 2002.

holds the two most sacred sites of the Islamic faith, the

In contrast to Europe, a higher value is placed on fat

Holy Mosques of Mecca and Madinah, and Islam is

than protein in milk and this is reflected in the nutrition *the all-embracing force which is seen in every aspect of*

of dairy cows and in sire selection. This is primarily

Saudi society. The nation was united into its present

because of the demand for traditional breakfast cream

form by King Abdul Aziz in 1932 and is still ruled as an

called ghiste. However the demand for skimmed and

absolute monarchy by his descendants.

semi-skimmed milk is increasing and both products are

Saudi Arabia consists almost entirely of desert or

readily available. Milk quality is generally excellent and

semi-desert areas and is one of the driest countries on

most companies produce milk with a bacterial count

earth, with an annual rainfall in most areas of around 100

and somatic cell count that would qualify for the highest

mm. The rainfall that is seen is irregular and unreliable.

payment bands offered by UK milk purchasers.

There are two distinct seasons with summer lasting from

The beef industry is quite small. The majority of

March to early October, when daytime temperatures are

locally produced red meat consumed is sheep, goat

consistently above 40°C and commonly reach as high *and camel and the best quality beef is imported. Most*

as 50°C, while at night the temperature will remain

local beef is slaughtered at up to 18 months of age and

above 30°C. The daytime temperatures during the winter

is referred to as veal. Veal cattle are usually castrated

months are usually in the range 20–30°C. Coastal regions

Holstein bulls sourced from the dairy sector. There is

suffer with extremely high humidity, especially in the

also a small amount of beef produced by nomadic

summer, whilst the central regions are characterized by

farmers who keep suckler cows.

a very dry atmosphere.

There are effectively no private veterinary surgeons

Saudi Arabia has the largest known oil reserves in

working in the cattle industry; veterinary surgeons

the world, together with vast amounts of natural gas and

are exclusively employed directly by individual farming

mineral wealth. The discovery of these natural resources

companies.

had a dramatic effect on the nation during the latter half

of the twentieth century and the health of the economy is *now closely linked to the price of oil on the world market.*

Dairy farming

Milking cattle are Holsteins which are zero grazed

Cattle industry

with a diet based on home-grown alfalfa hay and maize

silage. Saudi Arabia is fortunate in having enormous

The dairy industry is sophisticated and is concentrated

underground reservoirs of water and it is this water

in the hands of relatively few large, integrated compa-

which is used for both dairy farming and arable pro-

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Dairy Farming in Saudi Arabia • 1173

duction. Certain areas of the desert are extremely

cooling during the summer months and even during

fertile if water is provided and the basis of crop and

the winter cooling still plays an important role. A good

forage production is an irrigation system known as the

illustration of the high temperatures experienced is the

centre pivot (Fig. 71.1). A pivot consists of a bore hole fact that mercury clinical thermometers are of little

producing water which then passes into a horizontal

use in the summer. The air temperature is considerably
overhead pipe mounted on wheels which makes a slow
higher than the normal body temperature of a cow and
circuit and irrigates a circular area of land around
so it is almost impossible to make an accurate meas-
the bore hole. Nutrients may be added to the water as
urement of a cow's rectal temperature.
required and pivots may have a diameter of up to
The technology for cow cooling was originally
800 m. From the air pivots may be seen as 'green circles
developed in the arid regions of Arizona, USA. One
in the desert'.
commonly used cooling system involves a large electri-
Forage is supplemented with imported products
cal fan mounted in the roof which blasts air downwards
such as soya, flaked maize, cottonseed, cottonseed hulls,
onto cattle. The air may be cooled by evaporating con-
sugar beet pulp and fishmeal. Feed is usually fed as a
trolled amounts of atomized water into it. A cow house
total mixed ration off the floor with the cattle in lock-
will need a whole series of fans to provide effective

able head stanchions. Feeding time provides an oppor-
cooling and for much of the year these will be operat-
tunity for breeding and other management procedures.
ing 24 hours a day (see Chapter 8). Cooling is also
The best dairy units have around 4500 to 5000 dairy
essential in parlour collecting yards (Fig. 71.2).
cows together with a large youngstock rearing opera-
Cows are housed on sand and, over time, the original
tion. Cows are milked four times a day in a two hundred
sand bedding accumulates increasing amounts of dung.
stall parallel parlour which operates 24 hours a day, with
This provides a peaty type of bedding which is com-
breaks between shifts for cleaning and routine main-
tenance. A farm of this size has a total staff of about
145 men, including everyone from the farm manager to
cooks and administration staff. Rolling herd average
milk yield in the best units is over 12 000 litres per head.
Lactating cows are housed in groups of 300 and con-
siderable effort is spent to ensure that this number of
animals calves in as short a period as possible to fill the
house quickly. The spread of calving dates in the house

must be minimal so that they can be managed and fed

as a single group. First lactation cows are housed sepa-

rately from older cows.

The extremely high temperatures experienced both

day and night throughout the summer months make

careful control of the cows' environment essential.

Efficient milk production is difficult without effective

Fig. 71.2

Coolers over a collecting yard. Note the udder

Fig. 71.1

A centre pivot irrigation system.

washers on the floor.

fortable and works extremely well, provided it remains

ment of livestock into the region from the Horn of

dry. To maintain the beds in good condition houses are

Africa and from more northerly states such as Turkey, groomed four times a day by scraping the top layer of Iraq and Iran. The greatest threat to dairy units comes bedding outside and leaving it in the sun to dry, whilst from the large, mobile population of sheep and goats in previously dried material is scraped back inside. It is the region and these may commonly be infected whilst possible to maintain a house for several years before showing only minor clinical signs.

completely cleaning out and starting with fresh sand.

Prevention of FMD is maintained in two ways:

Rain is uncommon, but when it does fall it can cause physical security of the unit and a stringent vaccination serious problems with the bedding which is associated policy. The principle of physical security is that live- with an increased incidence of mastitis and lameness. stock, people and vehicles do not enter the unit unless Mastitis is maintained on well-run units at a level absolutely necessary. When they do, sensible precau- of less than 20 cases per 100 cows per year, and levels tions are taken in terms of disinfection of vehicles and *would be considerably lower in some cases. Meticulous*

provision of farm overalls and footwear. However,

attention to the Five Point Plan for many years has been

these precautions are no substitute for preventing entry

very successful in reducing contagious mastitis to very

to the unit and this must always be the main thrust of

low levels and most of the cases are environmental mas-

physical security.

titis. There is still a lot to be learned in the management

Farms are fenced with a single point of entry (Fig.

of cows and housing in this type of system to reduce

71.3) which is manned 24 hours a day. Cattle sales

environmental mastitis further.

and disposals are done through a separate gate at the

Staff are divided into several teams with responsibil-

perimeter so that cattle trucks do not enter the farm

ity for areas such as milking, feeding, health, breeding,

(Fig. 71.4). There is a large separation between the

calving and youngstock rearing. Because of the large

perimeter fence (Fig. 71.5) and the cow houses, typically

number of cows being dealt with, members of these

200 m or more. Essential deliveries are kept to a mini-

teams gain a great deal of experience.

mum and lorries are disinfected before entry. Visitors

are not allowed and all company staff entering the site

must leave their vehicles outside the perimeter fence.

Role of the veterinary surgeon

There are special risks when companies with

multiple sites have to move livestock between their own

The veterinary surgeon has an essential, proactive role

farms. The risk is reduced by using lorries exclusively

to play in the productivity and health of the herd.

for their own animals, efficient disinfection and

First and foremost he must establish performance

ensuring a member of farm staff always accompanies

targets, monitor them continuously and intervene

the driver to ensure that cattle are not exposed to any

immediately when performance starts to deviate

unnecessary risk during transit. Forage is only sourced

from that target. As well as collecting, handling and

from suppliers known to have effective fencing to keep

interpreting data this involves working closely with farm *their pivots free from livestock.*

staff at all levels to investigate problems as they arise.

Examples include the calving live birth rate, incidence of mastitis, conception rates, incidence of ketosis and cow and calf mortality. If any of these parameters fall below the set target investigations must start immediately.

Secondly, he must establish the optimal working practices for each team and produce written manuals to set these out in a clear and methodical manner. It is important to utilize the very best current knowledge available in an area and produce firm guidelines that can be applied simply on a very large scale.

Thirdly, he has the responsibility for the maintenance of herd disease security. There is probably no other situation in the world where herd disease security takes on such an important role. Foot-and-mouth disease (FMD) and rinderpest are a real risk and if either of these were to enter a large unit the results could be catastrophic.

FMD is endemic in the region and attempts to

Fig. 71.3

A farm gatehouse, which is controlled to reduce the

control it on a national scale are thwarted by the move-

risk of foot-and-mouth entering the farm.

Fig. 71.4

Loading ramp at the perimeter fence for livestock

Fig. 71.5

Farm perimeter fence. Security is important in a

movement. Cattle are moved through a separate gate from the

region where foot-and-mouth is endemic. The perimeter fence is main entrance to ensure that cattle trucks do not enter the farm.

separated from the cattle housing by several hundred metres.

One feature of farming in this region is that a large

proportion of farm staff are expatriates from countries

such as the Philippines, Kenya, Sri Lanka, Nepal,

Pakistan, India, UK and Ireland. Most staff are resident

on site and this reduces the chance of staff coming

into contact with other local livestock.

Preventing the movement of cattle and personnel

does nothing to prevent the chance of airborne spread

between units. This is a particular risk if another dairy

unit in the region is suffering a clinical FMD outbreak.

The chance of infection by airborne spread appears to

be greatest when humidity is above 60 per cent.

The second component of FMD prevention is vacci-

nation. The antigenic components included in the

Fig. 71.6

A 100-stall parallel milking parlour.

vaccine available in Saudi Arabia are authorized by the

Saudi Ministry of Agriculture and Water, based on

the best scientific advice available from authorities such

as the Institute of Animal Health at Pirbright, UK.

FMD vaccination is carried out every 75 days in all

stances and the schedule described above would be

stock over 6 months old. This routine is carried on a

amongst the most vigorous seen in the region.

predetermined day and all cattle are included regard-

Despite the great attention given to FMD preven-

less of any other considerations. Calves less than 6

tion, outbreaks of the disease do occur sporadically and

months old are given a course of three vaccinations at

they will probably remain a feature of dairy farming

4, 5 and 6 months old before joining the whole herd

while the disease remains endemic in the region.

schedule.

A fourth role is the development of effective control

Vaccination against FMD is a tremendous cost to any

and contingency programmes for a number of diseases dairy organization. Apart from the direct costs of vaccination and time involved, milking cows often suffer a significant but short lived reduction in milk yield. Typically total daily milk production may fall by an amount equivalent to between 0.5 kg and 2.0 kg per cow for a 24- or 48-hour period immediately following whole herd vaccination. This cost is, at present, an unavoidable loss associated with the keeping of dairy cattle in the region. Dairy companies do vary in the vaccination schedule employed depending on their own circum-

which may occur. FMD provides the most obvious example but other diseases such as mycoplasmal mastitis, brucellosis and tuberculosis, all of which may occur, need definite policies in place to deal with them. In the case of mycoplasmal mastitis a control programme must ensure that sensible precautions are in place to prevent it, that sampling and laboratory procedures are effective in continuously monitoring for the disease and that should an outbreak occur a well-organized response can be implemented immediately.

Other roles include the coordination of parlour

Any cows that show problems are removed and given

testing and maintenance, which assumes great impor-

a full clinical examination in a crush. Cows are then

tance when cows are being milked around the clock in

returned to their houses or retained in the hospital for

one or two hundred stall parlours (Fig. 71.6); mainte-

treatment as necessary.

nance and monitoring of raw milk quality, co-ordination

The most common disease identified in fresh cows is

with consultant nutritionists and selection of bulls.

ketosis and the diagnosis of this condition is assisted

with the use of a urine dipstick. Any fresh cow that is

submitted for clinical examination will have a urine test

Function of the health team

done as a routine. The incidence of diseases such as

ketosis and left displaced abomasum is recorded daily

Staff on a large dairy unit are commonly divided into

and this information is used by nutritionists, the farm

a number of specialist teams, one of which is the health

manager and the feeding team to assess the effective-

team. The principle of a health team's activity is that
ness of their feeding management.
problems must be detected early and rapid intervention
Careful observation of cattle at frequent intervals
must ensure that affected cows are returned to full pro-
during the day is a very time consuming activity, but it
ductivity as soon as possible. Any cows that do require
is considered essential to the effective management of
treatment are moved to a separate hospital area which
a dairy unit. A successful health team is judged by an
has its own dedicated milking parlour. All the milk pro-
empty hospital area and not by the amount of sophisti-
duced in this parlour is disposed of as waste to prevent
cated treatments being given to cows in it.
any mastitic or drug-contaminated milk from entering
the main milk output of the farm.
Health teams concentrate most of their efforts on

Summary

the observation of cattle in their houses. All cows are
locked in their stanchions for feeding four times each
The dairy industry in Saudi Arabia has developed

day and it is during this ‘lock up’ period that health
rapidly over a period of about 25 years and has been
teams walk the cows and observe carefully for any signs
greatly influenced by the experience gained from dairy
of abnormality. Particular attention is given to cows
farming in arid regions of the USA. It is now probably
within the first three weeks after calving. These
as efficient and advanced as anywhere in the world.
fresh cows are checked four times a day whilst others
Prevention and control of foot-and-mouth disease is a
are checked twice a day. Although this type of dairy
major challenge and is very expensive.
farming is carried out on a large scale, great attention
Regardless of the size and scale of any operation, a
is paid to the health of individual cows as judged by
herd is comprised of individual cows. A herd can only
careful observation and basic clinical skills. Health men
operate efficiently if full attention is given to the indi-
have to be satisfied that each and every cow is eating
vidual members of that herd. This applies as much in a
properly and looks healthy at the time of each lock up.

unit of five thousand cows as it does in one of fifty.

Chapter 72

Bovine Medicine in New Zealand

and Australia

N.D. Sargison and J.J. Vermunt

New Zealand

1177

Recently, there has been an increased interest in autumn

Dairy farming

1177

calving, thereby spreading the workload for both the

Beef production

1177

farmer and the dairy factory. Inputs to factory supply

Animal health

1178

herds are low, with little supplementary feeding, no

Reproductive management

1178

winter housing, efficient milking plant and a low labour

Major problems

1179

requirement. Farms are subdivided into small paddocks

The Australian scene

1182

and most lactating cows are mob stocked and shifted

daily. The annual production of 3000–3500 l/cow is low

New Zealand

by comparison with grain-based systems. Cows are

stocked at an average of 2.7/ha and produce 600–1200 kg

milk solids (fat and protein)/ha. Only small amounts

Dairy farming

of hay or silage are conserved for winter feeding and

New Zealand's dairy herd of slightly over 3.3 million

the use of temporary electric fencing enables a variety

cows is small by comparison with Europe and America.

of winter grazing systems to ration winter pasture and

However, about 90 per cent of the milk production

ensure adequate spring growth. A small number of town

is processed for export as butter, cheese and milk

supply herds have a greater reliance on winter feed and

powders, making New Zealand a major contributor to *produce milk to quota all year round.*

the world dairy trade. New Zealand's unique climate

favours extremely efficient livestock production from

Beef production

clover and perennial ryegrass pastures, top dressed with

phosphatic fertilizers, which enables the unsubsidized

The majority of the beef produced in New Zealand

dairy industry to compete on the world market.

is exported to the USA as processing beef, some is

Dairy farming is concentrated in areas of reliable

exported to North and South East Asia and about a

high rainfall (Northland, Waikato, Taranaki and

fifth is consumed locally. About 50 per cent of the total

Southland) and where irrigation is possible and cost-

beef production is from suckler cows and 50 per cent is

effective (Canterbury). Most production is from New

derived from the dairy industry, comprising cull cows

Zealand–Friesian and Holstein–Friesian cows (57 per

and Friesian bulls which are reared to between one

cent), although there are still a significant number of

and two years-old on lowland pasture. The original role

Jersey (16 per cent) and crossbred herds (19 per cent).

of suckler cattle in New Zealand was to improve

The average herd size is about 230 cows and managed

pasture quality for more profitable sheep grazing and

by one person, but herds of 800 cows or more are not

to prevent reversion to bush. Whilst recently the price

uncommon. About 30 per cent of the dairy farms are

of beef has improved relative to wool and lamb, most

operated on a share milking basis where, for example,

of the country's 1.4 million suckler cows are still kept

the owner is responsible for the farm maintenance and

on steep and rolling hill country farms in a complement-

the fertilizer costs, whilst the share milker owns and

ary role to sheep. Angus cattle with mature weights of

milks the cows. This system traditionally provided a

about 475 kg are the predominant breed,

although

route of entry to the industry for young farmers, who

there are many herds of Hereford and crossbred cows.

could eventually accumulate enough capital to buy

The numbers of Charolais, Simmental and Limousin their own property.

cattle are low by comparison with Europe, partly

The majority of dairy farms are seasonal producers,

because of their high grazing requirements for main-

traditionally spring calving over a two month period

tenance relative to production.

timed with the lush spring growth, and supplying milk

Typical herds of 150–200 suckler cows achieve calving

processing factories for nine to ten months of the year.

percentages of 80–85 per cent depending on the topog-

raphy of the country. Beef production is wholly depend-

to three bulls per 100 cows, depending on the topogra-

ent on pasture nutrition so virtually all suckler cows

phy of the farm. Most reproductive problems are asso-

are spring calving. The various classes of cattle are kept

ciated with an extended calving period and veterinary

separate and regularly moved around the farm along

input is, therefore, based on the achievement and main-

with the sheep. Pasture is prioritized depending on the *tenance of a compact calving period.*

nutritional requirements of the different classes of live-

• Heifers or cows which calve late during one season

stock at different times of year and care is taken to

inevitably calve late during the following season

avoid competition with sheep, especially during the late

or do not become pregnant before the end of a

winter–early spring period. Winter grazing is managed

compact mating period.

by the rotation of mobs around paddocks. Store cattle

• Calves which are born late in the calving period are

are mostly finished on intensive lowland farms, where

younger and lighter at weaning than those born

weight gains from about 1 kg/day in spring to 0.5 kg/day

earlier and, therefore, of lower sale value.

in autumn are achieved on a pasture-only diet.

• The labour requirement for supervision is lower

when the calving period is compact.

Animal health

• Feed budgeting is more accurate for heifers and

cows calving over a known short period.

The unsubsidized New Zealand beef and dairy indus-
tries are very sensitive to world production and market
The annual performance of most of the country's
trends. The important economic constraints on produc-
beef cows and the published results of field studies of
tion and requirements for veterinary input are, there-
more than 150 000 suckler cows (Hanly & Mossman,
fore, different when compared to the current situation
1977) indicate that the average pregnancy rate is 60
in Europe. Reproductive performance is the most im-
per cent for each oestrous cycle, provided that heifers or
portant determinant of herd profitability and forms
cows are cycling and the bulls are sound. After calving,
the basis of veterinary input to most herds. The treat-
there is a post-partum anoestrus period of at least 40
ment of individual sick animals is often uneconomic,
days, which is related to body condition at calving and
especially in extensively grazed beef cattle where early
to the plane of nutrition and is about 20 days longer in
signs of disease may not be seen. However, there is
calved heifers than in mature cows with the same body

an important role for veterinary advice on the control condition. Thus, provided that all heifers or cows are and prevention of production limiting diseases. Whilst cycling at the beginning of the mating period, a 5- respiratory disease and calf scour are relatively un- oestrus-cycle (105-day) mating period is required for 99 important diseases in animals which are not housed, per cent of cows to be pregnant. However, in subse- dependence on a solely pasture diet can predispose to quent years if the bulls are introduced on the same date, specific animal health problems. New Zealand's vol- not all cows will be cycling at the time of bull intro- canic soils are generally deficient in trace minerals and duction and a 99 per cent pregnancy rate will not be in the absence of supplementary feeding, trace element achieved by 105 days. Therefore, a mean calving inter- deficiencies (copper and selenium) are commonplace. val significantly greater than 365 days is required to Mycotoxicoses such as facial eczema and ryegrass sustain a 99 per cent pregnancy rate. Alternatively, staggers, which are seldom seen in Europe, can also be *a sustainable 365-day calving interval can be*

important production limiting diseases. Most lameness

achieved when bulls are removed after three oestrus

in dairy cattle is associated with the unavoidable need

cycles, although annually about 6 per cent of the cows

to walk long distances from pasture to the milking shed,

will not be in calf (Mossman & Hanly, 1977). In the

and consequently the lameness-causing lesions differ

absence of annual cow subsidy support and provided

from those seen in winter-housed animals. Problems

that the difference between cull and replacement cows

of winter pasture feeding and management, the meta-

is low, this not-in-calf rate is more than compensated for

bolic demands of late pregnancy and early lactation and

by increased weaning weights due to the greater mean

stress associated with prolonged wet spring weather

age of calves at weaning.

often result in a high incidence of metabolic diseases in

Good heifer management is the key to achieving sat-

dairy cows.

isfactory reproductive performance in the whole herd.

Provided that heifer management is correct, nutrition is adequate and sound bulls, matched for size, with high

Reproductive management

libido and low estimated breeding values for calf birth-
The pattern of pasture growth in New Zealand means
weight are used, the achievement of good reproductive
that suckler cows must be spring calving and a mean
performance in subsequent years is relatively straight-
calving interval of 12 months is therefore essential.
forward. Traditional heifer calving at three years of age
Most suckler cows are mated in large groups with two
presents few problems. However, about 30 per cent of

New Zealand beef heifers are first calved as two-
formed by the farmer and 70 per cent by trained
year-olds, which necessitates careful management to
technicians. Heat detection is assisted by the use of tail
avoid dystokia and subsequent reproductive problems.
paint. Poor reproductive performance in dairy cows is
Heifers weighing 65 per cent of their mature weight
often associated with extended post-partum anoestrous

at 14–15 months of age should be cycling and achieve

periods due to failure of winter/spring pasture to meet

target pregnancy rates when mated. For 15-month-old

the nutritional requirements of advanced pregnancy

Angus, Hereford and Simmental heifers, this critical

and early lactation. Intravaginal progesterone releasing

minimum weight is in the order of 270 kg, 290 kg and

devices (e.g. CIDR, InterAg, NZ; Cue-Mate, Duirs,

310 kg, respectively. Heifers intended for calving as

NZ; PRID, Stockguard, NZ) are routinely used in an

two-year-olds are preferentially managed and regularly

attempt to overcome this problem and to induce

monitored to ensure that target weights are achieved

oestrus in later calving animals.

through good nutrition and control of growth-limiting

diseases, such as parasitism and trace element deficien-

cies. Heifers which do not reach the critical minimum

Major problems

weight at 15 months of age are usually culled from

Copper deficiency (see p. 298)

the breeding herd or mated the following year to avoid *the problems of poor pregnancy rates and failure to*

Copper deficiency is an important cause of ill-thrift

rebreed as second calvers. On many hill farms, or on

in cattle over the age of six months. Severe scours and

lowland farms with heavy breeds of cattle, the achieve-

copper-responsive post-parturient haemoglobinuria in

ment of critical minimum weights by the age of 15

dairy cows used to be common in some areas, associ-

months is not possible and calving as two-year-olds is

ated with high spring levels of molybdenum in peat soils

uneconomic.

or the application of molybdenum to pasture as a fer-

Bulls are removed from the herd of replacement

tilizer. There are also reports of poor reproductive per-

heifers one cycle ahead of the cow herd to overcome

formance associated with copper deficiency, although

the problem of a longer post-partum anoestrous period

it is unclear whether this is due to copper deficiency,

in calved heifers. When cows are mated over a period

the toxic effects of molybdenum or just secondary to

of 63 days, this is achieved by mating replacement *ill-thrift.*

heifers for only 42 days or by mating heifers for 63 days,

Whilst the copper levels of New Zealand pastures

but introducing the bulls 21 days before the start of

vary little throughout the year, the levels of interfering

mating in the cow herd. Forty-two-day heifer mating is

factors, molybdenum and iron, increase significantly

suited to calving at two years of age, because animals

throughout the winter and spring. Copper availability

are three weeks older at the time of bull introduction,

is therefore lowest in spring, at the time of year when

which can make a significant difference to achieving

animal requirements for late pregnancy, lactation and

critical minimum weights and subsequent herd repro-

early growth are highest.

ductive performance, while 63-day heifer mating is best

Both serum and liver copper concentrations are used

suited to traditional three-year-old heifer calving.

in the diagnosis of poor animal performance, but liver

Poor body condition at calving results in long calv-

is the only useful sample when the reasons for sampling

ing to conception intervals and a high not-in-calf rate

are to determine whether reserves are adequate to

when a short mating period is employed. Furthermore,

last throughout the winter or to monitor a supplemen-

thin calved heifers that do become pregnant usually

tation programme (Ellison, 1992). The correct number

conceive late in the breeding season, calve later, wean

of samples is essential (minimum of eight sera or four

lighter calves and fail to become pregnant as second

liver samples), because the laboratory reference values

calvers. Under intensive grazing conditions, replace-

are based on mean values from these numbers. Liver

ment heifers cannot compete with adult cows for nutri-

samples are obtained by biopsy or from slaughterhouse

ents unless managed as a separate group through to

or necropsy material.

their second calving. Having achieved good heifer man-

There are no recipes for trace element supplemen-

agement, day-to-day management is based on assess-

tation, which depends on many factors including the

ing the body condition of cows in accordance with their

severity of the deficiency, production system, stock-
reproductive status. If feed inputs are below require-
ing density and availability of labour (Wakelin, 1992).
ments, cows will lose weight and fail to reach target con-
Short-term supplementation of dairy cattle can be pro-
dition score for mating and eventually fail to rebreed.
vided by daily drenching with copper sulphate in the
The same requirement for a compact spring calving
milking shed or administration of copper salts through
period applies to the dairy herd, where 60 to 70 per cent
the drinking water, but requires careful monitoring.
of the cows conceive to proven sires by artificial insemi-
Intermediate-term supplementation is achieved in
nation. About 30 per cent of inseminations are per-
both dairy and beef cows by the parenteral injection of

copper glycinate or copper edetate, whilst long-term
and autumn, in many areas of the North Island of
supplementation can be provided by the oral adminis-
New Zealand. Facial eczema is caused by ingestion of
tration of copper oxide particles (capsules or bullets) or

the mycotoxin sporidesmin, which is present in the

pasture top dressing with copper sulphate.

spores of the saprophytic fungus Pithomyces chartarum.

Under the ideal conditions of high humidity (close to

100 per cent) following a prolonged warm period

Selenium deficiency (see p. 302)

(>20°C with a minimum night temperature of 12°C),

About 30 per cent of farmed land in New Zealand is

spore numbers can increase rapidly in the mat of

considered to be selenium deficient. The most important

leaf litter beneath shaded pasture. Sporidesmin is

selenium responsive condition in New Zealand cattle is

rapidly absorbed and becomes concentrated in the liver

ill-thrift in growing calves and growth responses of 5–10

where it causes epithelial necrosis of the bile ducts

per cent can be achieved by supplementation on most

with periductal oedema and inflammation, leading to

deficient pastures. Selenium responsive infertility and

cirrhosis. Most affected animals show no outward

poor milk production have been reported on severely

clinical signs. However, the resulting liver damage *deficient pastures (Grace, 1994). The selenium respon-*

causes ill-thrift and a significant reduction in milk

sive condition of nutritional muscular dystrophy is now

production. Photosensitization occurs in about 10 per

quite rare due to the awareness of selenium deficiency

cent of affected animals and is due to derangement of

and widespread supplementation.

the biliary excretion of phylloerythrin (Bruère et al. , The selenium status of cattle is usually confirmed by

1990).

the laboratory analysis of blood glutathione peroxidase

Outbreaks of facial eczema are both distressing and

(GSH-Px) or selenium concentrations in serum, whole

expensive, therefore intensive monitoring is performed

blood or liver, all of which provide useful diagnostic

to assess the risk of disease and expedite preventive

information (Wichtel, 1998). Liver samples collected

measures. Monitoring consists of recording weather

from finished calves at slaughter are commonly used

conditions and carrying out pasture spore counts using

to determine the need to supplement. Within any herd, *spore trapping or pasture washing methods. When there is little between-animal variation in the concen- counts rise rapidly, or reach threshold value, the options trations of selenium in blood, serum or liver, or blood are to move stock to safer pasture, to instigate protec- GSHPx concentrations, therefore samples from three tive treatment with zinc salts, to apply fungicides to the or four animals usually provide adequate information. pasture or a combination of these practices. Fungicide The New Zealand reference ranges for selenium are spraying can provide safe pasture for six weeks, but based on numerous calf growth response trials can be expensive, especially when it has to be repeated (Ellison, 1992). Overseas reference ranges are of no due to heavy rainfall or a prolonged risk period. Oral value to New Zealand conditions and vice versa, administration of large doses of zinc oxide, before expo- because the vitamin E status of New Zealand cattle is sure to toxic levels of sporidesmin, effectively reduces generally more than adequate due to their year-round the severity of liver damage, although the mechanism*

pasture nutrition. Economically significant growth
is unclear. Milking cows can be dosed daily in the milk-
rate responses to supplementary selenium are unlikely
ing shed, but other classes of cattle are usually drenched
at liver selenium concentrations above 600 nmol/kg
weekly at a higher dose rate to overcome the impracti-
(wet weight).
calities of yarding and handling. Alternatively, zinc
Sodium selenate or selenite administered orally, as
sulphate can be administered to dairy herds through
a pour-on or by subcutaneous injection can provide a
the water supply. Wax-coated, slow-release zinc oxide
useful method of short-term supplementation. Long-
intraruminal boluses (Time Capsule, AgResearch, NZ)
term supplementation is achieved by controlled re-
are available for use in calves. The boluses slowly dis-
lease subcutaneous injections of barium selenate paste,
solve in the rumen to provide four weeks' protection
intraruminal selenium pellets or pasture top dressing
and are useful when animal handling is difficult. Zinc
with sodium selenate or sodium-barium selenate prills.

salts have no therapeutic value when administered after

Pasture top dressing is an efficient supplementation

exposure to sporidesmin.

method where stocking rates are high and is the pre-

Outbreaks of facial eczema can be avoided by judi-

ferred supplementation method on about 30 per cent of

cious farm management practices such as feeding of

selenium deficient properties.

hay or other supplements during high risk periods,

avoidance of close grazing and removal of stock from

high risk areas. Affected animals should be provided

Facial eczema

with shade or if possible housed in darkness during day

Facial eczema is an important cause of ill-thrift and

light hours. Milking cows should be dried off and skin

hepatogenous photosensitization during late summer

lesions treated topically.

Ryegrass staggers

the back of the group. The problem is compounded by

poorly maintained tracks which cause direct trauma

Ryegrass staggers occurs under close grazing condi-
to the sole and slow the herd down, causing further
tions during summer and autumn in perennial ryegrass
impatient handling. Impatient forcing of cows results in
(Lolium perenne) dominant pasture-fed livestock
cows skidding as animals from the back of the group
throughout most areas of New Zealand. The disease is
are forced against those in the middle; tussling to
caused by tremorgenic mycotoxins (lolitrem A and B)
avoid body contact, resulting in unplanned placement
which are produced by the perennial ryegrass endo-
of limbs; abnormal forces being taken on the abaxial
phytic fungus Acremonium loliae and is characterized
wall of the lateral claw as cows attempt to resist being
by tremors, incoordination and depressed growth rates.
forced off the track; shortening of the stride so that the
The prevalence of the endophyte in perennial ryegrass
hind limbs are no longer placed in the same safe spot
is greatest during summer and autumn, in particular
as the fore limbs and cows being unable to see their
in the plants' lower sheaths, old leaves and seedheads.

lower limbs as their heads are forced up and above the

Many modern ryegrass cultivars have been selected

animals in front (Chesterton, 1989).

for high levels of the A. Loliae endophyte, because it Most lameness problems can be managed by patient

is associated with resistance to attack by the Argentine

movement of cows along the farm track to the milking

stem weevil (Listronotus bonariensis), an important

shed, proper maintenance of tracks and careful han-

agronomic pest. Such selection has inadvertently re-

dling in the shed. Congestion points and distractions

sulted in an increased incidence of ryegrass staggers

should be removed and the track surface should be non-

(Bruère et al. , 1990).

abrasive, correctly crowned and well drained, especially

Clinical signs develop within one to two weeks after

the parts closest to the milking shed (Vermunt &

introduction to toxic pasture. At rest, the only visible

Greenough, 1997).

signs may be fine tremors of the head and neck, but

when animals are disturbed, clinical signs immediately *become apparent with development of head nod-*

Bloat (see p. 832)

ding and jerky movements of the neck and limbs.

Pasture bloat is a common cause of sudden death in

Moderately affected animals have a wide-based, sway-

cattle in New Zealand. It is caused by the production

ing stance and a high-stepping gait. Severely affected

of a stable foam which traps the normal gases of fer-

animals show a stiff-legged gait and usually collapse

mentation in the rumen (frothy bloat) and inhibits eruc-

when moved. Whilst the disease is distressing to ob-

tation. Pasture bloat occurs most commonly when cattle

serve, most losses are associated with misadventure.

graze pastures dominated by lush, immature, rapidly

However, affected animals are difficult to handle,

growing legumes (clovers, lucerne), but there are also

interfering with normal management practices. There is

reports of the disease when cattle are grazed on other

no specific treatment for the disease, but animals re-

materials such as turnips, brassica and cereal crops, and

cover within days of removal from the toxic pasture.

young grass with a high soluble protein content. While

However, the avoidance of close grazing of high endo-

death is the most obvious loss associated with bloat,

phyte ryegrass dominant pastures can be problematic,

subclinical and mild bloat are associated with consider-

especially during dry summer conditions.

able production losses.

Although bloat susceptibility is heritable, progress

in the genetic selection for low bloat susceptibility

Lameness (see Chapter 31)

has been slow (Morris et al. , 1991). Outbreaks of bloat Lameness is a significant problem in New Zealand dairy

with several cows dead and/or stabbed are devastating,

herds. Unlike the situation in winter housed cattle, the

and nowadays most farmers take precautions by using

main problems are excessive wear and bruising of the

antifoaming agents, which are still the only reliable way

sole, perforation of the sole (septic pododermatitis) and

of controlling or preventing bloat. Historically, farmers

white line disease. Most herd problems are associated

have used detergent based products for controlling *with poor design, construction or maintenance of farm*

bloat. These have included oils, marlophens, pluronics

tracks and impatient animal handling.

or turps, and currently the most favoured are the

Observational case-control studies of New Zealand

alcohol ethoxylate derivatives due to their extended

dairy herds have shown that when cows walk at their

persistency of action. Most commercially available

own pace, each limb is accurately placed to avoid injury.

products are suitable for daily drenching, trough treat-

The incidence of claw injury is low in herds which are

ment or pasture spraying. The rumen modifier mon-

allowed to drift to and from the milking shed, even on

ensin (Rumensin Liquid and Rumensin Anti-Bloat

rough or poorly maintained tracks. Significant problems

capsule, Elanco, NZ), is marketed as an effective

occur when cows are hurried by pushing the animals at

product in the prevention of milk bloat. Monensin is

not a detergent, but acts to reduce the bacterial/proto-

problems associated with this grain feeding (e.g. abo-

zoal activity that releases foam producing compounds

masal displacement, ruminal acidosis, salmonellosis and

in the normal rumen.

laminitis/lameness) are therefore relatively common.

Specific diseases common to Australia but exotic

to New Zealand are the insect-borne diseases such

The Australian scene

as anaplasmosis, babesiosis (ticks), ephemeral fever or

'three-day-sickness' and Akabane disease (midges).

Dairy farming in Australia is largely confined to

those climatic regions which are favoured by higher

rainfall and better quality soils, especially in the eastern

References

seaboard states and Tasmania. Flood irrigation is used

extensively in areas where rainfall is very seasonal.

Bruère, A.N., Cooper, B.S. & Dillon, E.A. (1990) Mycotoxi-

Although each of the states in Australia maintains its

coses. In Veterinary Clinical Toxicology, pp. 167–84. Foun-own highly regulated dairy industry, the entire industry

dation for Continuing Education of the New Zealand

is influenced by the dominance of the southern dairy

Veterinary Association, Palmerston North.

industry, particularly that of Victoria, which produces

Chesterton, R.N. (1989) Examination and control of lame-

well over half of the total Australian production.

ness in dairy herds. New Zealand Veterinary Journal, ***37****, Like New Zealand, the Victorian and Tasmanian dairy*

133–4.

industries depend heavily on world markets for their

Ellison, R.S. (1992) A review of copper and selenium refer-

manufactured and export products. The ability of

ence ranges in cattle and sheep. Proceedings of the New

farmers freely to sell market milk contracts (quota) is

Zealand Veterinary Association Sheep and Beef Cattle

limited in most states, as is the ability to establish new

Society, ***22****, 3–27.*

Grace, N. (1994) Selenium. In Managing Trace Element Defi-

dairy enterprises. This is in contrast to New Zealand,

ciencies, pp. 9–23. AgResearch, Palmerston North.

where dairy conversions are occurring on a large scale.

Hanly, G.J. & Mossman, D.H. (1977) Commercial beef pro-

The average milk price to the farmer is slightly higher *duction on hill country. New Zealand Veterinary Journal,* ***25****, than in New Zealand, but is still low when compared to*

3–7.

Europe or the USA.

Morris, C.A., Cockrem, F.R.M., Carruthers, V.R., McIntosh,

Similar to New Zealand, dairy farming in Australia

O.T. & Cullen, N.G. (1991) Response to divergent selection is highly efficient in labour and land usage and is prefor bloat susceptibility in dairy cows. New Zealand Journal dominantly seasonal with the majority of the herds

of Agricultural Research, ***34****, 75–83.*

being spring calving. The average Australian dairy herd

Mossman, D.H. & Hanly, G.J. (1977) A theory of beef pro-

is smaller than in New Zealand, but the degree of

duction. New Zealand Veterinary Journal, ***25****, 96–100.*

‘Holsteinization’ of the national dairy herd is further

Vermunt, J.J. & Greenough, P.R. (1997) Management and

control of claw lameness – an overview. In Lameness in

advanced. Dairy cows graze pasture all year round

Cattle (ed. by P.R. Greenough & A.D. Weaver), 3rd edn, pp.

and this forms the major portion of the diet. In addition

308–15. W.B. Saunders, Philadelphia.

to this, supplementary feed sources such as grain are

Wakelin, R.L. (1992) Copper supplementation for ruminants.

widely used. Consequently, the average milk produc-

Proceedings of the New Zealand Veterinary Association

tion is higher and the average days in milk longer. Grain

Sheep and Beef Cattle Society, ***22****, 43–51.*

is fed at a much lower cost, because of the proximity to

Wichtel, J.J. (1998) A review of selenium deficiency in grazing the main grain producing areas. Certain animal health

ruminants. New Zealand Veterinary Journal, ***46****, 47–52.*

Chapter 73

North American Dairy Production and

Veterinary Involvement

T.W. Graham

Milk production trends

1183

animal health, give expert advice in milk production,

Veterinary involvement

1183

reproduction and growth, help design and modify

Approaching a herd problem – an example

1184

facilities, design and monitor food safety protocols

Veterinary monitoring on the dairy farm

1185

(pathogen- and chemical-free meat and milk) and

Disease monitors

1185

provide information to producers on-cost-effective pro-

Mastitis monitoring

1185

duction of meat and milk products sold.

Fertility monitoring

1185

Production monitoring

1186

Veterinary involvement

Milk production trends

The focus of this discussion is to outline those aspects

of dairy production (meat and milk) about which vet-

Production of high quality nutrient-dense milk and

erinarians can provide information to dairy owners to

meat is a primary goal of dairy operators throughout

enhance performance of their enterprise. Clearly our
North America. As our populations become more
training as veterinarians is focused on animal health
aware of human health concerns regarding food safety,
aspects of dairy cattle production. Ironically, it is often
they have required that we provide them with products
poorly planned and maintained housing, milking
without pathogens or chemical contaminants. As they
parlour/equipment design and inadequate or unbal-
should, consumers expect their food to be safe, whole-
anced rations that will curtail production and lead to
some and highly nutritious. With urbanization, con-
disease. Understanding the requirements for clean
sumers have become less aware of how their food is
comfortable housing and bedding and then helping pro-
produced, both as a raw and manufactured product.
ducers implement those changes greatly increases
Animal welfare issues have increasingly become a
animal welfare and performance. The use of inorganic
concern for consumers. Now, more than ever, veteri-
bedding (i.e. sand) in properly designed freestall barns

narians are expected to provide leadership in animal
has a positive effect on feet and legs, mastitis and milk
husbandry and care, ensuring that all animals are
production. Reducing the time that cows spend stand-
treated humanely throughout their lives. Veterinarians
ing on concrete reduces the incidence of laminitis and
are in a key position to provide leadership in animal
sole abcess formation. Increasing the time cows spend
welfare, health and food safety.
laying down chewing their cud increases mammary
As an industry North American dairies are increas-
blood flow, with the subsequent effect of increasing
ing in cow numbers, but the number of facilities con-
milk production. Laying down a manure-free environ-
tinues to decline. Because of increasing animal density
ment greatly reduces exposure to environmental strep-
it is likely that future dairy owners will face more envi-
tococci, staphylococci and coliform bacteria, which
ronmental constraints. Environmental constraints are
helps reduce the incidence of environmental mastitis.
increasing the operating costs for existing and newly

Knowledge of nutrient needs from birth to slaughter

built dairies. Environmental laws are likely to restrict

greatly increases our ability to reduce health problems

building and expansion of existing and new dairy facil-

and manipulate growth, reproduction and milk produc-

ities. Cost of production for meat and milk continues to

tion. From our classical veterinary training, knowledge

rise, while the value of raw products sold has increased

of the pathophysiology of disease allows the attending

at a slower pace. The narrowing margin of profit per

veterinarian to recognize the conditions being diag-

unit of product sold requires that animals produce meat

nosed and guide therapeutic intervention. Taking diag-

and milk with high efficiency and that animals remain

nostic methods to the population level requires an

healthy. Veterinarians are now expected to maintain

understanding of the epidemiology and dynamics of

diseases in groups of animals. Understanding the

tion string were collected directly from the feed wagon

aetiopathogenesis of disease allows for intervention on
as it delivered feed to cows. Rations, as formulated,
a herd basis after identifying the affected groups and
were evaluated to determine any deviations from gov-
underlying causes of diseases within a herd. Knowing
ernmental recommendations (Subcommittee on Dairy
what factors predispose cows to disease and what
Cattle Nutrition, National Research Council, 2001).
control methods can be used to remove or attenuate
Antepartum cows had elevated NEFA levels, indi-
risk for disease in exposed cattle will greatly help dairy
cating weight loss in the last weeks before calving. Cows
owners to produce milk and meat profitably, often with
had low calcium levels before and after calving with
less labour.
only rare milk fever, suggesting that the antepartum
diet was not well balanced for prevention of hypocal-
cemia. Urine pH was 8.0 in antepartum cows, indicat-
Approaching a herd problem – an
ing that the anionic diet was not effective. Non-lactating
example

and lactating cows had high serum magnesium levels,
suggesting higher than normal intake of magnesium
As a case example, an 1100 cow herd had several
(Mg). Diet analysis suggested that antepartum cows did
hundred cows with diarrhoea throughout the lactating
not have adequate protein intake and their daily diet
herd (900 lactating cows). The incidence of mastitis
intake was low. This suggested that cows should be
varied from zero to ten new cases per day. The expected
losing weight before calving, predisposing them to peri-
incidence was 0–1/day. In the first 10 days after calving,
parturient immunosuppression, retained placenta, mas-
30–40 percent of newly calved cows had retained
titis, metritis and displaced abomasum. The lactating
placenta and/or metritis. The expected incidence of
cows also had high Mg levels and diet analysis indicated
retained placenta was 5–8% and was principally asso-
that they were fed a ration containing 0.6% Mg on a
ciated with dystokia and twin birth. The expected inci-
dry matter (DM) basis (upper levels recommend 0.4%
dence of metritis in newly calved cows was 3–5 per cent

DM). Lactating cow diets also contained 22 per cent

and mostly associated with retained placenta. The

protein in the DM. Mycoplasma bovis was discovered

number of cows with displaced abomasum varied from

in a few cows with mastitis in the early lactating period

three to ten per week across all lactating strings, but

and several cows were culture positive for environ-

mostly in the first month post partum. The expected

mental streptococci,

staphylococci and coliform

incidence of displaced abomasum was 1–3 per cent of

bacteria.

cows calving, with none of the cases coming from cows

Ration and feed analysis suggested the milk cows

later than 30 days post calving. Cows dying or being

were oversupplemented with Mg and protein, and

sold as unproductive approached 50 per cent of the

effective fibre may have been limiting. Salmonella cul-milking herd over a 5-month period and the expected

tures were negative and results of BVD serology and

rate was 30–35 per cent. The milk production was 30

PCR probes for BVD suggested that neither Salmo-

litres (68 lb) per cow per day and the expected produc-

nella nor BVD were the cause of diarrhea. As formu-

tion was 35–36 litres (78–80 lb).

lated, dry cows should have been fed a ration adequate

As an approach to the herd problem, cows identified

in energy and protein, but intake was low, probably

by the herd manager as poorly producing or sick were

causing weight loss and contributing to periparturient

held for diagnosis of underlying disease. Visual exami-

metabolic disease (retained placenta, mastitis, milk

nation of all cows in the herd was done during biweekly

fever, displaced abomasum, ketosis, low milk produc-

fertility examinations. All calving and mastitic cows had

tion). The prevalence of diarrhoea was 80–90 per cent

composite milk samples collected aseptically for iden-

of lactating cows. There was no apparent diarrhoea in

tification of Mycoplasma and aerobic bacteria. Approx-non-lactating cows.

imately 10 per cent of cows in three groups had blood

New rations were formulated to reduce Mg through-

samples collected: cows before calving, in the first 10

out the herd, reduce protein in the lactating cow rations
days after calving and approximately 100 days after
and to increase the effective fibre in the lactating herd.
calving. Metabolic profiles (haemograms and serum
Close-up and far-off dry cow rations were reformulated
chemistries) were run to help determine the underlying
to reduce feed sorting and to increase intake for all
causes of disease. Faecal cultures for Salmonella sp.
cows. String cultures (emphasizing newly calved and
were collected, as well as blood for determining expo-
hospital cows) and retrospective reculture of all cows
sure to or active infection with bovine virus diarrhoea
having had mastitis within the past two months were
(BVD). Antepartum blood samples were collected to
initiated to identify mycoplasma-positive cows. From
determine serum non-esterified fatty acid (NEFA)
interviews with the dairy manager it was noted that
levels. Urine pH was determined to evaluate the effec-
most cows were administered 40–120 mg of dexam-
tiveness of the anionic dry cow diet. Diets by produc-
ethasone for udder oedema in the first one to four

days after calving. Routine use of dexamethasone was
may be needed to reduce disease to expected levels.
greatly curtailed to alleviate the immunosuppression
Identifying factors that may contribute to lower than
associated with its use.
expected levels of disease can advance the science of
After reducing the protein and Mg levels to govern-
veterinary medicine. Communicating new ways to
mental recommendations for level of milk production,
reduce disease incidence can allow those of us in prac-
diarrhoea in the milking cow herd was reduced to one
tice to contribute to our personal growth, advance our
to two cases/900 cows per week. These were mostly
clients' needs and advance the way veterinary practice
attributed to indigestion. Replacement of long-stem oat
is carried out.
hay with corn silage from the dry cow diets and refor-
A traditional and still important area for veterinary
mulation of the close-up mineral package reduced the
intervention is development of cost-effective vaccina-

urine pH to 6–6.5 and increased diet intake and uni-

tion protocols and evaluation of their success. This

formity of consumption of these two rations. Of cows

should be done for all stages of life and production.

calving, retained placenta and metritis incidence was

Evaluating calving and calf facilities and performance

reduced to 6–8 per cent and 3–5 per cent, respectively.

is a way to begin routine herd health monitoring and

The incidence of displaced abomasum declined to 0–3

intervention. Evaluation of the calving facility cleanli-

cases/month. Cows at three to five days post calving or

ness, calving protocols for ensuring healthy cows and

identified with mastitis had milk aseptically collected

calves after calving (e.g. hygiene in assisting with

from all four quarters and all cows positive for

dystokia or the force applied when pulling calves),

mycoplasma were removed from the herd. All pur-

colostrum monitoring (bacteria counts,

amount,

chased cows were routinely monitored for contagious

density) and calfhood disease control (cleanliness of the *mastitis and treated, segregated, culled or returned to*

calving and newborn facilities, cleanliness of the feeding

the supplier as needed. It was thought that periparturi-

utensils, milk and feed and protocols for routine disease

ent immunosupression, both from poor feed intake and

treatment) are good starting points. Focusing veterinary

from use of dexamethasone, facilitated the mycoplasma

care in these areas has a high return on investment for

outbreak. After initial identification of the index

producers as they are areas that are often neglected, yet

mycoplasma-positive cows it took approximately one

have a great effect on profitability when well main-

month to bring the incidence down to zero. Evaluation

tained.

of the freestall environment and cows in the milking

parlour indicated that the freestalls were not well main-

***Mastitis monitoring** (see Chapters 23, 25)*

tained (wet and manure/urine contaminated), but the

cows were clean and dry when milked. It was recom-

Mastitis control and evaluation of pathogens in milk is

mended that the freestalls be dug out and refilled with *still a very important service provided by veterinarians.*

sand to encourage stall acceptance and reduce exposure

Evaluation of types of bacteria in individual and bulk

to organic bedding.

tank samples, individual and herd somatic cell counts

and total bulk tank bacteria counts can direct

where and when intervention is needed to correct a

Veterinary monitoring on

herd/equipment problem. Routine milking equipment

evaluation, quality control for teat dips and milker

the dairy farm

training schools are valuable services to producers to

help ensure the sale of quality milk.

In addition to traditional veterinary tasks of routine

health care (including biosecurity protocols), surgical

and reproductive intervention, and disease monitoring,

Fertility monitoring *(see Chapter 41b)*

veterinarians should be involved in facility design,

With several strategies of intervention for improving

selecting equipment and monitoring its performance

pregnancy rates within a herd (e.g. timed insemina-

(feed trucks, milking equipment), personnel training

tion and prostaglandin synchronization programmes),

and management, ration formulation, monitoring milk

assessing the success and cost-effectiveness of these pro-

production and heifer growth, forage production and

grams is important. Evaluation of personnel skills on a

monitoring of stored feed quality.

facility will help determine the likelihood of success and

whether these types of programmes should be used in an

enterprise. Use of bull breeding may be most appropri-

Disease monitors

ate for some herds, while in others highly successful arti-

Routine monitoring of disease prevalence and inci-

ficial breeding programmes can greatly aid in creating a

dence allows the veterinarian to interpret changes in

high quality and uniform genetic base for a herd. Goals

expected levels of disease and whether intervention

for reproductive performance have been well described

over the past 40 years, but with the advent of products

count) will help guide decision-making for feeding *such as recombinant bovine somatotropin (rBST) some changes, forage selection, production, harvest, storage of these goals have changed. Some have suggested that and removal for feeding. Examination of foodstuffs can increasing the calving interval in these rBST herds can help identify those practices that alter cow health be economically advantageous. However, maintaining a and milk production. Poor quality forage production, high proportion of the herd pregnant (50 per cent or harvest, storage and removal for feeding can directly more) with good conception rates (2.0–3.0 services/ affect both both feed intake and cow health. Overly conception) still remains a primary goal to ensure mature feed that is too dry when ensiled can become profitability of a dairy enterprise.*

mouldy or compost, leading to both an unhealthy feed Evaluation of body condition at calving, one to two and one that is unpalatable and poorly available. Too months after calving, at conception and at cessation of wet a forage or contamination of feed with animal lactation can help maintain reproductive performance.

carcasses can lead to high levels of clostridial growth,

Increasing rates of anoestrous cows in early lactation

predisposing animals to diseases such as botulism.

(60–120 days in milk) suggest weight loss in the dry

Improperly stored corn, barley, canola, cottonseed, soy-

period or early post-parturient period (0–90 days), heat

beans and other protein meals can lead to mould pro-

stress or inadequate nutrition in the current ration.

duction and subsequent mycotoxicosis. Contamination

High levels of endometritis at 30–45 days' lactation

of feed from bird droppings and wild and domestic

suggest problems in the periparturient period and

animal faeces allows for spread of Salmonella,

require that all factors contributing to the endometritis

Leptospira

and other shared pathogens.

Cross-

be identified (e.g. nutrition, hygiene practices, dystokia,

contamination of feeds with cattle manure increases the

twinning). Correcting these deficits will help keep the

spread of Johne's disease, BVD, Salmonella spp., etc.

herd reproductively sound, reduce treatment costs,
Recommendations for facility design to limit feed trans-
lower culling rates and help maintain profitability.
mission of infectious diseases facilitate disease control
The use of progesterone assays to verify heat
at the population level. This type of activity is analo-
detection accuracy (at the time of insemination) is
gous to the design of vaccine and treatment protocols
another tool the veterinarian can use to help monitor
that veterinarians have engaged in for years. Taking
herd health, although anoestrous cows can also lack
steps to reduce exposure of the animals on farms to
detectable levels of progesterone. Holding breeder
these agents is also becoming a goal for limiting con-
training schools to teach or review heat detection
tamination of food at the consumer level.
techniques, semen handing and proper insemination
Feed sorting, or the selection of high concentrate
techniques can maintain high fertility in a herd.
feedstuffs over forages by cattle, increases the likeli-
As part of any herd monitoring programme, evalua-

hood of lameness, subacute ruminal acidosis, reduction
tion of the incidence of periparturient disease allows
in the production of fat in milk and ultimately lower
for a retrospective evaluation of the health of non-
milk yield. Directing forage production (selecting seed,
lactating cows and cows in the first month of lactation.
fertilization, planting density), timing (immature or
Recording and evaluating the incidence of ketosis, dis-
mature) and method of harvest (e.g. kernel processing
placed abomasum, milk fever, diarrhoea, pneumonia,
or rolling of corn silage as it is harvested, chop length),
mastitis, etc., are critical so that action or target levels
size and dimensions of storage facilities for forages,
for intervention may be set. Certainly diseases should
management of forage removal (face management of
be monitored at all stages of life (birth to sale) and goals
silage) will help producers keep cattle healthier and
of performance evaluated for each stage of production.
more productive. Veterinarians, by the very nature of
Routine monitoring of urine pH and fresh cow meta-
our relationship with producers, often are in the best

bolic profiling (Ca, Mg, P, K, Na, Cl, liver function,

position to evaluate feeding practices. If we are evalu-

serum protein) will help evaluate the success of

ating those practices it makes sense that we are the ones

non-lactating and early lactating feeding and housing

directing how to feed the cows for health and produc-

programmes. This will help ensure that cows perform

tion. An evolving role of veterinarians is routine ration

well throughout lactation. Monthly or bimonthly eval-

evaluation and formulation. Because cow health is

uation is appropriate and can be more or less inclusive

directly affected by improper nutrition, it is increasingly

depending on the frequency of farm visits.

important that veterinarians become directly involved

in ration formulation.

As part of the routine evaluation of cattle health,

Production monitoring

veterinarians should monitor why cattle are sold from

Routine evaluation of production parameters, such as

the herd and the number sold in a given time. Culling

feed intake, calf growth and milk production (milk flow, *rates directly affect profitability. While production may*

butter fat, solids not fat, protein, lactose, somatic cell

appear very good for cows in a herd, this can be deceiv-

ing if the number of cows entering and leaving the herd

tional and financial advice including commodity con-

is high. If replacement costs are low and the value of

tracts, crop selection and forage production. The oppor-

milk high that strategy could be very profitable. Today

tunities for veterinarians are ever expanding, allowing

in North America, cattle prices are high and the average

several avenues of input into animal agricultural

price for milk sold has remained relatively steady. If a

production.

producer has a high cull rate (45–55 per cent of the

herd/year), milk production per cow can be quite high

(13 000 litres (£3000) per 305-day lactation). However,

Further reading

because of the high removal rate and high cost of

replacements, this strategy can reduce net profitability

Martin, S.W., Meek, A.H. & Willeburg, P. (1987) Veterinary or prevent a dairy

from growing if cows are removed

Epidemiology, Principles and Methods. Iowa State Univerfor disease. If the high cull rate is because cows are

sity Press, Ames.

being sold for dairy production (highly valued cattle) to

Radostits, O.M., Leslie, K.E. & Fetrow, J. (1994) Herd Health, other herds and the producer has an excellent calf

Food Animal Production Medicine, 2nd edn. W.B. Saunders, raising programme, this strategy could prove to be very

Philadelphia.

profitable. Helping producers evaluate their return on

Sniffen, C.J. & Herdt, T.H. (1991) Dairy Nutrition Management, Veterinary Clinics of North America, Food Animal

investment of a given strategy is an appropriate task for

Practice. W.B. Saunders, Philadelphia.

veterinarians to engage in.

Subcommittee on Dairy Cattle Nutrition, Committee on

In summary, the role of veterinarians is rapidly

Animal Nutrition, National Research Council (2001) Nutri-

changing in North America. Today more of the focus of

ent Requirements of Dairy Cattle, 7th edn (revised). National veterinarians will be in operations management, includ-Academy Press, Washington, DC.

ing herd health, personnel training, udder health and

Van Soest, P.J. (1982) Nutritional Ecology of the Ruminant.

milking equipment evaluation, facility design, nutri-

Cornell University Press, Ithaca, NY.

Chapter 74

The North American Beef Industry

D. Sjeklocha and S. Sweiger

Introduction

1188

because of their ability to deal with the extreme heat.

Cow-calf sector

1188

In the northern United States Bos taurus breeds are

Cattle distribution

1188

used because of their ability to withstand the cold

Cattle feeding sector

1189

temperatures.

Meat packing sector

1190

Sixty per cent of the United States' cattle herd is

The practice of beef cattle veterinary medicine in North

located in the south east. Amongst others, states in this

America

1190

area would include Florida, Georgia, Alabama, Missis-

sippi, Louisiana, Tennessee, Kentucky, North Carolina

Introduction

and South Carolina. In this area, only 1 to 5 acres (0.4–

2 ha) are required to sustain a cow and her calf for one

year. There are a few very large herds in this region,

The North American beef industry is very diverse and

the vast majority are very small herds. Many of these

complex. It is distinctly separate from the dairy indus-

small herds are either a hobby or a secondary source of

try, with the exception of cull dairy cows and castrated

income for the producer. Often, these producers simply

male dairy stock (steers), which are eventually added to

have a small parcel of grass that would not be utilized

the beef supply. 'Dual purpose' breeds are very seldom

at all unless the producer owned a few cows to graze it.

used for true dual purposes. There are three sectors to

*These producers are not necessarily in the cattle busi-
the North American beef industry: the cow-calf, cattle
ness to produce beef, but rather use cattle to harvest a
feeding and meat packing sectors. A very short synop-
forage that would otherwise go to waste. Because of
sis would say that the cow-calf sector provides cattle for
this, genetic control of production is not taken very
the cattle-feeding sector, which provides cattle for the
seriously in many cases. In recent years, producers and
meat packing industry. One may wonder why the meat-
veterinarians in this area have taken steps to improve
packing sector would be included in this discussion. It
genetic selection and to market cattle in uniform
has become evident in recent years that all three sectors
groups.
must work together and share information in order to
The remaining 40 per cent of the nation's cattle herd
deliver a beef product that provides a good eating expe-
is spread throughout the rest of the United States' graz-
rience for the end consumer. So, in this light, each of
able landmass. In some regions of this land mass, only*

these sectors will be discussed.

one acre (0.4 ha) is required to support a cow and her

calf, while in other areas, as much as 100 acres (25 ha)

Cow-calf sector

is required to support a cow and her calf. Generally, as

the carrying capacity of the land decreases, the size of

the herd increases. The regions that have a high carry-

Cattle distribution

ing capacity are also regions that produce a great deal

This sector is undoubtedly the most diverse. This is due

of cereal grains. Cow-calf producers in these areas take

to the fact that it uses grazed forage (primarily grass)

advantage of the crop residues by allowing their cattle

as its primary raw material. Grazable forage is available

herds to graze the fields after they have been harvested,

in every geographic region. The landscape and climate

gleaning the grains that were missed by the harvesting

throughout North America differ greatly between geo-

machines (combines). In regions where there is very

graphic regions. As the landscape and climate changes,

little cereal grain production, there is more reliance on

so do the types of forages available in that region as
harvested forage (grass hay, alfalfa hay, etc.) for winter
well as the type of herd management. Cattle herds are
feed. Herds in these regions can be as small as one up
developed in such a way to best deal with the environ-
to as many as 15 000 head or more.
ment in which they live. For example, in the southern
It is generally considered to be good management for
United States, Bos indicus breeds are very popular
cow-calf producers to adhere to a fairly rigid ‘calving

season’. Producers will turn bulls out with the cattle for
predicted by the use of expected progeny differences
45 to 90 days for breeding. At the end of this time
(EPDs). EPDs give the bull buyer an idea of how a par-
period, the bulls are removed from the herd. This allows
ticular bull’s calves may perform in various traits.
for better use of the producer’s time and a more uni-
formly sized calf crop. Some producers do not adhere
to this type of calving season, some of whom allow their

Cattle feeding sector

cows to have calves all through the year. The majority

of calves are born in the late winter or spring and are

The cattle feeding sector has become very specialized.

weaned in late summer or in the fall.

In the 1960s, many cow-calf producers fed their own

Weaning of calves is yet another area of great diver-

cattle to harvest weight. As more science and technol-

sity within the cow-calf sector. Some producers will go

ogy have been put to use, it has become more efficient

through a strict 'preconditioning' programme, in which

and cost-effective for cattle feeding operations to get

the calves are vaccinated once while still on the cow

increasingly larger, and less efficient and cost-effective

(typically against IBR, BVD, PI3, BRSV and clostridial

for the cow-calf producer to feed his own cattle. Many

disease). Then, approximately three weeks later, they

of the modern cattle feeding operations (known as

are revaccinated against the viruses, implanted with a

'feedlots' or 'feedyards') can hold 100 000 head of cattle

growth-promoting hormone and weaned. The calves *or more at one time.*

are then fed a grain and roughage ration for anywhere

A feedyard is a collection of pens that are used to

from a couple of weeks to several months, depending

confine cattle while they are being fed a high-energy

on the marketing plans of the producer. Other

ration. One side of the pen is lined with a concrete feed

producers will vaccinate their calves once, pull them off

trough (feed bunks). Trucks, fitted with a special box

the cow and sell them. Still others will simply pull their

that is capable of mixing feed, auger feed into the feed

calves off the cow without vaccinating them and sell the

bunks as they drive alongside them. Feed management

calves. Most bull calves are castrated at some point

is considered to be one of the most important and

prior to marketing, becoming known as 'steers'.

detailed jobs around the feedyard. Calling for the

Some cow-calf producers will retain ownership of

wrong amount of feed can hurt the performance of the

their calves through the feeding period up to harvest.

cattle in that pen for the rest of the feeding period.

These producers most commonly send their calves to a

Feedyard cowboys ride through each pen of cattle every

‘custom’ or ‘commercial’ feedyard and pay the feedyard

day looking for sick cattle. Sick cattle are removed from

to feed the calves for them. This will be discussed in

the pen and placed in a hospital pen, where treatment

more depth in the cattle feeding section. Most cow-calf

is administered and the animal is given time to recover

producers sell their calves at some point prior to the

before being returned to the original pen.

feeding period. The most common form of marketing

Cattle are usually hauled into feedyards by semi

calves is done through a livestock auction (also com-

tractor-trailers. These large trucks can carry 50 000 to

monly known as a ‘sale barn’). Calves are taken to the

56 000 lb (22.5–25.4 tonnes). It is not uncommon for

livestock auction, sorted for size or other common char-

cattle to be hauled for 8 to 24 hours before arriving at the

acteristic and sold to the highest bidder. Disadvantages

feedyard. This puts the cattle under a great deal of stress

of this type of marketing are that cattle are commin-

and increases the chances that they will become sick.

gled, thus allowing disease transfer. Cattle can also be

Over the years, feedyards have become very adept at

sold via 'satellite auctions' in which video images of

dealing with this stress. Many feedyards have pens that

calves are transmitted by satellite all over the country

are used especially for receiving cattle. These pens are

for bidders to view and bid on. Still more cattle are now

usually smaller than other pens on the feedyard and have

being sold over the internet/world wide web. These

excellent drainage so the newly arrived cattle have a dry

latter two marketing options offer the advantage of not

place to rest. Fresh feed and clean water are provided at

commingling different groups of cattle, as the cattle are

all times. After the cattle have eaten, drunk and rested,

marketed directly from the ranch of origin.

they are put through a series of procedures known col-

Within the cow-calf sector is a group of producers

lectively as 'processing'. Processing may include any or

collectively known as 'seedstock producers'. These are

all of the following: vaccination (against pathogens such

producers who specialize in producing breeding stock
as IBR, BVD, PI3, BRSV, Pasteurella/Mannheimia, spp.
to be used by the commercial cow-calf producer. Careful
clostridial pathogens, Haemophilus somnus, etc.),
attention is paid to fertility, carcass traits, muscling and
implantation with a growth hormone, eartagging,
performance characteristics (average daily gain,
administration of a parasiticide, administration of a
weaning weight, yearling weight, feed conversion, etc.).
vitamin/mineral supplement, castration of bulls or preg-
There is a wide range of criteria that cow-calf producers
nancy examination of heifers. If a heifer is found to be
use to select breeding stock and many of these are
pregnant, the pregnancy may be aborted.

Upon completion of processing, the cattle are moved
in the United States, there are three very large ones that
to a regular pen on the feedyard. Over the next two to
control the bulk of the industry. As many as 5000 head
three weeks, the cattle are fed a series of rations
per day can be harvested through these meat packing

designed to acclimate the rumen to starch digestion.

plants. Cattle are humanely harvested and the carcasses

The 'finishing' ration will contain approximately 90 per

are hung on an overhead rail to cool. The United States

cent concentrate. Feeding concentrates at this level may

Department of Agriculture provides quality inspectors

result in lactic acidosis, thus proper feed management

and veterinary inspectors to ensure a safe, wholesome

is of the utmost importance.

food supply.

Historically, finished cattle were sold to meat packing

Possibly one of the most positive changes that the

companies simply as a commodity. There were no pre-

meat packing industry has made in recent years is the

miums paid for exceptional quality, so there was no

implementation of information sharing. It is currently

reason for feedyards to feed for quality – just perform-

possible for a cow-calf producer to receive information

ance. Beginning in the 1970s, consumption of beef

about how well his cattle performed, in terms of quality

declined steadily, year after year. It became apparent *grade and yield grade. This type of feedback is very*

that more attention needed to be paid to the quality of

important for genetic advancement in the cattle herd.

the beef produced. Meat packing companies and feed-

yards started to enter into arrangements that would pay

premiums for superior beef quality and yield and would

The practice of beef cattle veterinary

penalize for inferior beef quality and yield. These

medicine in North America

pricing arrangements are commonly known as 'grids' or

'formula pricing'. Most grids are developed to reward

Beef cattle veterinary practice has evolved a great deal

for both beef quality and yield, but there are some that

in the last 20 years. This evolution has developed from

primarily reward for yield or primarily reward for

a primarily ambulatory practice in which individual

quality. Feedyards enter into grid agreements that best

animals were treated to a much more production-

fit their feeding abilities. Even with grid agreements,

oriented approach of veterinary medicine. As Ameri-

there are still a large number of cattle sold on a cash *can food production has become more and more effi-*

basis as a commodity.

cient, American society has become less and less aware

This discussion would be incomplete if ‘stockers’ and

of how their food is produced. This has led to many mis-

‘backgrounders’ were not included. Stockers are cattle-

conceptions among the American people about how

men who purchase calves at approximately weaning age

food animals are handled and treated for disease.

and turn these calves out to pasture. These calves gain

Society is very concerned about animal welfare, anti-

anywhere from 200 to 400 lb (90–180 kg) while on

biotic resistance and food safety. Beef producers are

pasture. The calves are then sold to a cattle feeder or

very concerned about these things as well, but are also

the stocker retains ownership of the cattle through the

concerned about production performance,

cost-

feeding period. Backgrounders (or preconditioners), on

effectiveness and the ever-tightening profit margin.

the other hand, are cattlemen who specialize in feeding

Individual treatment of animals is still a substantial
and taking care of high risk calves (calves that have a
part of beef cattle practice. Veterinarians are still called
high risk of sickness). Many feedyards will send their
upon to treat respiratory disease, lameness, reproduc-
high risk calves to backgrounders or growyards because
tive disorders, digestive and nutritional problems,
the feedyard does not have enough employees to give
among other things. However, veterinarians are also
these calves the level of attention they need. Often,
taking a more active role in preventing these situations.
calves in a backgrounding operation are checked two
Beef cattle producers are being economically forced to
or more times per day for sickness. After a few weeks,
provide cattle with added value. This means that the
the health problems subside. The calves will adjust to a
cattle must have the genetics and the immune integrity
concentrate-based ration and learn to eat out of a feed-
to perform well and stay healthy through each stage of
bunk. After several more weeks, the calves are removed
production.

from the backgrounding operation and sent to their

Many new opportunities in veterinary medicine have

respective feedyard, where they are fed out to harvest.

arisen because of this change from individual treatment

to preventive medicine. In the cow-calf sector, many

new computer software programs have been developed

Meat packing sector

that can help with production parameters, record

keeping and genetic selection. Because of the labour

Once the cattle have reached the appropriate harvest

intensity involved in beef production, many producers

weight and condition, they are sent to the meat packing

simply do not have the time to get comfortable with the

plant. While there are several meat-packing companies

software and its capabilities, although they still want the

information that the software provides. Many veteri-

veterinarian. Veterinarians play a key role in control

narians have taken this opportunity to help their clients

and/or elimination of pathogens in the food chain. Edu-

by serving as a data analyst. Veterinarians gather the *cating the beef producer and the consumer in areas information needed and record the information in such as how these pathogens develop and how they can the software program. Because the veterinarian has the be controlled is important for human health and for the opportunity to work with several herds, he/she also has survivability of the industry. Another food safety the opportunity to understand the software and its concern is the use of growth-promoting implants. The capabilities at a deeper level. The veterinarian can then European Union has stopped the importation of beef analyse a client's data, work up reports in various areas from the United States that has been exposed to growth of production and consult with the client on topics that promoting hormones. The use of growth promoting may include replacement heifer selection, herd sire hormones has been proven to be a safe practice. selection, culling, preventive health programmes, nutri- However, the EU's ban has caused some Americans to tion, effective treatment schedules and the cost- question its safety (see Chapter 63). Veterinarians are*

effectiveness of various production practices. There is
playing a key role in quelling rumours and misinfor-
still plenty of opportunity for some of the traditional
mation about the safety of American beef and the use
services of veterinary practice, such as pregnancy exam-
of growth-promoting hormones by applying good,
ination, vaccination of calves and cows and treatment
sound science.
of diseased stock, but veterinary consultation has the
Beef cattle veterinary practice will continue to move
potential of a wide scope of development in the cow-
away from individual animal medicine and move
calf sector.
toward population medicine. Veterinarians must be
In the cattle-feeding sector, veterinary consultation
cost-effective and must be able to demonstrate their
already has a tremendous foothold. With the very large
cost-effectiveness. Applying good science to decision-
numbers of cattle in these feedyards, it is very cost-
making is a major key to being cost-effective. Skills in
effective for the feedyard to hire a consulting veteri-

critical evaluation of the scientific literature need to be

narian to design health programmes, evaluate treat-

honed to a high level of precision so science-based deci-

ment protocols, help in the training of new employees

sions can be made. This is very important in an increas-

and advise on the construction of new facilities and the

ingly litigous society, as good science is much easier to

repair of current facilities. This type of practice can be

defend in court than anecdotal decisions.

very satisfying professionally, but there is a great deal of

There are and will be many, many opportunities

travel involved.

available in beef cattle veterinary practice in the

Whether a veterinarian specializes in the cow-calf

future. The beef industry is changing at a rapid pace and

sector, the cattle feeding sector or both, the issues that

the same is true of beef cattle practice. Veterinarians

the beef industry faces will affect his/her practice. One

must be willing and able to adapt to a changing indus-

of those issues is food safety. Food safety has captured

try and be able to recognize an opportunity when it *the attention of the consumer, the producer and the*

arises.

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