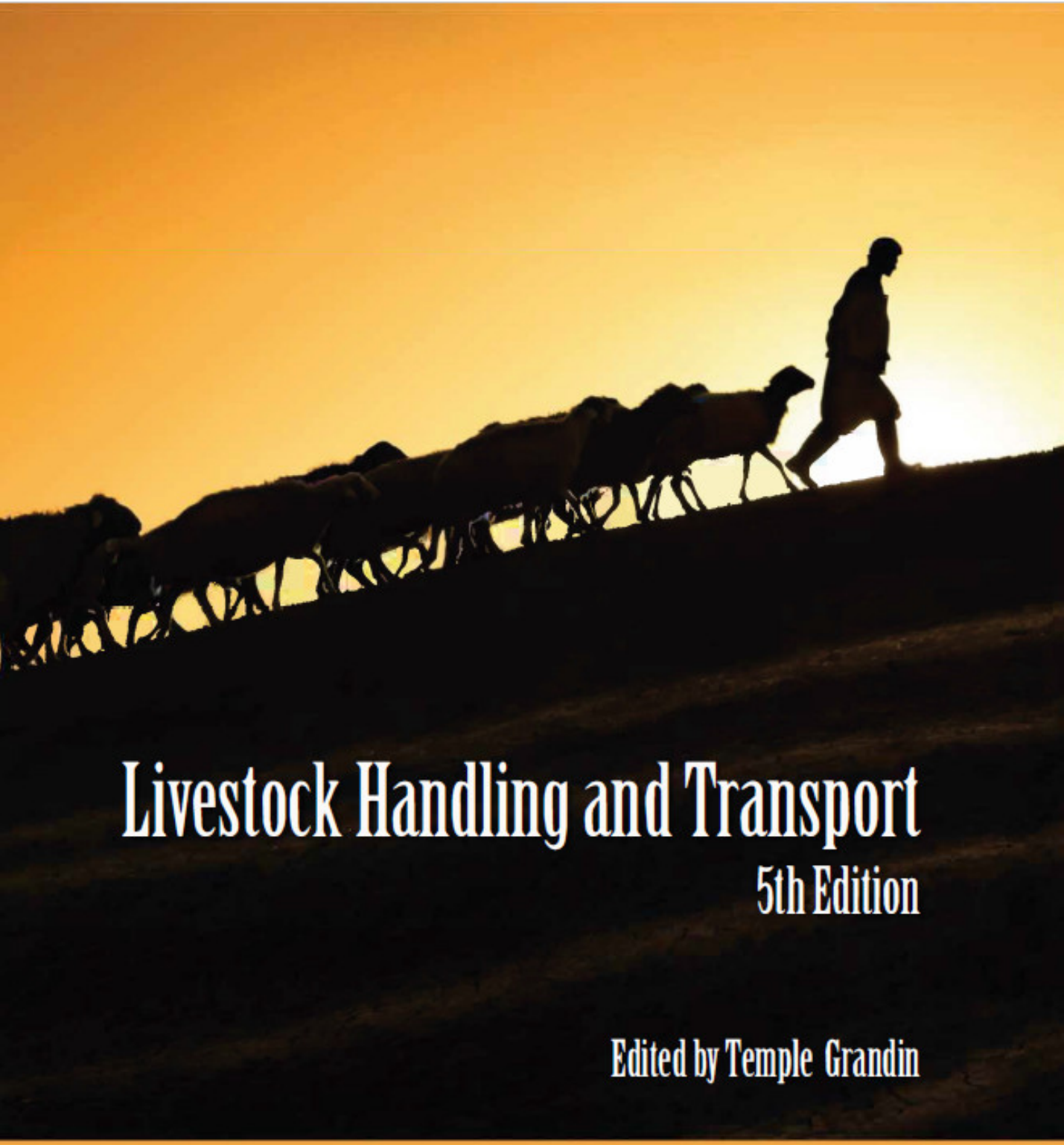


Livestock Handling and Transport

5th Edition

Edited by Temple Grandin

CABI

Livestock Handling and Transport

5th Edition



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Edited by

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Preface to the 5th Edition

The purpose of this book is to serve as both a source of recent research studies on handling and transport of livestock and poultry, and to be an archive of valuable older information. Older literature is still important because well done behavioural studies never become obsolete. If they disappear from the literature, then today's researchers will be forced to rediscover the lost information. The chapters on handling and transport of cattle, sheep, deer, poultry, pigs and horses have all been fully updated. Three completely new chapters have been added on the handling of goats, robotic milking of dairy cows and transport of livestock by ship or air.

The first edition of *Livestock Handling and Transport* was published in 1993. This fifth edition is being published 26 years later. A new introductory chapter on the importance of having skilled, knowledgeable stock people has been added. The latest technology does not replace the need for skilled, caring stock people. Throughout the fifth edition, both old and new studies clearly show that stock people who have a positive attitude and understand animal behaviour have more productive animals.

Each chapter has an extensive reference list. This helps preserve the best of the old knowledge and provide easy access to new studies that have been completed since the publication of the fourth edition in 2014. There is also a list of websites, videos on proper animal handling and sources of information on handling and transport. Two classic chapters on the design of sheep yards, and herding and guarding dogs have been retained.

Other topics covered are updated chapters on: stress physiology during handling and transport, livestock behaviour patterns during handling, and animal welfare issues. The design of corrals, stockyards, transport vehicles and lairages is also included. The authors of the 23 chapters provide information on the unique conditions in different countries. There is new information on methods of handling Brazilian Nellore cattle. Another extensively updated chapter discusses the effects of both genetics and previous experiences of an animal's reaction to handling. There are contributors from Australia, Brazil, Canada, Chile, Mexico, The Netherlands, Spain, Uruguay, United Kingdom and the USA, providing a true international perspective.

Temple Grandin
June 2019

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1 The Importance of Stockmanship to Maintain High Standards of Handling and Transport of Livestock and Poultry

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Summary

Both practical wisdom and scientific research show the importance of good stockmanship. Cattle, pigs, sheep and poultry that fear people have lower productivity. Animals that willingly approach people are more productive. The best stock people have a positive attitude, and like animals. Equipment and technology will never replace the need for skilled stockmanship and handling to reduce stress. Managers often make the mistake of attempting to use new technology as a substitute for stockmanship and handler training. To motivate continuous improvement and to prevent practices from slipping back into old bad habits, the use of numerical outcome measures is strongly recommended. The following parameters should be measured – falling, stumbling, vocalization during handling, becoming miscaught in a squeeze chute, and electric prod (goad) usage. There are six steps for continuous improvement of stockmanship:

1. Teach people to have a positive attitude, to remain calm and not to yell.
2. Teach stock people to be observant.
3. Teach basic livestock behaviour and movement patterns.
4. Use numerical scoring to prevent deterioration of handling practices.
5. Maintain the highest level of herding and handling, which will require a high skill level.
6. Do not understaff or overwork stock people.

Introduction

Good stockmanship when handling livestock is really important. In 1885, W.D. Hoard, the founder of *Hoard's Dairyman* magazine, stressed the importance of good stockmanship and gentle handling of dairy cows (Geiger, 2013). In his notice to help, he wrote, 'A man's usefulness in a herd ceases at once when he loses his temper or bestows rough usage. The giving of milk is a function of motherhood. Rough treatment lessens the flow.' H.W. Mumford, Professor of Animal Husbandry at the University of Illinois, has also written about the importance of good animal husbandry and stockmanship. In his poem 'A Tribute to the Stockman' he wrote, 'Behold the Stockman! / Artist and Artisan. / … / May his kind multiply and replenish the earth.' (Garrigus and Garrigus, 1995)

Scientific Validation of the Importance of Good Stockmanship

Both of these people had written about the importance of skilled stock people before scientific studies proved that people who practise good stockmanship will have more productive animals. Three early studies showed the benefits of good stockmanship to improve productivity of pigs, cows and chickens (Hemsworth *et al.*, 1986, 1994, 1999). Seabrook (1984) found that the personality of the stockperson influenced production. The confident introvert had

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the most productive dairy cows (Reid, 1977). Stock people who had the highest-producing dairy cows had cows that would approach them for stroking (Seabrook, 1984). Herdsmen who had the highest-producing dairy cows knew every single cow and may well have given them names (Bertenshaw and Rowlinson, 2009). Fulwider *et al.* (2008) found that dairy cows that were more willing to approach people had lower [better] somatic cell counts. The preferred location to stroke the cow is on the neck (Schmied *et al.*, 2008).

Detrimental Effects of Poor Stockmanship

Hemsworth *et al.* (1981) found that sows that were afraid of people had lower reproductive performance. Chapter 16 in this volume by Paul Hemsworth will review the many studies that clearly show that aversive treatment of animals, such as slapping, will reduce weight gain and milk production (Hemsworth *et al.*, 2000). A survey of 31 dairies showed that poor handling practices, such as slaps and tail twists, resulted in 16% less milk (Breuer *et al.*, 2000). Table 1.1 clearly shows that aversive handling of dairy cows increases the size of flight zone and cows will be slower to enter the milking centre. Sheep that came from farms with poor, aversive handling practices had lambs that feared all people (Destrez *et al.*, 2013). Other studies have also shown that cattle and pigs can recognize individuals who have treated them badly (Munksgaard *et al.*, 1997; Rushen *et al.*, 1999a, b; Sommavilla *et al.*, 2016). Positive treatment by stock people improves reproductive performance of pigs (Hemsworth *et al.*, 1986). Adult dairy cows can recognize people's faces (Rybarczyk *et al.*, 2001). Visual cues, such as a particular type of clothing, can be associated with either positive or negative treatment (Rushen *et al.*, 2001; Rybarczyk *et al.*, 2003; Grandin and Johnson, 2005). Research with pigs clearly shows that pigs can recognize individuals with visual or auditory cues (Tanida and Nagano, 1998; Koba and Tanida, 2001; Tallet *et al.*, 2018).

Yelling and screaming at cattle is highly stressful (Pajor *et al.*, 2003). South American studies have also shown the detrimental effects of poor handling practices. Cows used for embryo production had 19% less viable embryos when they were handled roughly (Maedo *et al.*, 2011). Lima *et al.* (2018) found that the elimination of dogs, yelling and electric prods significantly reduced cortisol levels. Research clearly shows the detrimental effects of poor stockmanship and rough handling. Further information may be found in Taylor and Davis, 1998; Rushen *et al.*, 1999 a,b; Waiblinger *et al.*, 2002, 2004, 2006; Hemsworth and Coleman, 2010; Rushen and de Passille, 2015; and Hemsworth *et al.*, 2018).

A Positive Attitude and Liking Animals Is Important

The first step to improving stockmanship is having the right attitude. Attitude precedes ability (Machen and Gill, 2014). A good stockperson teaches the cattle to trust their caregivers (Noffingser *et al.*, 2015). Patience and empathy are important when handling difficult sheep (Burnard *et al.*, 2015). Stock people can be trained to have better attitudes towards animals and welfare (Coleman and Hemsworth, 2014; Pulido *et al.*, 2018). A study in the Philippines with goats showed that stockmanship training improved productivity (Alcedo *et al.*, 2014). Research has also shown that people who like animals and have a positive attitude will have more productive dairy cows and pigs (Kauppinen *et al.*, 2012; Jaaskelainen *et al.*, 2014; Fukasawa *et al.*, 2017). Coleman *et al.* (2000) and Hemsworth *et al.* (2002) reported that stock people who liked pigs and dairy cows had more productive animals.

Attitudes about Pain Need to Improve

There is still a need to change people's beliefs about pain in farm animals (Hemsworth, 2007). When 500 Dutch dairy farmers were surveyed, only 25% believed that cows felt pain (Bruijnis *et al.*, 2013).

Table 1.1. General response of dairy animals under different handling treatments. (From Seabrook, 1991; Fulwider, 2014)

Action of cow	Pleasant handling	Aversive handling
Mean entry time to milking centre (s/cow)	9.9	16.1
Flight distance (nervousness) (m)	0.5	2.5
Dunging in milking centre (times/h)	3.0	18.2
Free approaches to humans (times/min)	10.2	3.0

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One of the reasons so few believed that cattle felt pain is that cattle, sheep and other prey species animals will act normally when they know they are being watched, even though they may be feeling pain. The author has observed this behaviour. At a feedlot, I hid in the scale house and watched the behaviour of six-month-old bulls after they had been castrated by banding. One of the animals rolled around on the ground and moaned. When I suddenly came out of the scale house, and he saw me, he jumped up and acted completely normally. It is important that stock people are informed about how cattle and sheep may cover up that they are hurting. If cattle trust the stockperson they may be more likely to exhibit pain symptoms in front of them (Tom Noffingser, personal communication, 2015). Pigs will squeal loudly during castration, but sheep will not vocalize when in pain. In a Canadian survey, there were some producers who thought that the pain of castration was short-term and not important (Spooner *et al*., 2014). In the same survey, producers stressed the importance of low-stress handling and being opposed to animal neglect (Spooner *et al*., 2014). Pork producers may have better attitudes about relieving long-term pain from chronic conditions such as lameness or gastrointestinal disease (Ison and Rutherford, 2014).

Equipment and Technology Does Not Replace Stockmanship and Low-stress Handling

I have a saying, when problems on a farm need to be solved, 'People want the thing more than they want the management.' I learned this during consulting with hundreds of farms and abattoirs around the world. They want to solve all their problems with a new corral, milking centre, computer or drug. Many managers believe that a single large purchase of new equipment will solve all their problems. Good stockmanship and low-stress handling require attention to many details every day. Maintaining high levels of good management requires continuous attention to many different small details. It is not accomplished by a single purchase of new equipment. I often get asked, 'What would you rather have, the new fancy equipment with poor management or an older well-maintained system with good management?' I would prefer the good manager with older facilities. The swine industry is in the process of switching from individual gestation stalls to group sow housing. These systems often require a higher level of stockmanship. At the pork conference in Banff, Alberta, a producer described his experiences in making the switch. He reported that a calm, patient 'Hog Whisperer' was required to train young gilts how to use the electronic sow feeders (Coleman, 2016). Coleman also emphasized the importance of training the animals through trust. This requires a calm, patient person who could connect with the pigs.

Maintaining High Standards of Stockmanship

Good stockmanship is impossible if people are overworked and the farm is understaffed. People will get too tired to care. The most important person on the farm for maintaining high levels of good stockmanship is the manager. The manager must care about stockmanship. Top management must fully support the importance of stockmanship and good animal handling (Machen and Gill, 2014; Beaver and Hoagland, 2016). In my consulting business, I have learned that the most important person for me to train is the manager. Training of the employees had little effect if the manager treated animals poorly or encouraged handlers to be rough.

How people are paid can also affect the quality of stockmanship and livestock handling. Payment on a piece-work basis can cause problems (Grandin, 2015a). Examples of piece-work are payment based on how many cows are milked per hour or how many cattle or pigs are vaccinated per hour. Piecework, unless it is very carefully supervised, can result in sloppy, rough handling. People who are good at working with animals are highly skilled; they need better pay so that they will be motivated to make stockmanship a career (Daigle and Ridge, 2018).

Prevent Bad from Becoming Normal

Today there are many workshops and classes on the behavioural principles of livestock handling and stockmanship. There is also lots of information online and videos that show calm, low-stress livestock handling. After attending a class, both the manager and the employees are often positive and enthusiastic about stockmanship and improved handling of their cattle, pigs and sheep. The problem is that old, bad practices can slowly re-emerge and people do not realize it. I call this 'bad becoming normal'. To prevent this from happening, livestock handling can be evaluated with numerical scoring

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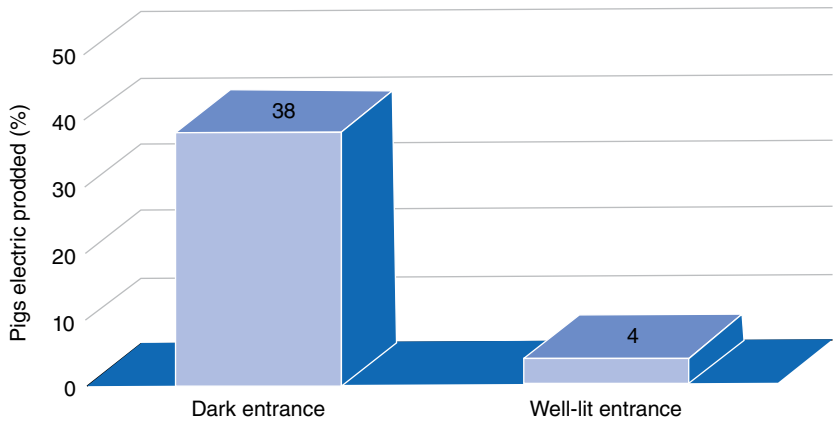


Fig. 1.1. Numerical outcome-based scoring can be used to determine if a change in either the equipment or handling procedures improved handling. Adding a light at the entrance to a chute (race) reduced balking, and the use of an electric prod was greatly reduced (From Grandin, 2015b).

(Grandin, 1998; Welfare Quality, 2009; Simon *et al*., 2016; Barnhardt *et al*., 2016; Woiwode *et al*., 2016a; Losada-Espinosa *et al*., 2018). The variables that should be measured are:

- percentage of animals falling during handling;
- percentage of animals stumbling or slipping;
- percentage of animals that vocalize (moo, bellow or squeal when restrained – applicable to cattle, pigs and goats, not sheep);
- percentage of animals miscaught in the wrong position in a restrainer;
- percentage of animals moved with an electric prod (goad);
- percentage of animals refusing to move forward (balking).

Keeping score with these simple measurements can help both management and employees determine if practices are improving or becoming worse. Numerical measurements can also be used to determine if a simple change in a facility improved the flow of livestock through a race. Sometimes a single change such as installing a light to illuminate a dark chute (race) entrance can reduce electric prod use because fewer animals balk and refuse to move (Fig. 1.1).

Collect Baseline Data and then Work to Improve

Two surveys done in the USA showed that staff at large cattle feedlots have improved their practices when handling cattle for vaccinations (Woiwode *et al*., 2016a; Barnhardt *et al*., 2016). They collected data in 26 and 56 feedlots, respectively. In addition, a survey carried out by Simon *et al*. (2016) showed that some California ranches needed to improve their practices and reduce electric prod use. At the feedlots, the average percentage of cattle moved with electric prods was 5.5% (Woiwode *et al*., 2016a) and 4% (Barnhardt *et al*., 2016). The ranches' performance was much poorer with an average 23% of cattle moved with an electric prod. The worst ranch had employees that used electric prods on 78% of the cattle and others used them on 0% of the animals.

All three surveys had good scores for the percentage of cattle falling during handling. Falls (body touching the ground) were counted when cattle exited the squeeze chute. The scores were 0.8% (Woiwode *et al*., 2016a), 0.2% (Barnhardt *et al*., 2016) and 0.9% (Simon *et al*., 2016). Stumbling while exiting was higher than falling, at 6.7%, 1.8% and 4.7%, respectively. Scores can often be highly variable. A study done in Brazil showed that the best slaughterhouses had 0.4% of the pigs slipping and the worst had 48% (Dalmau *et al*., 2016).

Vocalization Indicators of Poor Restraint Methods

Cattle vocalizing when they are restrained in a squeeze chute is an indicator of welfare problems.

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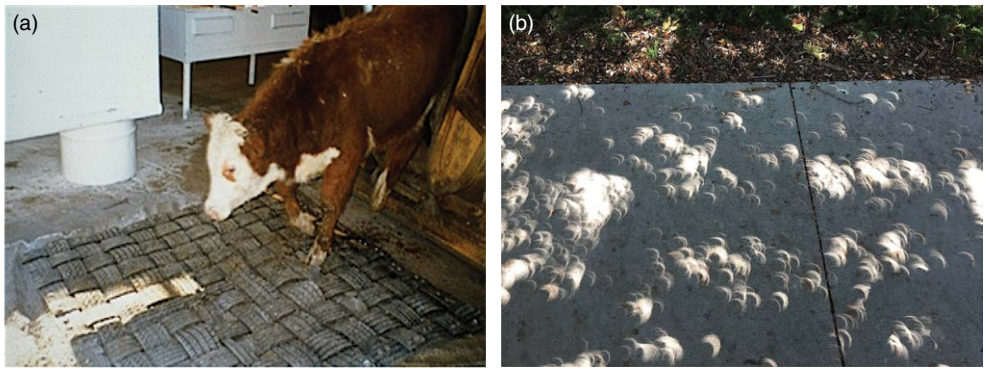


Fig. 1.2. People need to learn to be better observers. When Fig. 1.2a was shown to many livestock producers, most failed to see that the calm calf was looking directly at the sunbeam. Fig. 1.2b shows a shadow pattern on a university campus sidewalk, which was cast by the trees during a 90% solar eclipse. Most students walked over it and failed to see it. The tree leaves act like multiple pinhole cameras. A person skilled in stockmanship would probably see this strange shadow because he/she is a better observer of detail. (Photos: Courtesy of Temple Grandin)

Vocalization during handling can be caused by electric prods, excessive pressure from a restraint device, or sharp edges (Grandin, 1998, 2001; Bourquet *et al*., 2011). When there are problems, vocalization scores can rise quickly. Examples of high percentages of cattle vocalizing were: 23% caused by excessive pressure on the neck by a head stanchion (Grandin, 2001); 25% caused by excessive pressure from a restraint device (Bourquet *et al*., 2011); and 47% due to almost 100% electric prod use to move cattle (Hayes *et al*., 2015). The three surveys on the feedlots and ranches had low average vocalization scores of 1.4% and 0.9% (Woiwode *et al*., 2016a; Barnhardt *et al*., 2016, respectively), and 5.2% (Simon *et al*., 2016). Woiwode *et al*. (2016b) showed that beef cattle that vocalized in the squeeze chute during vaccination had lower weight gains.

Steps to Improve Stockmanship

Stockmanship expertise can range from the most basic to the highest levels of herding skills on open range. Below are six steps for improving stockmanship and handling of livestock:

1. Teach stock people to have a positive attitude. Managers should never understaff or overwork them. Abuse and neglect of livestock is never allowed. Train people to be quiet and stop yelling. In order to learn more about stockmanship, people must calm down. Livestock are more easily handled by calm people who like animals. Training courses can be used successfully to improve attitudes towards pigs and dairy cows (Coleman *et al*., 2000; Hemsworth *et al*., 2002).

2. Teach stock people to be observant. They need to look at small details of animal behaviour such as ear position, posture or what the animal is looking at (Fig. 1.2). If cattle are vocalizing when they are not being handled, a stockperson needs to be observant to determine if they need something (Williams and McConnell, 2018).

3. Teach the basics of livestock behaviour and movement patterns (see Chapter 5 and other available training materials).

4. Use numerical scoring to prevent slipping back into old, bad practices.

5. The highest levels of herding and handling on extensive pastures will require a high level of skill and weeks of practice.

6. Do not understaff and overwork stock people.

Good Stock People and Euthanasia

People who care about animals and are good stock people are often reluctant to euthanize an animal that is suffering. This is called the caring/killing paradox (Reeve *et al*., 2005). A survey done for the US National Pork Board indicated that there is disagreement among industry leaders

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on conditions that require immediate euthanasia (Mullins, 2017; Mullins *et al*., 2017). It is psychologically easier for stock people if they are given clear guidance on when to euthanize. When the 'book' makes the decision, it is less stressful for the stockperson (Blackwell, 2004; Grandin and Johnson, 2009; Woods and Shearer, 2015). Following the rules in the 'book' relieves a caring person of having to make the decision. Research has shown that both the act itself and the decision-making process can have a negative effect on stock people (Rault *et al*., 2017). Sometimes the best approach is to have somebody else from a different part of the farm come and euthanize the animals.

Skill-dependent versus Less Skill-dependent Handling Facility Design

When stock people are highly knowledgeable of the behavioural principles of livestock handling, simpler, less expensive facilities may be very effective and may provide good animal welfare. The author watched six wild Karakul sheep being herded by two very skilled stock people who moved them around the perimeter of a corral and expertly restrained them for injections behind a long gate. The sheep were moved calmly by two handlers who worked the edge of the flight zone and stood at the correct positions. The rudimentary corral system had no race or forcing pens. It would have been terrible if it had been used by less skilled people. In a place with high employee turnover, or less skilled people, a system with races, alleys and a forcing pen would have been required. Since the fourth edition of this book, there has been increasing interest in learning low-stress cattle-handling methods and an emphasis on using simpler facilities (Burt, 2008; Kidwell, 2011; Grandin, 2017). People who successfully adopt this approach must develop their stock-handling skills to a higher level. This often requires several weeks of dedicated practice. The use of these methods reduces the flight zone of the animals and they become less wild. Grandin (1997) and Grandin and Deesing (2008) have designed curved handling facilities for many years. These work effectively with less skilled people who can be easily trained in a single day. To summarize, handling facilities can be either:

More skill-dependent

Simple, economical and highly skill-dependent (see Fig. 1.3). This approach to design will also work well with less flighty cattle that have been bred for a calm temperament.

Less skill-dependent

More expensive and less dependent on the skill of the stockpersons (Fig. 1.4) (see designs in Chapter 5). Recommended for more flighty, extensively raised cattle that may have larger flight zones.

Safety Issues during Livestock Handling

The use of very simple facilities often requires more time to handle the animals. If they are used by less skilled people, there may also be safety issues for the handlers. More elaborate facilities can be designed so that people do not have to go inside small pens with wild cattle with large flight zones. Douphrate *et al*. (2009) found that accidents that occur while handling livestock were the cause of many of the worst injuries on the farm. In the USA, between 2011 and 2014, 36% of human fatalities involving animals were inflicted by cattle (Barros and Langley, 2017). Mature bulls are the cause of many fatalities. A survey of Australian veterinarians indicated that 57% of serious injuries were during pregnancy checking of cattle (Lucas *et al*., 2012). Sorge *et al*. (2014) reported that 73% of worker injuries on a dairy occurred while working with livestock. To provide safety for both people and animals, wild, extensively raised cattle, sheep, deer and other animals will require more elaborate expensive handling facilities than tame animals.

Providing Healthcare

Healthcare, such as vaccinations and treatment for sickness, is more likely to be administered if there are races, headgates (head stanchions) and other facilities for easy restraint and handling of livestock. The only exception to this rule is totally tame animals that are completely trained to lead. Figure 1.4 shows a simple compact race and round crowd pen system that is being used by farmer feeders for handling cattle. Tim Hadley

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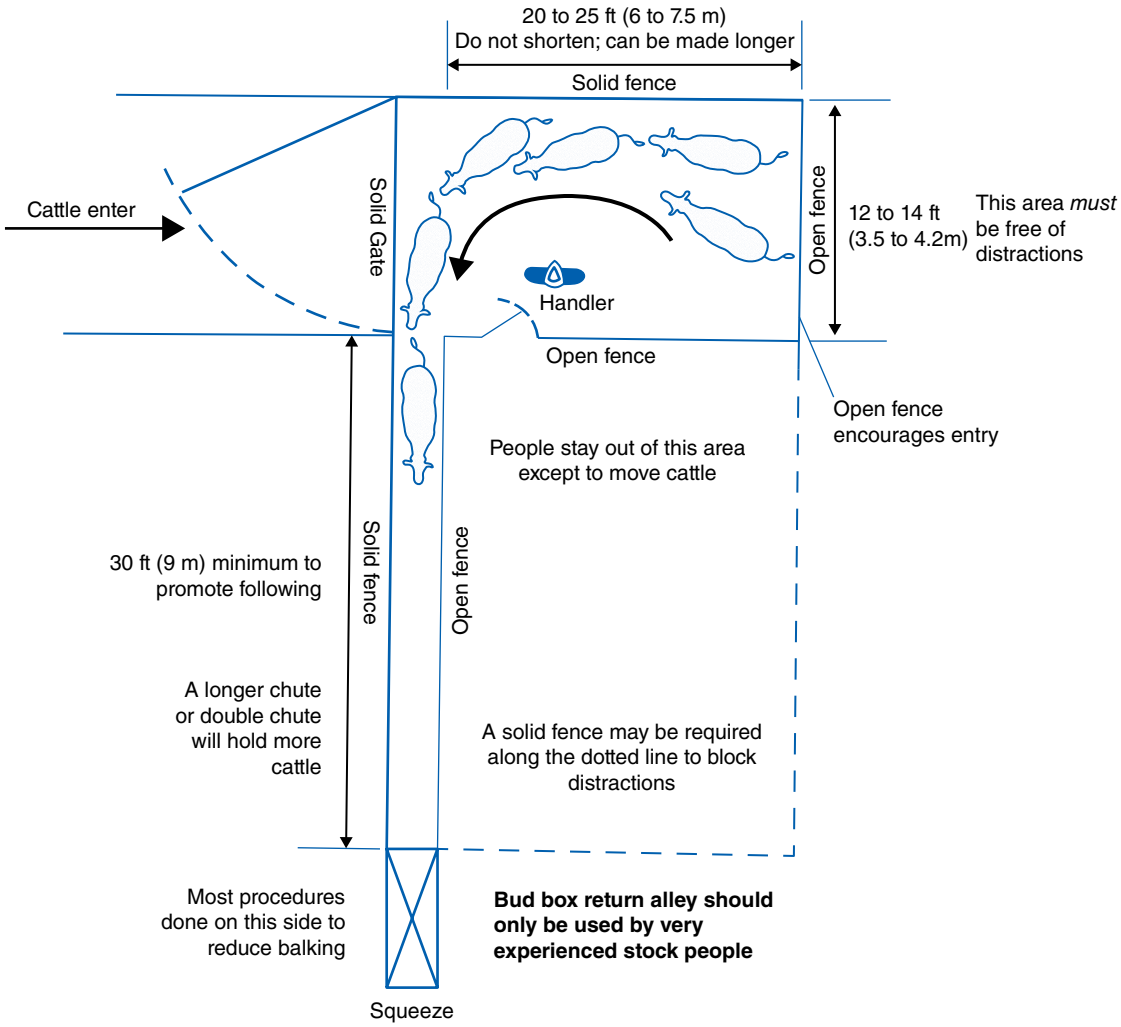


Fig. 1.3. Simple, economical Bud Box design invented by cattle-handling specialist Bud Williams. Another name for this is a return alley; it exploits the natural behaviour of livestock to want to go back to where they came from. To use it safely requires a higher level of skill. There are four principles for use: (i) all livestock put in the Bud Box must immediately enter the single file; (ii) all the cattle must fit into the single-file race; (iii) do not store livestock in it; (iv) fill it half full, do not overload.

from Eblex, in the UK, reports that use of this design has greatly facilitated veterinary care for cattle. The layout fits into a relatively small space between the support columns in a building. It takes advantage of the natural behaviour of cattle to go back to where they came from. The cattle on these farms have a small flight zone because they live in barns, but they are not trained to lead.

Conclusion

Good stockmanship reduces stress, and livestock will have higher productivity. Both new research and older studies show the importance of low-stress handling methods and management attention to detail. People who like animals will have more productive livestock and poultry. Managers must be careful not to overwork stock people to the point where they become too tired to care.

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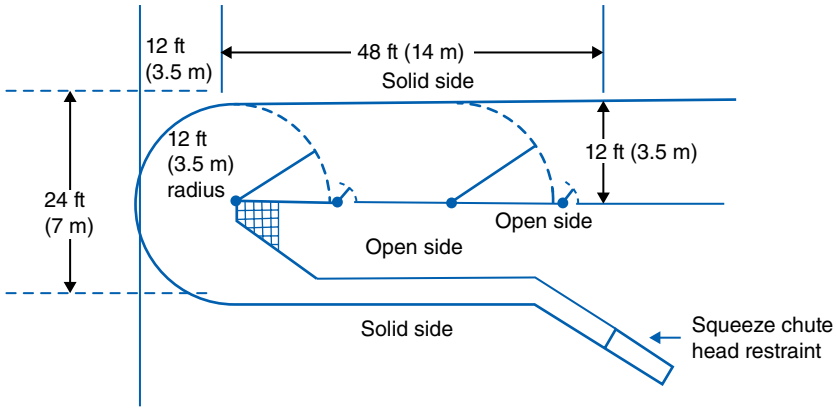


Fig. 1.4. A simple system using a round crowd pen that was designed by the author to improve safety and take advantage of the natural behaviour of cattle to go back to where they came from. The handler stands on the small catwalk located at the gate pivot point. The cattle will circle around the handler. It will work best if there is space in the single-file race chutes so that cattle in the round crowd pen can immediately enter it.

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Videos of Handling and Livestock

Due to licensing restrictions on YouTube, a number of these videos are not currently available outside the US. To access them from other countries, please search for the video title followed by the word 'video', using your preferred search engine.

Ron Gill, Texas A&M, *Using Natural Cattle Behavior to Move Cattle* – demonstrates how small differences in the handler's position will direct an animal's movement. https://www.youtube.com/watch?vgTZR1Dj-80M

Temple Grandin, Colorado State University, *Cattle Behavior and Handling* – shows how distractions, lighting and shadows can cause livestock to balk and refuse to move through races, chutes and corrals. https://www.youtube.com/watch?v=r9ZM9DaMv-w

NCBA, Cattlemen to Cattlemen, *Moving Cattle on Foot* – cattle handling specialist Curt Pate and Temple Grandin demonstrate sorting and handling cattle in a 3.5 m (12 ft) wide alley. https://www.youtube.com/watch?v=g6Sxfw4F

Temple Grandin, *Handling Cattle Quietly in Pens* – shows moving a group of cattle out of a gate with small handler movements to regulate the flow. https://www.youtube.com/watch?v=Cpggjn_G6NU

Daniels Manufacturing, *Daniels Bud Box* – shows correct operation of Bud Box cattle handling system. This system is economical to build but more skill-dependent than the system shown in Figure 1.4. https://www.youtube.com/watch?v=o58f4_uNbxo

Temple Grandin, *Cattle Handling in Crowd Pens* – shows moving cattle quietly from the crowd pen into the single file chute (race) https://www.youtube.com/watch?v=Cpggin_GGNU

Priefert Bud Box February 2012 – cattle handling specialists Curt Pate and Ron Gill demonstrate how to use a portable Bud Box that is easy to set up on a pasture. https://www.youtube.com/watch?v=7Xs6HmrRTUs

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2 Welfare of Transported Animals: Welfare Assessment and Factors Affecting Welfare

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Summary

All farmed animals are regarded as sentient beings, so their welfare is a matter of much public concern. Positive and negative aspects of the welfare of animals during transport should be assessed using a range of behavioural, physiological and carcass-quality measures. Health is an important part of welfare, so the extent of any disease, injury or mortality resulting from, or exacerbated by, transport should be measured. Many of the indicators of welfare are measures of stress, involving long-term adverse effects or indicators of pain, fear or other feelings. Some welfare assessment methods are research tools while others are welfare outcome indicators that can be used by a veterinary or other inspector.

Keywords: cortisol, handling, heart rate, physiological measurements, transport, welfare, sustainability

Introduction

Some of the key factors affecting the welfare of animals during handling and transport are: attitudes to animals and the need for staff training; methods of payment of staff; laws and retailers' codes; journey planning; traceability of animals; genetic selection; rearing conditions and experience; the mixing of animals from different social groups; handling procedures; driving methods; space allowance per animal on the vehicle; journey length; increased susceptibility to disease; increased spread of disease; and the extent to which each individual can be inspected during the journey.

Welfare and the Sustainability of Animal Transport Procedures

Why are animals transported and does the reason for their transport affect the sustainability of the action? In some cases, animals used by people are transported for their own benefit. For example, an animal may be transported for veterinary treatment or a companion animal may be transported because it will be happier if it can stay with its human family. However, most animal transport is for the financial benefit of people. As explained below, animals that are well-accustomed to transport can often travel with no adverse effect on their welfare, but the effects of transport on the welfare of the vast majority of animals is somewhat, or very, negative. As a consequence, all of this transport should be avoided if possible, and any financial advantage that may accrue to people should be balanced against the negative effects on the animals. If animals are killed for meat or other production, wherever possible they should be killed at source, or close enough to source to minimize any poor welfare, rather than being transported.

Sustainability of transport is also affected by unintended consequences of transport such as the spread of disease. During major farm animal disease outbreaks, disease has been spread by transported animals (Lebi *et al.*, 2016). For example, at the beginning of a foot-and-mouth disease outbreak in the UK, animals were moved from one place to another in order that the owners could get a slightly higher price for them, and this resulted in an industry loss of many millions of pounds. Even

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without any disease consequence, such repeated travel has animal welfare costs. Long-distance travel may occur because the owners of the animals can get a better price for them in a different country or area, or because the killing and processing costs are lower at the destination than they are near the origin of the transport, or because the purchasers want to kill the animals themselves for religious or other reasons. Some of the extreme examples of animals transported for commercial purposes, with very negative consequences for the animals, are described by Wambui *et al*. (2016) for cattle in Kenya, by Phillips (2015) in relation to long-distance trade in general and by Carr and Broom (2018) in relation to tourism.

Some animal transport practices are not sustainable because they result in an impact on one of the many components of sustainability that is not acceptable to the public. Consumers now have a big say in what can or cannot be done in the course of animal production and retailers are becoming increasingly important for enforcing compliance with guidelines (Fraser, 2015). The impact might, for example, be on pollution, greenhouse gas output or on usage of world resources, but the most likely component of sustainability that would be negative is on the welfare of the animals. Handling, loading, transport conditions and unloading of animals can cause poor welfare. The welfare of an individual is its state as regards its attempts to cope with its environment (Broom, 1986; Broom and Fraser, 2015) and includes both the extent of failure to cope and the ease or difficulty in coping. Where an individual is failing to cope with a problem, it is said to be stressed (Broom and Johnson, 2000), so stress is a form of poor welfare. Health is also an important part of welfare, while feelings such as pain, fear and various forms of pleasure are components of the mechanisms for attempting to cope, so should be evaluated where possible in welfare assessment (Broom, 1998, 2006a, 2008a; Fraser, 2008). Whilst animal welfare is a characteristic of an individual animal and varies from very good to very poor, animal protection is a human activity directed towards the prevention of poor welfare in animals.

In this chapter the factors that affect welfare during transport are first introduced. The methodology for assessing the welfare of the animals during handling and transport is then explained. Finally, some of the various factors that affect the likelihood of stress are discussed with examples.

Factors that Can Result in Poor Welfare of Animals during Handling and Transport

The attitude to animals of the people involved in the transport can result in harsh or careless treatment and hence injuries or other poor welfare. Farmed animals are regarded as aware and sentient by some people but as objects valued only according to their use by others (Broom, 2010b; Rollin, 2013). During handling and transport, these attitudes may result in one person causing high levels of stress in the animals while another person doing the same job may cause little or no stress. People may hit animals and cause substantial pain and injury because of selfish financial considerations, or because they do not consider that the animals feel pain, or because of lack of knowledge about animals and their welfare. Training of staff can substantially alter attitudes to, and treatment of, animals (Ceballos *et al*., 2018).

Laws can have a significant effect on the ways in which people manage animals. Within the European Union, the Council Regulations and Directives on animal transport take up some of the recommendations of the EU Scientific Committee on Animal Health and Animal Welfare's report of 2002 and of the European Food Safety Authority's Opinion on the Welfare of Animals during Transport of 2004 and 2011 (EFSA, 2011). Laws have effects on animal welfare provided they are enforced and the mechanisms for enforcement have major effects on welfare.

One key issue in relation to animal transport is the traceability of animals from farm of origin to the point where some indicator of welfare is obtained (Broom, 2006b). Traceability is important to animal welfare, both as a check on the consequences of ill treatment of animals and in relation to the control of disease, because disease is a major cause of poor welfare in animals. Another issue, considered below, is the use of welfare outcome indicators that can be used in the course of inspection of animals, often by a veterinary inspector at a slaughterhouse.

Consumers demand, more and more, that animal production and management systems should be sustainable (Van Loo *et al*., 2014). This depends on what is acceptable to the public and includes the welfare of animals as an important component (McKendree *et al*., 2014). Codes of practice are therefore produced and can have significant effect on animal welfare during transport. The most effective

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of these, sometimes just as effective as laws, are retailer codes of practice since retail companies need to protect their reputation by adhering to their codes (Broom, 2002, 2010a).

Some animals are much better able to withstand the range of environmental impacts associated with handling and transport than other animals. This can be because of genetic differences associated with the breed of the animal (Hall *et al*., 1998a) or with selection for production characteristics. Differences among individuals in coping ability also depend on housing conditions and with the extent and nature of contact with humans and conspecifics during rearing.

Since physical conditions within vehicles during transport can affect the extent of stress in animals, the selection of an appropriate vehicle for transport is important in relation to animal welfare. Similarly, the design of loading and unloading facilities is of great importance. The person who designs the vehicle and facilities has a substantial influence, as does the person who decides which vehicle or equipment to use.

Before a journey starts, there must be decisions made about whether or not the animals are fit to travel, the stocking density of animals on the vehicle and the grouping and distribution of the animals. Animals with injuries or diseases that would result in poor welfare during travel should not be transported. Schwartzkopf-Genswein *et al*. (2012) concluded from North American studies that poor welfare, poor-quality meat and death are all much more likely in cattle that are unfit to travel. If there is withdrawal of food from animals to be transported, this can affect welfare. For all species, tying of animals on a moving vehicle can lead to major problems, and for cattle and pigs, any mixing of animals can cause very poor welfare.

The behaviour of drivers towards animals whilst loading and unloading and the way in which vehicles are driven are affected by methods of payment. If people are paid more if they load more or drive fast, welfare will be worse, so such methods of payment should not be permitted (Grandin, 2018). Payment of handling and transport staff at a higher rate if the incidences of injury and poor meat quality are low improves welfare. Insurance against bad practice resulting in injury or poor meat quality should not be permitted.

All of the factors mentioned so far should be taken into account in the procedure of planning for transport. Planning should also take account of temperature, humidity and the risks of disease transmission. Disease is a major cause of poor welfare in transported animals. Planning of routes should take account of the needs of the animals for rest, food and water. Drivers or other persons responsible should have plans for emergencies including a series of emergency numbers to telephone to receive veterinary assistance in the event of injury, disease or other welfare problems during a journey. Livestock vehicle accidents can have substantial effects on animal welfare and are often due to driver fatigue (Miranda-de la Lama *et al*., 2011).

The methods used during handling, loading and unloading can have a great effect on animal welfare. The quality of driving can result in very few problems for the animals or in poor welfare because of difficulty in maintaining balance, motion sickness, injury etc. The actual physical conditions, such as temperature and humidity, may change during a journey and action on the part of the person responsible for the animals may be needed. A journey of long duration will have a much greater risk of poor welfare and some durations inevitably lead to problems (Nielsen *et al*., 2011; Alam *et al*., 2018). Hence, good monitoring of the animals with inspections of adequate frequency, and in conditions that allow thorough inspection, is important.

Assessing Welfare

A variety of welfare indicators that can be used by animal welfare scientists to assess the welfare of animals whilst handling or transporting are listed below. Some of these measures are of short-term effect while others are more relevant to prolonged problems. Where animals are transported to slaughter, it is mainly the measures of short-term effects such as behavioural aversion or increased heart rate that are used, but some animals are kept for a long period after transport and measures such as increased disease incidence or suppression of normal development give information about the effects of the journey on welfare. The following types of measures have been used in the assessment of welfare (from Broom, 2000):

- physiological indicators of pleasure;
- behavioural indicators of pleasure;
- extent to which strongly preferred behaviours can be shown;
- variety of normal behaviours shown or suppressed;
- extent to which normal physiological processes and anatomical development are possible;

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- extent of behavioural aversion shown;
- physiological attempts to cope;
- immunosuppression;
- disease prevalence;
- behavioural attempts to cope;
- behaviour pathology;
- brain changes, e.g. those indicating self-narcotization;
- body damage prevalence;
- reduced ability to grow or breed;
- reduced life expectancy.

Details of these and other measures may be found in Broom and Johnson (2000) and Broom and Fraser (2015).

Some of the measures of welfare used in research on animal welfare are also suitable for use by an inspector or animal owner checking on the animal's welfare at a particular time. In relation to animal transport, inspection may occur at the beginning of a journey, during the course of a journey or at the slaughterhouse. In each case, a short time and limited amount of equipment are available. Hence prolonged observation of behaviour, experimental studies of behaviour or physiology, and complex laboratory analysis are not possible. The measures are of the animal and what has happened to it to affect its welfare, so they are referred to as 'welfare outcome indicators'. Most of the indicators are animal-based, rather than being measures of the system or methods of management. Such measures are the subject of reports by the European Food Safety Authority (EFSA) that are available on-line.

Behavioural Assessment

Changes in behaviour are obvious indicators that an animal is having difficulty coping with handling or transport. Some of these help to show which aspect of the situation is aversive. The animal may stop moving forward, freeze, back off, run away or vocalize. The occurrence of each of these can be quantified in comparisons of responses to different races, loading ramps etc. Examples of behavioural responses such as cattle stopping when they encounter dark areas or sharp shadows in a race, and pigs freezing when hit or subjected to other disturbing situations may be found in Grandin (1980, 1982, 1989, 2000).

Behavioural responses are often shown in response to painful or otherwise unpleasant situations. Their nature and extent vary from one species to another according to the selection pressures that have acted during the evolution of the mechanisms controlling behaviour. Human approach and contact may elicit anti-predator behaviour in farm animals. However, with experience of handling these responses can be greatly reduced in cattle (Le Neindre *et al*., 1996).

Animals of some social species can collaborate in defence against predators, e.g. pigs or humans, and these vocalize a lot when caught or hurt. Animals unlikely to be able to defend themselves, such as sheep, vocalize far less when caught by a predator, probably because such an extreme response merely gives information to the predator that the animal attacked is severely injured and hence unlikely to be able to escape. Studies of several species, including sheep, goats and horses, show that facial grimace scales are useful indicators of pain (Dalla Costa *et al*., 2014; McLennan *et al*., 2016). In cattle, a useful indicator of fear is the amount of eye white visible (Core *et al*., 2009).

Cattle can also be relatively undemonstrative when hurt or severely disturbed. Human observers sometimes wrongly assume that if an animal is not squealing, it is not hurt or disturbed by what is being done to it. In some cases, the animal is showing a freezing response, associated with fear, and in most cases, physiological measures must be used to find out the overall response of the animal.

Within species, individual animals may vary in their responses to potential stressors. The coping strategy adopted by the animal can have an effect on responses to the transport and lairage situation. For example, Geverink *et al*. (1998) showed that pigs that were aggressive in their home pen were also more likely to fight during pre-transport or pre-slaughter handling but pigs that were driven for some distance prior to transport were less likely to fight and hence cause skin damage during and after transport. This fact can be used to design a test to reveal whether or not the animals are likely to be severely affected by the transport situation (Lambooij *et al*., 1995).

The procedures of loading and unloading animals into and out of transport vehicles can have very severe effects on the animals and these effects are revealed in part by behavioural responses. Species vary considerably in their responses to loading procedures. Any animal that is injured or frightened by people during the procedure can show extreme responses. However, during efficient loading procedures, sheep and cattle may not be greatly affected. Broom *et al*. (1996) and Parrott *et al*. (1998a)

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showed that sheep loaded carefully have largely physiological responses associated with the novel situation encountered in the vehicle rather than the loading procedure.

Once journeys start, some species of farm animals explore the compartment in which they are placed and try to find a suitable place to sit or lie down. Sheep and cattle try to lie down if the situation is not disturbing but stand if it is. After a period of acclimatization by sheep and cattle to the vehicle environment, during which time sheep may stand for two to four hours looking around at intervals and cattle may stand for rather longer, most of the animals will lie down if the opportunity arises. Unfortunately for the animals, many journeys involve so many lateral movements or sudden brakings or accelerations that the animals cannot lie down.

An important behavioural measure of welfare when animals are transported is the amount of fighting they show. When male adult cattle are mixed during transport or in lairage, they may fight, and this behaviour can be recorded directly (Kenny and Tarrant, 1987). Calves of six months of age may also fight (Trunkfield and Broom, 1991). The recording of such behaviour should include the occurrence of threats as well as the contact behaviours that might cause injury.

A further, valuable method of using behaviour studies to assess the welfare of farm animals during handling and transport involves using the fact that the animals remember aversive situations in experimentally repeated exposures to such situations. Any stock-keeper will be familiar with the animal that refuses to go into a crush after having received painful treatment there in the past, or which hesitates about passing a place where a frightening event such as a dog threat occurred once before. These observations give us information about the welfare of the animal in the past as well as at the present time. If the animal tries to avoid returning to a place where it had an experience, then that experience was clearly aversive. The greater the reluctance of the animal to return, the greater the previous aversion must have been.

This principle has been used by Rushen (1986) in studies with sheep. Sheep that were driven down a race to a point where gentle handling occurred traversed the race as rapidly or more rapidly on a subsequent day. Sheep that were subjected to shearing at the end of the race on the first day were harder to drive down the race subsequently, and those subjected to electro-immobilization at the end of the race were very difficult to drive down the race on later occasions. Hence the degree of difficulty in driving and the delay before the sheep could be driven down the race are measures of the current fearfulness of the sheep, and this in turn reflects the aversiveness of the treatment when it was first experienced.

Qualitative behavioural assessment (QBA) can correlate with physiological measures of stress and provide additional information about welfare during transport (Wickham *et al*., 2012, 2015). However, QBA can be subject to observer bias so should never be the only method of assessing welfare (see review in Broom and Fraser, 2015).

Physiological Assessment

General methodological points

The physiological responses of animals to adverse conditions, such as those that they may encounter during handling and transport, will be affected by the anatomical and physiological constitution of the animal, as mentioned later.

Whenever physiological measurement is to be interpreted, it is important to ascertain the basal level for that measure and how it fluctuates over time (Broom, 2000). For example, plasma cortisol levels in most species vary during the day, tending to be higher before noon than after noon. A decision must be taken for each measure concerning whether the information required is the difference from baseline or the absolute value. For small effects, e.g. a 10% increase in heart rate, the difference from baseline is the key value to use. With regard to major effects where the response reaches the maximal possible level, for example cortisol in plasma in very frightening circumstances, the absolute value should be used.

In order to explain this, consider an animal severely frightened during the morning and showing an increase from a rather high baseline of 160 nmol l^{-1}, but in the afternoon showing the same maximal response, which is 200 nmol l^{-1} above the lower afternoon baseline. It is the actual value that is important here rather than a difference whose variation depends on baseline fluctuations. In many studies, the value obtained after the treatment studied can usefully be compared with the maximum possible response for that measure. A very frightened animal may show the highest response of which it is capable.

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Heart rate

Heart rate can decrease when animals are frightened, but in most farm animal studies, tachycardia, which is increase in heart rate, has been found to be associated with disturbing situations. Heart rate increase is not just a consequence of increased activity: heart rate can be increased in preparation for an expected future flight response. Baldock and Sibly (1990) obtained basal levels for heart rate during a variety of activities by sheep and then took account of these when calculating responses to various treatments. Social isolation caused a substantial response, but the greatest heart rate increase occurred when the sheep were approached by a man with a dog. The responses to handling and transport are clearly much lower if the sheep have previously been accustomed to human handling.

Heart rate is a useful measure of welfare but only for short-term problems such as those encountered by animals during handling, loading onto vehicles and certain acute effects during the transport itself (Kovacs *et al*., 2014). However, some adverse conditions may lead to elevated heart rate for quite long periods. Parrott *et al*. (1998b) showed that heart rate increased from about 100 beats per minute to about 160 beats per minute when sheep were loaded onto a vehicle and the period of elevation of heart rate was at least 15 minutes. During transport of sheep, heart rate remained elevated for at least nine hours (Parrott *et al*., 1998a). Heart rate variability has also been found to be a useful welfare indicator in cattle and other species (van Ravenswaaij *et al*., 1993).

Breathing rate

Observation of animals can provide information about physiological processes in animals without any attachment of recording instruments or sampling of body fluids. Breathing rate can be observed directly or from good-quality video recordings. The metabolic rate and level of muscular activity are major determinants of breathing rate but an individual animal that is disturbed by events in its environment may suddenly start to breathe faster.

Other directly observable responses

Muscle tremor can be directly observed and is sometimes associated with fear. Foaming at the mouth can have a variety of causes, so care is needed in interpreting the observations, but its occurrence may provide some information about welfare.

Adrenal medullary hormones

Changes in the adrenal medullary hormones adrenaline (epinephrine) and noradrenaline (norepinephrine) occur very rapidly and measurements of these hormones have not been used much in assessing welfare during transport. However, Parrott *et al*. (1998b) found that both hormones increased more during loading of sheep by means of a ramp than by loading with a lift.

Adrenal cortical hormones and acute phase proteins

Adrenal cortex changes occur in most of the situations that lead to aversion behaviour or heart rate increase but the effects take a few minutes to be evident and they last for 15 minutes to two hours or a little longer. An example comes from work on calves (Kent and Ewbank, 1986; Trunkfield and Broom, 1990; Trunkfield *et al*., 1991). Plasma or saliva glucocorticoid levels gave information about experiences of animals lasting up to two hours, so on transport journeys they indicate the effects of what has happened to the animals recently. This is useful where there are changes in driving conditions or various aspects of the environment. Blood concentrations of acute phase proteins, such as haptoglobin or serum amyloid A, are affected by difficult transport conditions and remain elevated for longer than glucocorticoids (e.g. in horses (Casella *et al*., 2012) and in pigs (Soler *et al*., 2013)) so can be useful welfare indicators.

Salivary cortisol measurement is useful in cattle. In the plasma, most cortisol is bound to protein but it is the free cortisol that acts in the body. Hormones such as testosterone and cortisol can enter the saliva by diffusion in salivary gland cells. The rate of diffusion is high enough to maintain an equilibrium between the free cortisol in plasma and in saliva. The level is ten or more times lower in saliva, but stimuli that cause plasma cortisol increases also cause comparable salivary cortisol increases in humans (Riad-Fahmy *et al*., 1982), sheep (Fell *et al*., 1985), pigs (Parrott *et al*., 1989) and some other species.

The injection of pilocarpine and sucking of citric acid crystals, which stimulate salivation, have no effect on the salivary cortisol concentration. However, any rise in salivary cortisol levels following some

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stimulus is delayed a few minutes as compared with the comparable rise in plasma cortisol concentration.

Animals demonstrating substantial adrenal cortex responses during handling and transport also show increased body temperature (Trunkfield *et al*., 1991). Electronic technology can be useful for monitoring body temperature (Pascual-Alanso *et al*., 2017). The increase is usually of the order of 1°C but the actual value at the end of a journey will depend upon the extent to which any adaptation of the initial response has occurred. The body temperature can be recorded during a journey with implanted or superficially attached temperature monitors linked directly or telemetrically to a data storage system.

Parrott *et al*., (1999) described deep body temperature in eight sheep. When the animals were loaded into a vehicle and transported for 2.5 hours, their body temperatures increased by about 1°C and in males were elevated by 0.5°C for several hours. Exercise for 30 minutes resulted in a 2°C increase in core body temperature, which returned rapidly to baseline when the exercise finished. It would seem that prolonged increases in body temperature are an indicator of poor welfare.

Pituitary hormones

The measurement of oxytocin has not been of particular value in animal transport studies (e.g. Hall *et al*., 1998b). However, plasma ß-endorphin levels have been shown to increase during loading (Bradshaw *et al*., 1996a). The release of corticotrophin-releasing hormone (CRH) in the hypothalamus is followed by release of pro-opiomelanocortin (POMC) in the anterior pituitary. POMC quickly breaks down into components, including adrenocorticotrophic hormone (ACTH), which travels in the blood to the adrenal cortex, enkephalins and beta-endorphin.

A rise in plasma beta-endorphin often accompanies ACTH increases in plasma but it is not yet clear what its function is. Although beta-endorphin can have analgesic effects via mu-receptors in the brain, this peptide hormone is also involved in the regulation of various reproductive hormones. Measurement of beta-endorphin levels in blood is useful as a back-up for ACTH or cortisol measurement.

Enzymes

Creatine kinase is released into the blood when there is muscle damage, e.g. bruising, and when there is vigorous exercise. It is clear that some kinds of damage that effect welfare result in creatine kinase release, so it can be used in conjunction with other indicators as a welfare measure. Aradom *et al*. (2012) found that pigs subjected to transport lasting up to 12 hours had higher lactate and creatine kinase blood concentrations after the longer periods of transport. Lactate dehydrogenase (LDH) also increases in the blood after muscle tissue damage but increases can occur in animals whose muscles are not damaged. Deer that are very frightened by capture show large LDH increases (Jones and Price, 1992). The isoenzyme of LDH, which occurs in striated muscle (LDH5), leaks into the blood when animals are very disturbed, so the ratio of LDH5 to total LDH is of particular interest.

Consequences of water or food shortage

On long journeys, animals will have been unable to drink for many times longer than the normal interval between drinking bouts. This lack of control over interactions with the environment may be disturbing to the animals and there are also likely to be physiological consequences. The most obvious and straightforward way to assess this is to measure the osmolality of the blood (Broom *et al*., 1996). When food reserves are used up, there are various changes evident in the metabolites present in the blood. Several of these, for example beta-hydroxy-butyrate, can be measured and indicate the extent to which the food reserve depletion is serious for the animal (Tadich *et al*., 2009). If chickens reared for meat production were deprived of food for ten hours prior to three hours of transport, when compared with undeprived birds, their plasma had higher thyroxine and lower tri-iodothyronine, triglyceride, glucose and lactate concentrations, indicating negative energy balance and poor welfare (Nijdam *et al*., 2004).

Even after short journeys, animals may become water-deprived. Aoyama *et al*. (2008) found that after one hour of transport that led to increased cortisol, glucose and free fatty acids, goats consumed less water during the following three hours.

Another measure that gives information about the significance for the animal of food deprivation is the delay since the last meal. Most farm animals are accustomed to feeding at regular times, and if feeding is prevented, especially when high rates of metabolism occur during journeys, the animals will be disturbed by this. Behavioural responses, when allowed to eat or drink (e.g. Hall *et al*., 1997), also give important information about problems of deprivation.

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Haematocyte measures

The haematocrit, the percentage volume of blood occupied by red blood cells, is altered when animals are transported. If animals encounter a problem, such as those that may occur when they are handled or transported, there can be a release of blood cells from the spleen and a higher cell count (Parrott *et al*., 1998a). More prolonged problems, however, are likely to result in reduced cell counts (Broom *et al*., 1996).

Increased adrenal cortex activity can lead to immunosuppression. One or two studies in which animal transport affected T-cell function are reviewed by Kelley (1985), but such measurements are likely to be of most use in the assessment of more long-term welfare problems. The ability of the animal to react effectively to antigen challenge will depend on the numbers of lymphocytes and the activity and efficiency of these. Measures of the ratios of white blood cells, for example the heterophil to lymphocyte ratio, are affected by a variety of factors, but some kinds of restraint seem to affect the ratio consistently so they can give some information about welfare. Studies of T-cell activity, e.g. *in vitro* mitogen stimulated cell proliferation, give information about the extent of immunosuppression resulting from the particular treatment. If the immune system is working less well because of a treatment, the animal is coping less well with its environment and the welfare is poorer than in an animal that is not immunosuppressed.

Examples of the immunosuppressive effect of transport are the reduction in four different lymphocyte sub-populations after 24 hours of transport in horses (Stull *et al*., 2004) and the reduction in phytohaemagglutinin-stimulated lymphocyte proliferation in *Bos indicus* steers during the six days after they had been transported for 72 hours (Stanger *et al*., 2005).

As with behavioural measures, some physiological measures are good predictors of an earlier death or of reduced ability to breed, so are measures of stress, whilst others are not measures of stress because the effect will be brief or slight.

Carcass and Mortality Assessment

Measures of body damage, or of a major disease condition, or of increased mortality are indicators of long-term adverse effects and hence stress. However, a slight bruise or cut will result in some degree of poor welfare but not necessarily stress, as the effect may be very brief. Death during handling and transport is usually preceded by a period of poor welfare. Mortality records during journeys are often the only records that give information about welfare during the journey and the severity of the problems for the animals are often only too clear from such records.

Amongst extreme injuries during transport are broken bones. These are rare in the larger animals but poor loading or unloading facilities and cruel or poorly trained staff who are attempting to move the animals may cause severe injuries. It is the laying hen, however, that is most likely to have bones broken during transit from housing conditions to point of slaughter (Gregory and Wilkins, 1989), especially if the birds have had insufficient exercise in a battery cage (Knowles and Broom, 1990).

Bruising, scratches and other superficial blemishes can be scored in a precise way (Correa *et al*., 2013) and when carcasses are downgraded for these reasons, the people in charge of the animals can reasonably be criticized for not making sufficient efforts to prevent poor welfare. There is a cost to the industry of such blemishes, as well as to the animals. The cost, in monetary and animal welfare terms, of dark firm dry (DFD) and pale soft exudative (PSE) meat is very high.

DFD meat is associated with fighting in cattle and pigs, but cattle that are threatened but not directly involved in fights also show it (Gregory, 2007). PSE meat is, in part, a consequence of possession of certain genes and occurs more in some strains of pigs than others, but its occurrence is related in most cases to other indicators of poor welfare (Gregory, 2007). Poultry meat quality can often be adversely affected for similar reasons (Schwartzkopf-Genswein *et al*., 2012). In a large-scale study of chickens reared for meat production and transported to slaughter in Holland and Germany, Nijdam *et al*. (2004) found that the mean mortality was 4.6 and the number with bruises was 22 per 1000 birds. In the Czech Republic, the average loss was 0.37% with a range of 0.3–0.72% (Vecerek *et al*., 2016). The major factors that increased mortality rate were increased stocking density in transport containers, increased transport time (Arikan *et al*., 2017) and increased time in lairage before slaughter.

When animals are subjected to violent handling, and they respond by an energetic struggle, a possible consequence is capture myopathy. The muscle damage that occurs will impair muscular action in

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the future, at least in the short term, and is an indicator of poor welfare because it reduces coping ability and may be associated with pain (Ebedes *et al*., 2002).

Experimental Methods of Assessment

As Hall and Bradshaw (1998) explain, information on the stress effects of transport is available from five kinds of study: (i) studies where transport, not necessarily in conditions representative of commercial practice, was used explicitly as a stressor to evoke a physiological response of particular interest (Smart *et al*., 1994; Horton *et al*., 1996); (ii) uncontrolled studies with physiological and behavioural measurements being made before and after long or short commercial or experimental journeys (Becker *et al*., 1985; Dalin *et al*., 1988; Becker *et al*., 1989; Dalin *et al*., 1993; Knowles *et al*., 1994); (iii) uncontrolled studies during long or short commercial or experimental journeys (Lambooij, 1988; Hall, 1995); (iv) studies comparing animals that were transported with animals that were left behind to act as controls (Nyberg *et al*., 1988; Knowles *et al*., 1995); and (v) studies where the different stressors that impinge on an animal during transport were separated out either by experimental design (Bradshaw *et al*., 1996b; Broom *et al*., 1996; Cockram *et al*., 1996) or by statistical analysis (Hall *et al*., 1998c).

Each of these methods is of value because some are carefully controlled but less representative of commercial conditions whilst others show what happens during commercial journeys but are less well controlled.

Discussion of Some Key Factors

For an extensive review of studies involving all of the factors mentioned here, see EFSA (2011).

Animal genetics and transport

Cattle and sheep have been selected for particular breed characteristics for hundreds of years. As a consequence, there may be differences between breeds in how they react to particular management conditions. For example, Hall *et al*. (1998d) found that introduction of an individual sheep to three others in a pen resulted in a higher heart rate and salivary cortisol concentration if it was of the Orkney breed than if it was of the Clun Forest breed. The breed of animal should be taken into account when planning transport.

Farm animal selection for breeding has been directed especially towards maximizing productivity. In some farm species there are consequences for welfare of such selection (Broom 1994, 1999; Grandin and Whiting, 2018). Fast-growing broiler chickens may have a high prevalence of leg disorders and Belgian Blue cattle may be unable to calve unaided or without the necessity for Caesarean section. Some of these effects may affect welfare during handling and transport.

Certain rapidly growing beef cattle, which have grown fast, have joint disorders that result in pain during transport and some strains of high-yielding dairy cows are much more likely to have foot disorders. Modern strains of dairy cows, in particular, need much better conditions during transport and much shorter journeys if their welfare is not to be poorer than the dairy cows of 30 years ago.

Rearing conditions, experience and transport

If animals are kept in such a way that they are very vulnerable to injury when handled and transported, this must be taken into account when transporting them, or the rearing conditions must be changed. An extreme example of such an effect is the osteopenia and vulnerability to broken bones, which is twice as high in hens in battery cages than in hens that are able to flap their wings and walk around (Knowles and Broom, 1990). Calves are much more disturbed by handling and transport if they are reared in individual crates than if they are reared in groups, presumably because of lack of exercise and absence of social stimulation in the rearing conditions (Trunkfield *et al*., 1991).

Human contact prior to handling and transport is also important. Unbroken ponies are much disturbed by transport (Knowles *et al*., 2010). If young cattle have been handled for a short period just after weaning, they are much less disturbed by the procedures associated with handling and transport (Le Neindre *et al*., 1996). All animals can be prepared for transport by appropriate previous treatment. In a comparison during transport, of naïve sheep and sheep that had previous experience of transport, Wickham *et al*. (2012) found the naïve sheep to be more alert and anxious and to have higher heart rate, heart rate variability and core body temperature.

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Mixing social groups and transport

If pigs or adult cattle are taken from different social groups, whether from the same farm or not, and are mixed with strangers just before transport, during transport or in lairage, there is a significant risk of threatening or fighting behaviour (McVeigh and Tarrant, 1983; Guise and Penny, 1989; Tarrant and Grandin, 2000). Male and female pigs mixed with strangers prior to transport showed more aggression and mounting at the farm and the lairage (Van Staaveren *et al*., 2015). A period of socialization with other pigs, prior to mixing, reduced aggression and skin lesions (Rhydmer *et al*., 2013).

The glycogen depletion associated with threat, fighting or mounting often results in dark, firm, dry meat, injuries such as bruising and associated poor welfare. The problem is sometimes very severe, in welfare and economic terms, but is solved by keeping animals in groups with familiar individuals rather than mixing strangers. Cattle might be tethered during loading but should never be tethered when vehicles are moving because long tethers cause a high risk of entanglement and short tethers cause a high risk of cattle being hung by the neck.

Handling, loading, unloading and welfare

Well-trained and experienced stock people know that cattle can be readily moved from place to place by human movements that take advantage of the animal's flight zone (Kilgour and Dalton, 1984; Grandin, 2000). Cattle will move forward when a person enters the flight zone at the point of balance and can be calmly driven up a race by a person entering the flight zone and moving in the opposite direction to that in which the animals are desired to go.

Handling animals without the use of sticks or electric goads results in better welfare and less risk of poor carcass quality. Huertas *et al*. (2010) and many other authors have reported that the use of electric goads to move animals causes bruising of the carcass and other measures of poor welfare. Good knowledge of animal behaviour and good facilities are important to ensure good welfare during handling and loading.

Ambient temperature and other physical conditions during transport

Extremes of temperature can cause very poor welfare in transported animals. Exposure to temperatures below freezing has severe effects on small animals, including domestic fowl, but with appropriate vehicles and management, poor welfare due to cold conditions can be avoided (Burlingette *et al*., 2012).

However, temperatures that are too high are a more common cause of poor welfare. Poultry, rabbits and pigs are especially vulnerable. For example, behavioural, physiological and carcass-quality indicators of poor welfare were higher in turkeys transported at 35°C than at 20°C (Vermette *et al*., 2017) while de la Fuente *et al*. (2004) found that plasma cortisol, lactate, glucose, creatine kinase, lactate dehydrogenase and osmolarity were all higher in warmer summer conditions than in cooler winter ones in transported rabbits. The season of the year, the position on the vehicle and the associated temperature to which the animals are subjected affect the behaviour and welfare of transported pigs (Torrey *et al*., 2013). In each of these species, and particularly in chickens reared for meat production, stocking density must be reduced in temperatures of 20°C or higher or there is a substantial risk of high mortality and poor welfare (Mitchell and Kettlewell, 2009).

Sheep have significant ability to withstand high temperatures during sea transport (Stockman *et al*., 2011), but when sheep or cattle are transported by boat from Australia to the Middle East, high temperature is a major cause of poor welfare (Caulfield *et al*., 2014). Philips and Santurtun (2013) found that heat stress was a major problem for *Bos taurus* cattle, somewhat less for zebu (*Bos indicus*) cattle and less again for sheep, but that it was a major cause of poor welfare in all livestock carried by boat across the tropics. The impact of temperature on animal welfare is different according to humidity. Villarroel *et al*. (2011) calculated the air enthalpy time derivative (kg water/kg of dry air/s) during pig journeys and found that it was up to ten times higher during the journeys than on the farm or in the abattoir. The air enthalpy time derivative proved to be a good predictor of pig welfare.

Vehicle design, driving methods, stocking density and welfare

If vehicles are badly designed, animals may be injured during journeys. Among modern vehicles, some cause more injuries than others (Correa *et al*., 2013). Old and inappropriate vehicles can cause poor welfare and high costs in the meat industry. Huertas *et al*. (2010) found that 16% of vehicles

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used for cattle transport had faults in design that led to bruising in the animals. Poor-quality driving also led to bruising in apparently adequate vehicles. When humans are driven in a vehicle, they can usually sit on a seat or hold on to some fixture. Cattle, standing on four legs, are much less able to deal with accelerations such as those caused by cornering or sudden braking. Cattle always endeavour to stand in a vehicle in such a way that they brace themselves to minimize the chance of being thrown around and avoid making contact with other individuals. They do not lean on other individuals and are markedly disturbed by too much movement or too-high stocking density. Stocking density on the vehicle interacts with other factors in its effects. Pilcher *et al*. (2011) compared pigs transported at different stocking densities and found that at the two highest densities, 0.415 and 0.437 m^2/pig, pigs had more injuries, panted more and had more skin damage.

Poultry are normally transported in crates and high mortality rates during transport are often attributable to high temperatures in the crates. High stocking density in the crates leads to higher mortality rates in broilers than do lower densities (Chauvin *et al*., 2011).

In a study of sheep during driving on winding or straight roads, Hall *et al*. (1998c) found that plasma cortisol concentrations were substantially higher on winding roads than on straight ones. Tarrant *et al*. (1992) studied cattle at a rather high, an average, and a low commercial stocking density, and found that falls, bruising, cortisol and creatine kinase levels all increased with stocking density. González *et al*. (2012) in a large-scale study in North America, found that mortality during transport was substantially increased by high stocking density on the vehicle. Careful driving and a stocking density that is not too high are crucial for good welfare.

Journey duration and welfare

For all animals, except those very accustomed to travelling, as journeys continue, the duration of the journey becomes more and more important in its effects on welfare. Animals travelling to slaughter are not given the space and comfort that a racehorse or show-jumper are given. They are much more active, using much more energy, than an animal that is not transported, and hence they are using up their reserves. As a result they become more fatigued, more thirsty, more hungry, more affected by any adverse conditions, more immunosuppressed, more susceptible to disease and sometimes more exposed to pathogens on a long journey than they are on a short journey. These effects are all worse if conditions are difficult for animals to adapt to during the journey, so for many farm animal journeys, the conditions are more important than the duration (Cockram, 2007). The factors that change during transport and exacerbate adverse effects are reviewed by Broom (2008b) and Nielsen *et al*. (2011).

Mortality is increased progressively with longer transport times for broilers with four hours as the journey time after which mortality rises steeply (Warriss *et al*., 1992). Hens that have previously suffered painful traumatic injuries such as broken bones and dislocations, which are not uncommon, will suffer progressively more on longer journeys. Pig welfare declines as journey time increases (Sutherland *et al*., 2014). For pigs, a long journey is one of more than eight hours. Up to this duration, pigs cope quite well at a stocking density of 235 kg/m^2, but for journeys of 550 km, the pigs rest less and show more increases in several physiological indicators of poor welfare at this density than at 179 kg/m^2 (Gerritzen *et al*., 2013).

Animals may also become progressively more fatigued as journeys continue. Horses show increases in a range of physiological measures of poor welfare as journey length increases (Fazio and Ferlazzo, 2003; Padalino, 2015), and in a range of species, disease incidence can increase on longer journeys. However, there is much variation among species in the extent of adverse effects of long journeys, and in good conditions, sheep and cattle can tolerate longer journeys than poultry, pigs or horses (Fisher *et al*., 2010). If the animals have adequate rest, food and water at resting points, adverse effects of long journeys are reduced (Krawczel *et al*., 2007; Tadich *et al*., 2009). The extent of fatigue varies with species; sheep can walk on a treadmill for five hours without substantial fatigue effects (Cockram *et al*., 2012) so this helps to explain the greater resistance to fatigue of sheep as compared with other farm animals. A period of rest during a journey can be important to animals, especially those that are using up more than the usual amount of energy during the journey because of the position they have to adopt or because they have to show prolonged or intermittent adrenal responses that mobilize energy reserves. One way of judging

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how tired animals become during a journey is to observe how strongly they prefer to rest *after* the journey. Another way is to assess any emergency responses or adverse effects on their ability to cope with pathogen challenge. For example, Oikawa *et al.* (2005) found that horses on a 1500 km journey showed less adrenal response and fewer signs of harmful inflammatory responses if they had longer rests and had their pen on the vehicle cleaned during the journey. Journeys by ship, where adverse conditions may be prolonged because of rough sea conditions, can lead to high levels of injury, disease and mortality, even if the animals have space for rest on the ship (Phillips, 2015).

Disease, welfare and transport

The transport of animals can lead to increased disease, and hence poorer welfare, in a variety of ways. There can be tissue damage and malfunction in transported animals, pathological effects that would not otherwise have occurred resulting from pathogens already present, disease from pathogens transmitted from one transported animal to another, and disease in non-transported animals because of pathogen transmission from transported animals. Exposure to pathogens does not necessarily result in infection or disease in an animal. Factors influencing this process include the virulence and the dose of pathogens transmitted, route of infection and the immune status of the animals exposed (Quinn *et al.*, 2002).

Enhanced susceptibility for infection and disease as a result of transport has been the subject of much research (Broom and Kirkden, 2004; Broom, 2006a). Many reports describing the relationship between transport and incidence of specific diseases have been published. As an example, 'shipping fever' is a term commonly used for a specific transport-related disease condition in cattle. It develops between a few hours and one to two days after transport. In a study of horse health during long-distance transport, Marlin *et al.* (2011) found that of 1519 horses transported, 212 were deemed unfit for transport in a veterinary check prior to departure and there was a two-fold increase in the number found to be unfit when the same checking procedure was carried out on arrival.

Several pathogens can be involved such as *Pasteurella* sp., bovine respiratory syncytial virus, infectious bovine rhinotracheitis virus and several other herpes viruses, para-influenza 3 virus, and a variety of pathogens associated with gastrointestinal diseases such as rotaviruses, *Escherichia coli* and *Salmonella* spp. (Quinn *et al.*, 2002). Transport, in general, has been shown to result in increased mortality in calves and sheep (Radostits *et al.*, 2000; Brogden *et al.*, 1998), salmonellosis in sheep (Higgs *et al.*, 1993) and horses (Owen *et al.*, 1983). In calves, it can cause pneumonia and subsequent mortality associated with bovine herpes virus–1 (Filion *et al.*, 1984), as a result of a stress-related reactivation of herpes virus in latently infected animals (Thiry *et al.*, 1987).

In some cases, particular aspects of the transport situation can be linked to disease. For example, fighting caused by mixing different groups of pigs can depress anti-viral immunity in these animals (de Groot *et al.*, 2001). The presence of viral infections increases the susceptibility to secondary bacterial infections (Brogden *et al.*, 1998).

Transmission of a pathogenic agent begins with shedding from the infected host through oro-nasal fluids, respiratory aerosols, faeces or other secretions or excretions. The routes of shedding vary between infectious agents. Stress related to transport can increase the amount and duration of pathogen shedding and thereby result in increased infectiousness. This is described for salmonella in various animal species (Wierup, 1994).

The shedding of pathogens by the transported animals results in contamination of vehicles and other transport-related equipment and areas, e.g. in collecting stations and markets. This may result in indirect and secondary transmission. The more resistant an agent is to adverse environmental conditions, the greater the risk that it will be transmitted by indirect mechanisms.

Many infectious diseases may be spread as a result of animal transport. The major risks of cattle disease in the USA, when carrier animals are brought into a herd, are trichomoniasis, bovine viral diarrhoea (BVD), anaplasmosis, Johne's disease and bovine leukosis virus (BLV). Outbreaks of classical swine fever in Holland and of foot-and-mouth disease in the UK were much worse than they might have been because animals were transported, and in some cases the disease was transmitted at staging points or markets. Schlüter and Kramer (2001) summarized the outbreaks in the EU of foot-and-mouth and classical swine fever and found that, once this latter disease was in the farm stock, 9% of further spread was as a result of transport. In an epidemic of Highly Pathogenic Avian Influenza

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virus in Italy it was found that the movement of birds by contaminated vehicles and equipment created a significant problem in the control of the epizootic.

Major disease outbreaks are very significant animal welfare problems as well as economic problems, and regulations concerning the risks of disease are necessary on animal welfare grounds. If the procedures used during animal transport minimize the mixing of animals and other causes of stress, and the spread of animal products in the environment is also minimized, disease can be prevented or rendered less likely. Disease reduction improves animal welfare.

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3 Stress Physiology of Animals during Transport

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Summary

The assessment of welfare cannot always be totally objective. What level of physiological stress is acceptable? How hungry or thirsty can an animal become before the condition is not acceptable? Degrees of hunger, dehydration and other stresses can be assessed with objective biochemical or other tests but their interpretation is subjective. It is also important to remember that during mating, play or chasing prey animals, many of the biochemical variables that are commonly used as measures of welfare reach extreme values. In these situations, the welfare of the animal may well be good. Additionally, many stressors that occur during transport have a longer duration. In this chapter, studies on transport mortalities for poultry, cattle, calves, sheep and pigs are reviewed. It also reviews measures of physiological indicators of fasting, dehydration, general reactions to stress (heart rate, cortisol, respiration and glucose) and physical activity (lactate, glycogen, creatine kinase).

Keywords: transport, stress, physiology, welfare, mortalities, dehydration, fasting

Introduction

There is an increasing public interest in and concern for the welfare of livestock during transport. The majority of people now live in towns and cities and are no longer in day-to-day contact with farm animals. They are relatively unfamiliar with the animals and the methods of husbandry under which they are kept, and, to a large extent, have an idealized picture of farming and animal production. However, there is one point in most animal production systems that is commonly open to public view – the point at which animals are transported. Although necessary, transport is generally an exceptionally stressful episode in the life of the animal and one which is sometimes far removed from the idealized picture of animal welfare. So, increasing public concern for animals during transport has spurred research into their welfare, research that has attempted to quantify the severity of the stress imposed by the various stages of transport and to identify acceptable conditions and methods to minimize the adverse effects of transport.

Most work has concentrated on quantifying and ameliorating the effects of road transport as this is the major mode of animal transport, and it is road transport that is the main theme of this chapter. However, there have also been research programmes targeted at other forms of transport: the export of cull sheep from Australia to the Middle East by ship can result in exceptionally high mortality rates during the sea journey. This has prompted the Australian government to fund research into the problem. An introduction to the literature covering this research, and that of shipping cattle or sheep by sea, can be found in Norris (2005); Earley *et al*. (2012) or Ferguson *et al*. (2014). A limited number of livestock, usually only those of high value, are transported by air. Recommendations for transporting live animals by air are detailed in the IATA (2018) Live Animal Regulations, which are updated

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annually to take account of the latest research findings. These regulations are enforced for the air transport of all live animals by the European Union, the USA and many other countries. A few animals are transported by rail, with requirements essentially similar to those for road transport, focusing on standards for vehicles, rest periods and times for feeding and watering (Sossidou *et al.*, 2009).

The assessment of the welfare of animals during transport in any sort of objective and scientific way requires the measurement of something, in a quantifiable and repeatable manner. Broom (1986) defined an animal's welfare as 'the state of an individual with regard to its attempts to cope with its environment'. Within this definition, an animal attempts to maintain homeostasis through physiological and behavioural changes, and it follows that the greater the behavioural or physiological changes that are required the more an animal is having to do to cope with the situation or environment and the poorer its welfare is likely to be. This approach provides a working basis by which welfare can be judged and is very much in line with the clinical biochemical approach to the diagnosis of disease in both human and veterinary medicine. In clinical biochemistry, one or a number of measured biochemical or haematological variables in an individual are compared to population norms in order to identify specific disorders (see for example Farver, 1997). This sounds fairly straightforward; however, welfare itself is not an objective, measurable entity but an entirely human concept, and, as such, it cannot escape a high degree of subjective interpretation. Even when we can communicate with the animal that is being assessed, that is within our own species, there arise differences in the assessment of the welfare of individuals owing to differences between the opinions and backgrounds of the assessors, and these are not the only source of variability. As a whole, society's idea of what is acceptable human welfare has changed over time. How much more difficult it is, then, to try to second-guess the welfare of an animal with which we cannot communicate and which is unlikely to view or interpret its situation in anything approaching our own, human terms; and, furthermore, for a range of people to come to an overall agreement on the level of its welfare.

Thus, the idea of measuring the magnitude of the behavioural and/or physiological adjustments that an animal has to make to cope with its environment provides a useful structure underpinning the assessment of an animal's welfare. However well scientifically founded the measurements are, their interpretation cannot escape a high degree of subjective interpretation. We might ask, 'What is an unacceptable level of mortality?', when, however well animals are transported, there will always be some deaths. We can measure increasing 'hunger' and dehydration in an animal by changes in blood biochemicals, but how hungry or thirsty can that animal be allowed to become before the situation is unacceptable and when the biochemical changes that are observed increase linearly over time? During mating, play or chasing prey animals, many of the biochemical variables that are commonly used as measures of animal welfare reach extreme values, but most people would not consider the welfare of an animal in these situations to be impaired. Although this chapter is specifically focused on quantifying the adaptive changes in physiological function in animals during periods of stress response, it is important to acknowledge that assessment of animal behaviour is often necessary to provide a context to an animal's welfare. Duncan (2004) outlined the importance of understanding animal behaviour for robust assessment of animal welfare and the danger of exclusively focusing on physiological parameters for robust and quantitative animal welfare assessment.

The remainder of this chapter gives an introduction to the main physiological variables that have been used to assess the stress imposed on animals by transport. As far as possible these appear in functional groups. That is, they have been grouped as indicators of the various effects that are of interest; food deprivation, dehydration, muscular effort etc. Following this, we summarize best practice relating to research to date. Some further details of species-specific research on transport can be found in other chapters but a number of reviews in the scientific literature are listed in Table 3.1.

Physiological Variables

For a healthy, rested animal of a given species, there is a range of values for each biochemical and haematological variable within which the level of each measure for any individual would normally be expected to fall. The distribution of values found in a healthy, rested population usually form the familiar, bell-shaped, Gaussian distribution, except for the values of enzymes, for which the distribution is positively skewed, having a greater number of higher values. Published veterinary reference ranges for variables are quoted as the range of values within which 95% of the population would be expected to

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Table 3.1. Published reviews and large transportation studies under commercial conditions from the scientific literature covering the road transport of livestock.

Cattle

Tarrant, P.V. (1990) Transportation of cattle by road. *Applied Animal Behaviour Science* 28, 153–170.

Warriss, P.D. (1990) The handling of cattle pre-slaughter and its effects on carcass meat quality. *Applied Animal Behaviour Science* 28, 171–186.

Knowles, T.G. (1999) A review of the road transport of cattle. *Veterinary Record* 144, 197–201.

Eicher, S.D. (2001) Transportation of cattle in the dairy industry: current research and future directions, *Journal of Dairy Science* 84 (e-Suppl.), E19–E23.

Cernicchiaro, N., White, B.J., Renter, D.G., Babcock, A.H., Kelly, L. and Slattery, R. (2012a) Associations between the distance travelled from sale barns to commercial feedlots in the United States and overall performance, risk of respiratory diseases, and cumulative mortality in feeder cattle during 1997 to 2009. *Journal of Animal Science* 90, 1929–1939.

Cernicchiaro, N., White, B.J., Renter, D.G., Babcock, A.H., Kelly, L. and Slattery, R. (2012b) Effects of body weight loss during transit from sale barns to commercial feedlots on health and performance in feeder cattle cohorts arriving to feedlots from 2000 to 2008. *Journal of Animal Science* 90, 1940–1947.

Gonzalez, L.A., Schwartzkoft-Genswein, K.S., Bryan, M., Silasi, R. and Brown, F. (2012) Space allowance during commercial long distance transport in North America. *Journal of Animal Science* 90, 3618–3629. DOI: 10.2527jas2011-4771

Schvetze, S.J., Swandt, E.F., Maghirang, R.G. and Thomson, D.V. (2017) Review: Transportation of commercial finished cattle and animal welfare considerations. *Professional Animal Scientist* 33, 509–519.

Calves

Trunkfield, H.R. and Broom, D.M. (1990) The welfare of calves during handling and transport. *Applied Animal Behaviour Science* 28, 135–152.

Knowles, T.G. (1995) A review of post transport mortality among younger calves. *Veterinary Record* 137, 406–407.

Sheep

Knowles, T.G. (1998) A review of the road transport of sheep. *Veterinary Record* 143, 212–219.

Pigs

Warriss, P.D. (1987) The effect of time and conditions of transport and lairage on pig meat quality. In: Tarrant, P.V., Eikelenboom, G. and Monin, G. (eds) *Evaluation and Control of Meat Quality in Pigs*. Martinus Nijhoff Publishers, Dordrecht, The Netherlands, pp. 245–264.

Tarrant, P.V. (1989) The effects of handling, transport, slaughter and chilling on meat quality and yield in pigs – a review. *Irish Journal of Food Science and Technology* 13, 79–107.

Warriss, P.D. (1998a) The welfare of slaughter pigs during transport. *Animal Welfare* 7, 365–381.

Warriss, P.D. (1998b) Choosing appropriate space allowances for slaughter pigs transported by road: a review. *Veterinary Record* 142, 494–454.

Fitzgerald, R.F., Stalder, K.J., Mathews, J., Schultz Kaster, C.M. and Johnson, A.K. (2008) Factors associated with fatigued, injured and dead pig frequency during transport and lairage at a commercial abattoir. *Journal of Animal Science* 87, 1156–1166.

Haley, C., Dewey, C.E., Widowski, T. and Friendship R. (2008) Association between in transit loss, internal trailer temperature, and distance traveled by Ontario market hogs. *Canadian Journal Veterinary Research* 72, 385–389.

Ritter, M.J., Ellis, M., Berry, N.L., Curtis, S.E., Anil, L. *et al*. (2009) Review: transport losses in market weight pigs: a review of definitions, incidence, and economic impact. *Professional Animal Scientist* 25, 404–414.

Ritter, M.J., Ellis, M., Bertelsen, C.R., Bowman, R., Brinkmann, J. *et al*. (2009) Effects of distance moved during loading and floor space on the trailer during transport on losses in market weight pigs on arrival at the packing plant. *Journal of Animal Science* 85, 3454–3461.

Sutherland, M.A., Bryer, P.J., Davis, B.C. and McGlone, J.J. (2009) Space requirements for weaned pigs during sixty minute transport in summer. *Journal of Animal Science* 87, 363–370.

Edwards, L.N., Grandin, T., Engle, T.E., Ritter, M.J., Sosnicki, A.A., Carlson, B.A. and Anderson, D.B. (2010) The effects of pre-slaughter pig management from the farm to the processing plant on pork quality. *Meat Science* 86, 938–944.

Brandt, P. and Aaslyng, M.D. (2015) Welfare measurements of finishing pigs on the day of slaughter: a review. *Meat Science* 103, 13–23.

Goumon, S. and Faucitano, L. (2017) Review: influence of loading, handling and facilities on the subsequent response to pre-slaughter stress in pigs. *Livestock Science* 200, 6–13.

Rioja-Lang, F.C., Brown, J.A., Brockhoff, E.J. and Favcitano, L. (2019) A review of swine transportation research on priority welfare issues: a Canadian perspective. *Frontiers in Veterinary Science*. DOI: 10.3389/fvets.2019.00036/full

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Table 3.1. Continued.

Cattle, Sheep and Goats

Wythes, J.R. and Morris, D.G. (1994) Literature review of welfare aspects and carcass quality effects in the transport of cattle, sheep and goats (Parts A, B and C). Report prepared by Queensland Livestock and Meat Authority for Meat Research Corporation, PO Box 440, Spring Hill, Australia.

Schwartzkoft-Genswein, K.S., Faucitano, L., Dadgar, S. and Gonzales, L.A. (2012) Road transport of cattle, swine, and poultry in North America and its impact on animal welfare: a review. *Meat Science* 92, 227–243.

Appleby, M.C., Cussen, V., Carces, L., Lambert, L.A. and Turner, J. (2008) Long distance transport and welfare of food animals. CAB International, Wallingford, UK.

Sheep and Pigs

Hall, S.J.G. and Bradshaw, R.H. (1998) Welfare aspects of the transport by road of sheep and pigs. *Journal of Applied Animal Welfare Science* 1, 235–254.

Santurtun, E. and Phillips, C. (2015) Review: the impact of vehicle motion during transport on animal welfare. *Research in Veterinary Science* 100, 303–308.

Deer

Weeks, C.A. (2000) Transport of deer: a review with particular relevance to red deer (*Cervus elaphus*). *Animal Welfare* 9, 63–74.

fall. These limits are the 2.5 and 97.5 percentiles of any distribution and are approximately equivalent to ± 2 standard deviations about the mean when the variable does have a Gaussian distribution. Fig. 3.1 shows the frequency distributions of plasma albumin levels and of the enzyme creatine kinase (CK) from control samples obtained from cattle in a study by Knowles *et al*. (1999a).

The distribution of albumin values is very close to the Gaussian curve, which is superimposed on the graph, whilst the distribution of CK values is far from Gaussian. The 2.5 and 97.5 centiles of the albumin values are 34.9 and 45.4 $g.l^{-1}$, respectively, and for CK, 58.6 and 302.4 $U.l^{-1}$. The mean and standard deviation provide a useful summary of the albumin data and the percentiles are close to the mean ± 2 standard deviations. This is not the case for the distribution of the CK values, which are strongly left-skewed. Normally, the problem of this skewed distribution is addressed by analysing the logarithms rather than the untransformed data points. The resulting transformed distribution is acceptably close to normal.

Published reference ranges are useful in the diagnoses of a wide variety of diseases and can be useful for evaluating hypo- and hyperthermia, the degree of dehydration and, to a lesser extent, the degree of hunger arising during transport. However, it should be remembered that most of the physiological changes seen during transport are due to the action of normal homeostatic mechanisms taking place within a healthy population of animals in response to the variety of different stressors. Thus clinical reference ranges are of limited use in evaluating welfare during transport as the animals being transported generally are all healthy. So care should be taken in drawing any conclusions from comparisons with published normal ranges. What is really of interest is the change of a variable over time within an individual animal, as this is an indication of the scale of the response that an animal is mounting in order to cope; and because of the inherent variability between individuals, measurements are best taken at the level of the individual over time. The following is an overview of some physiological variables, which can give some insight into how an animal is coping with a given situation. However, instead of moving directly to descriptions of individual biochemical and haematological markers, we start with the ultimate indicator of the inability of an animal to cope – mortality.

Mortality

Mortality is a useful indicator of physiological stress. When an animal dies during transport it is because its physiological mechanisms have failed to maintain homeostasis. That transport is stressful is most readily quantified by the increased mortality that accompanies it. On average, in a given time period, a greater number of livestock will die if they are transported than if they are not. Of course, the animals that die initially are often those that are weaker, and the overall mortality rates during road transport for most livestock are usually only fractions of a percentage point. This means that the rate can only be accurately estimated when large-enough numbers are surveyed. However, increased mortality is interpreted by most people as an indicator of

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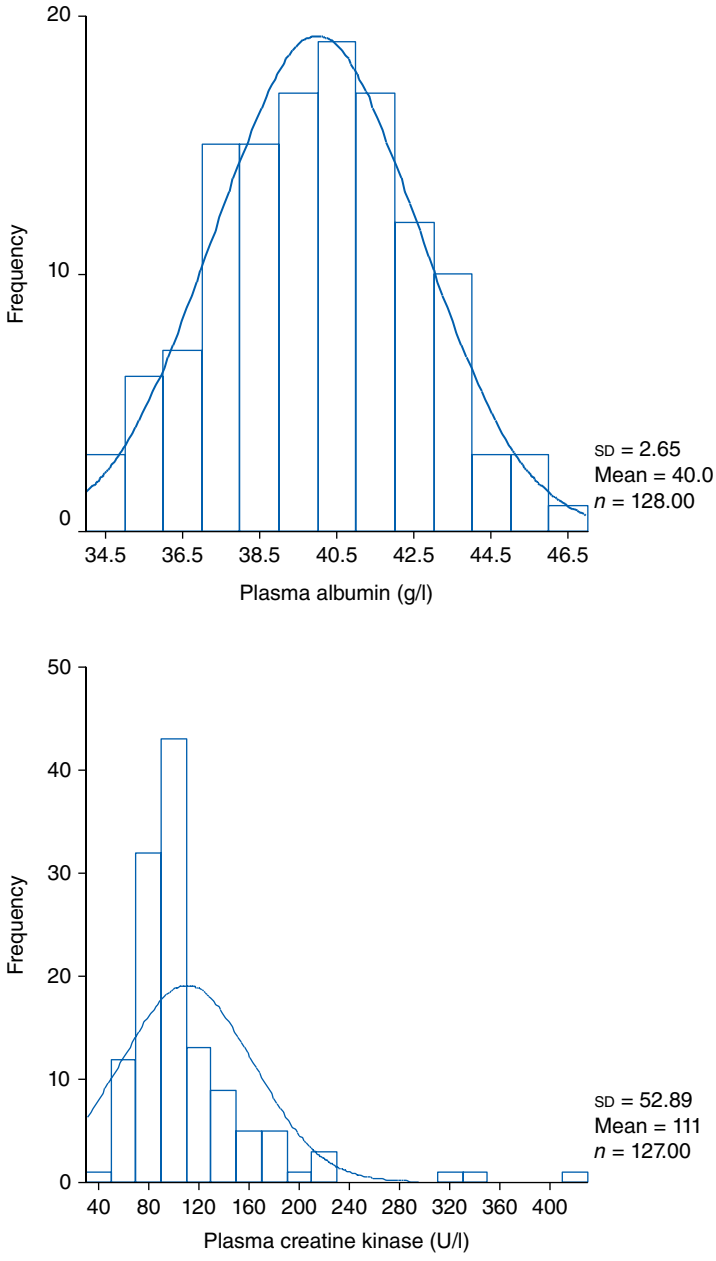


Fig. 3.1. The frequency histograms of plasma albumin and creatine kinase from rested cattle from a study by Knowles *et al*. (1999a). The Gaussian curves for distributions with the same means and standard deviations as the data are superimposed.

poor welfare and of the stressful nature of transport, in a way that many other types of measures are not so easily agreed upon.

If an increase in mortality is seen, even if mortality is only occurring amongst weaker animals, it is an indication that conditions are harsher and that the animals that do survive are probably facing a greater challenge. If a large-enough number of animals is being considered, mortality rate is also a useful measure of the relative 'stressfulness' of methods of handling and transport. For instance, Warriss *et al*. (1992) surveyed journey times and mortality rate among broilers transported to slaughter and found a strong relationship between the two variables. The results showed a marked non-linear increase in bird mortality for journeys greater than four hours,

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strongly suggesting that transporting for longer than four hours was undesirable. In another study, Warriss *et al.* (2005) used records from all 59 million broilers transported over three years to one processing plant in the UK to examine the relationship between the maximum daily ambient air temperature and the mortality rate in transport and lairage. This showed that up to a maximum daily temperature of about 17°C, increases in temperature had little or no effect on mortality. But above this temperature there were progressively larger increases in mortality so that between 17.0°C and 19.9°C, mortality was 30% higher than at temperatures less than 17.0°C. At temperatures above 23°C, mortality increased 6.6-fold. The overall implication was that above ambient air temperatures of about 17°C, significant improvements in commercial transport conditions needed to be made in order to reduce mortality and improve bird welfare. A Canadian study (Cockram *et al.*, 2018) identified risk factors associated with increased mortality during movement from the farm to the processor. They reported that the primary risk factors for increased mortality occurred in the winter and spring, with feed withdrawal greater than six hours prior to loading, increasing bird weight and an increase in on-farm mortality prior to transport.

Results like these are more easily obtained from broiler chickens as they have the highest mortality rates among the commonly transported types of livestock (the high mortality rates in broilers are, in part, due to the heavy commercial selection for improved growth rate and feed conversion to slaughter at 42 days, which has rather disregarded bird viability much beyond this age). The same trend can be seen occurring in pigs under similar selection pressures but which have a longer reproductive cycle and are not yet at the same level of selection. Mortality and morbidity in pigs have been recognized as key measures of welfare, which can inform about transport conditions. Sutherland *et al.* (2009) conducted an observational study including more than 2.7 million pigs to identify the main factors affecting pig morbidity and mortality during transport. Journey duration and environmental temperature (including ventilation) were the most notable factors. Barton-Gade *et al.* (2007) found that mortality increased from 0.0016% to 0.0223% when comparing transport distances of 100 km with distances of 200 km in Danish conditions. More recently, Brandt and Aaslyng (2015) reviewed the factors associated with mortality in pig transport. According to them, the selection of animals fit for transportation, road conditions, vehicle design and operation, space allowance, and temperature and ventilation are critical to safeguard animal welfare.

Other researchers have begun to investigate the relationship between transport distance and stress-induced disease and mortality in cattle during movement from markets to feedlots. Cernicchiaro *et al.* (2012a) reported that increased transport distance was significantly associated with increased overall mortality within a multi-year study of more than 14,000 cattle cohorts. These researchers found that when beef cattle were transported a median distance of 552 km to a feedlot, the average morbidity was 4.9%, and mortality was 1.3% (Cericchiaro *et al.*, 2012a). Some of these losses can be attributed to the fact that a significant percentage of weaned beef calves were not pre-weaned before transport and some ranchers still fail to vaccinate before shipment. Mortality is still the main welfare indicator for long-distance shipments of livestock, and the rate is higher at sea compared to the same period of transport on land (Phillips and Santurtun, 2013). Reasons for higher mortality rates during long transport can be heat stress, high concentration of ambient ammonia, change of diet and disease transmission.

Liveweight, β-hydroxybutyrate (β-OHB), Free Fatty Acids and Liver Glycogen as Indicators of Fasting

Transport can involve extended periods without food or water and, as a consequence, there is an initial loss of liveweight, which is predominantly due to loss of gut fill; approximately 7% of bodyweight in ruminants and 4% in pigs is lost during the first 18–24 hours. Generally, weight loss during transport is accelerated as it constitutes an additional stressful effect compared with deprivation of food or water without additional physical demand. In ruminants, the main loss of gut fill takes place during the first 18–20 hours of transport. Loss of gut fill, in itself, is unlikely to cause any deleterious effect to the animal other than temporary hunger. In ruminants, rumen fill can be used to assess the provision of feed during the hours prior to slaughter to reflect the nutritional welfare in the short period before slaughter (Llonch *et al.*, 2015). There is, however, an approximately linear loss of bodyweight,

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measured as a decrease in carcass weight, which is due to dehydration and the use of body reserves. Within species, this rate of loss of carcass weight has been found to show quite large variation across different studies, these differences being due to the condition of the animals, the environment and the conditions of transport. Despite the potential for dehydration to have a severe effect on the welfare of animals during transport, reliable and objective measures to assess it are still to be found. In part, this appears to be a result of the prioritization of water balance by the body as small disruptions in the concentrations of solutes can substantially impact body function. In addition, the water stored by the rumen allows ruminant animals to tolerate periods of time with reduced water access. For instance, Dalmau *et al*. (2013) found no signs of dehydration in lambs after a 24-hour transport journey with a water intake much lower than basal requirements.

In the longer term, body condition can be used as a measure of nutritional status as it can provide an estimate of body fat and muscle (Llonch *et al*., 2015). A very low body condition score indicates emaciation that can result from insufficient feed provision or disease. In sheep, body condition can be estimated using post-mortem carcass classification. The EUROP system is an example of an objective method of systematic carcass classification (Stubsjøen *et al*., 2011). Once an animal is deprived of food and water it has to rely on its body reserves to supply its energy needs until it can feed and drink again. The main energy store in the body is in the form of lipids, and by far the most important of these are triacylglycerols (or triglycerides), which can also provide thermal insulation. Triacylglycerols are mobilized by breaking them down into the constituent glycerol and fatty acids. These non-esterified fatty acids (NEFA) or free fatty acids (FFA) are transported in the blood bound to proteins. Triacylglycerols can be synthesized by many types of cell, but most synthesis takes place in the liver, adipose tissue and the small intestine. Lipolysis, the mobilization of body fat, is under hormonal control. As an animal fasts, much less glucose is available from the gut or glycogen reserves and this results in decreased levels of glucose in the blood plasma. This leads to hormone changes, increased glucagon levels and decreased insulin levels, which trigger hormone-sensitive lipase to break down adipose triacylglycerols, which are hydrolysed to FFA and glycerol. In ruminants, lipid mobilization may result in an excessive initial concentration of FFA in the blood. FFA can be utilized directly by most tissues and, as insoluble lipids, are bound to albumin in the plasma for transport around the body, whilst glycerol is transported dissolved in plasma water. Thus, during starvation, levels of FFA initially rise in the plasma, whilst actions that promote FFA synthesis suppress lipolysis. Plasma FFA levels, therefore, do not continue to rise in the longer term.

The liver holds a reserve of glycogen, and during the first day of fasting this reserve diminishes rapidly. Levels of liver glycogen can be measured by biopsy or at slaughter. Changes in liver weight can also be used as a measure of the use of these reserves. There are also reserves of glycogen within the skeletal muscle that tend to be conserved even after several days of fasting. However, glycogen depletion in skeletal muscle may proceed at a faster rate if the muscle is exercised or under distress conditions. Actually, glycogen depletion is the origin of a meat-quality defeat with notable impact in sheep and cattle; the dark, firm and dry (DFD) condition.

During fasting the usual metabolic pathways are modified and greater amounts of ketones are produced from FFA in the liver. Very high levels of FFA are damaging to tissues. The liver converts them to ketones when the level of acetylCoA from the breakdown of fatty acids increases above that needed to feed the TCA (citric acid) cycle. AcetylCoA is converted into acetoacetate and β-hydroxybutyrate. One of the main ketones is β-hydroxybutyrate (β-OHB) (or 3-hydroxybutyrate (3-OHB)). Despite the fact FFA can be utilized by most tissues, it appears that many tissues more easily utilize β-OHB than FFA. In fact, in some species, such as man, ketones appear to form the main energy source for the brain during prolonged fasting (Hasselbalch *et al*., 1994). This is not the case with the sheep or pig, where the brain still relies on glucose as the main energy source. Ketones are the main fuel of resting skeletal muscle during short-term fasting, but during long-term starvation or exercise, FFA become the main energy source. There is a biological limit to the amount of FFA that can be present in the plasma as all FFA have to be bound to albumin for transport. Levels of ketones in the plasma are not restricted in this way, which is important as levels of plasma albumin decrease during fasting thus reducing the

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amount of FFA that can be transported. Buckham-Sporer *et al*. (2008) reported decreased plasma albumin while plasma β-OHB concentration remained unchanged in Aberdeen Angus, Friesian and Belgian Blue × Friesian bulls during nine hours of road transportation. The authors noted that transportation duration and pre-transport fasting are significant factors in the relative changes in concentration of plasma proteins and ketones associated with transportation.

In pigs and poultry, the exchange between glucose in the blood and glycogen reserves in the muscle is the main energy metabolism. Glycaemia is stable as it is under hormonal control. Glucagon, glucocorticoids, adrenalin (epinephrine), thyroid hormones, growth hormone and progesterone are hyperglycemic and act by activating gluconeogenesis and glycogenolysis, or by interference of glucose utilized by tissue (Mota-Rojas *et al*., 2012). Under stress conditions, glucose levels rise due to the secretion of catecholamines and glucocorticoids. In events of acute stress, where the energy demand exceeds the aerobic capacity, anaerobic pathways, such as lactic fermentation, are upregulated, resulting in production of lactic acid.

Plasma Osmolality, Total Protein, Albumin and Packed Cell Volume as Indicators of Dehydration

Water is essential to all of the processes that take place within the body, accounting for 60% of the total bodyweight of most domestic animals. However, adipose tissue contains little water, and 'fat' animals such as fattened lambs and pigs will contain a lower percentage of water. The animal's capacity to respond to water deprivation is low or very low in most of the domestic species, particularly non-ruminants. Therefore, water availability is crucial to safeguard animal welfare. There are several measures to monitor dehydration. Total body water is considered, physiologically, to be made up of the extracellular fluid (ECF) volume and intracellular fluid (ICF) volume, where the ECF is all fluid outside the cells. Fluid present in the gut is sometimes considered as part of the ECF. In ruminants the forestomach may contain a substantial amount of fluid: up to 30–60 litres in adult cattle, which during periods of water deprivation can act as a buffer to maintain effective circulating volume. Vogel *et al*. (2010) reported that Holstein dairy cows were able to maintain baseline packed cell volume (PCV) during water deprivation in market conditions for up to 36 hours due to the reserve fluid volume of the forestomach. During periods of inadequate water uptake, the water losses are balanced proportionately between the ICF and non-gut ECF, thus electrolyte balance between the two is maintained. Packed cell volume, total plasma protein and plasma albumin are convenient and simple measures of dehydration. PCV is the percentage of the blood volume occupied by cells (predominantly the red blood cells), the remainder of the volume being fluid. Thus, as long as there is no loss or gain of cells, PCV is a measure of the plasma volume. However, many species have a reserve of red blood cells in the spleen that are readily released in response to excitement and stressors, so it is useful to use total plasma protein and albumin levels in conjunction with PCV when assessing levels of hydration. The assumption is made that the total amount of protein present in the plasma remains the same. Both total plasma protein and plasma albumin should show the same type of change if the change is due to dehydration and not a dietary effect. It should be noted that the percentage changes in protein and PCV will not be the same for a given loss of plasma volume, e.g. a 50% plasma volume deficit would result in a 100% increase in protein, but only, perhaps, a 40% increase in PCV. Osmolality can be used as a further, simple measure of plasma water content as it is a colligative property, and therefore reflects the overall concentration of all solute species. As a rough guide to the extent of dehydration, clinical signs are usually apparent when 4–6% of total bodyweight of 'effective' (not including fluid in the gut) total body water has been lost; moderate dehydration is when 8–10% has been lost; and severe dehydration is said to occur when losses are greater than 12% (Carlson, 1997). Skin-tenting time is commonly used to assess dehydration in cattle (Pempek *et al*., 2017). Dehydration is detected by a delay in the skin returning to its normal position. However, in other species, such as horses (Pritchard *et al*., 2006) and poultry (Vanderhasselt *et al*. 2013), skin tenting could not be proved to reliably monitor dehydration, and in sheep it has not been tested as an indicator of dehydration. The reliability of skin-tent time is still on evaluation as it may differ according to a number of other variables such as age, sex or production status. Thus, clinical measures of dehydration should always be used in combination with laboratorial measures.

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Heart Rate, Respiration Rate, Plasma Cortisol and Glucose as Indicators of a General Reaction to Stress

An initial response to stress is the release of the hormones adrenalin and noradrenalin into the bloodstream from the adrenal glands as a result of the activation of the sympathetic nervous system (SNS). Noradrenalin is also released from sympathetic nerve endings where it can act directly. The release of these hormones causes an acute increase in heart rate and blood pressure and stimulates hepatic glycogenolysis. This leads to an increased availability of glucose and a rise in plasma glucose levels within minutes. The effects of these hormones provide a useful measure of stress, but the hormones themselves have a rather short half-life in the blood stream and direct measurement of them is problematic. In the slightly longer term, an animal's response to stress is mediated mainly through the hypothalamic–pituitary–adrenal (HPA) axis, a system in which neural and endocrine control systems are integrated in such a highly complex and interdependent manner that it is only described here superficially. Glucocorticoid hormones, produced in and released from the cortex of the adrenal glands in response to an extremely wide range of stimuli/stressors, play a major role in mediating the physiological response. Cortisol is the central glucocorticoid in mammalian farm species and corticosterone in avian species. The pathway leading to the release and control of cortisol acts through the hypothalamus, pituitary and adrenal cortex and is summarized in Fig. 3.2. When the stress response is triggered, glucocorticoids are released into the bloodstream, which is perfused to other tissues, allowing samples to be collected from minimally invasive locations that do not cause an appreciable amount of stress (Cook, 2012).

Cortisol can be measured through a diversity of samples such as saliva, faeces and urine (Palme, 2012) providing a short- to medium-term quantification of HPA axis activity. Alternatively, concentration of cortisol in hair (Casal *et al*., 2017) or wool (Nejad *et al*., 2014) may inform about the activation of the HPA axis on a long-term basis.

The glucocorticoids play a major role in glucose metabolism, inhibition of protein synthesis, initiation of proteolysis and the modulation of immunological mediators such as lymphokines and as mediators of inflammatory reactions, causing anti-inflammatory effects. However, the effect of glucocorticoids appears to be variable (Earley *et al*. 2012).

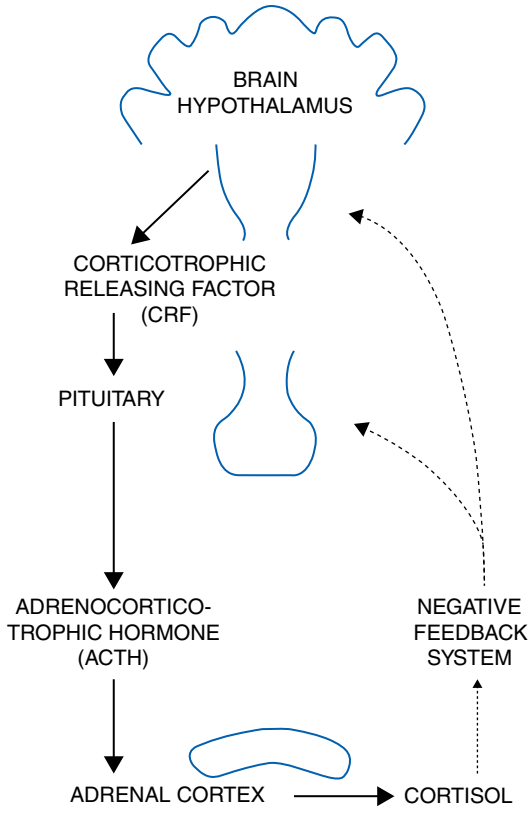


Fig. 3.2. The main pathways controlling the release of cortisol.

HPA and SNS activation can be elicited by appetitive and affectively neutral stimuli as well as aversive stimuli. Because of the role of the brain in the release of glucocorticoids, they are widely interpreted as a measure of an animal's psychological perception of a situation, in addition to the extent of its physiological reaction. A wide range of stressors can all cause elevations in heart rate, cortisol and other physiological measures (Grandin, 1997). For instance, cortisol levels have been found to increase during sexual behaviour, periods of increased exercise and while hunting prey (Dawkins, 2006). Therefore, the presence of eustress or distress must be considered because glucocorticoid release occurs, similarly, in response to stressors that the animal perceives as positive and negative, respectively.

However, assessing the output of the activation of the HPA axis has some limitations, as reviewed by Otovic and Hutchinson (2015). To mention a few, the sampling procedure itself, usually conducted in

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some form of animal restraint, can cause enough stress to confound the results. Salivary cortisol is released in different amounts as a function of the circadian rhythm, so the timing of collection must be controlled. Also, the impossibility of some presumed stressful conditions to increase cortisol concentration decreases its reliability to be taken as a unique stress biomarker. Instead, complementary stress biomarkers should be used to monitor stress, in addition to other indices of welfare, including behavioural and/or cognitive components, as suggested by Otovic and Hutchinson (2015).

In mammals, it is assumed that acute physical stress induces an amplification of growth hormone (GH) secretion, which, in addition to having a direct effect over body growth, also has an indirect effect over metabolism through the stimulation of insulin-like growth factor (IGF) production in a number of tissues, including the liver. In stress conditions, glucocorticoids influence levels of IGF and IGF-binding proteins (IGFBPs), suggesting an interference of acute stress with the IGF system. This association between the HPA and the somatotropic axis is known as the hypothalamic–pituitary–somatotropic axis (HPS axis). This concept reflects the ambivalent role of the pituitary glands on secretion of both glucocorticoids and somatotropic hormones, including GH and IGF. Recent studies, such as that of Wirthgen *et al*. (2017) have used this association to monitor the stress levels in pigs during transport, concluding that serum IGF and IGFBP work as stress biomarkers in pigs.

Creatine Kinase, Muscle Glycogen and Lactate as Indicators of Physical Activity

The enzyme creatine kinase (CK, also referred to as creatine phosphokinase (CPK)) is present in muscle, where it makes adenosine triphosphate (ATP), available for use in muscle contraction by the phosphorylation of adenosine diphosphate (ADP) from creatine phosphate. It appears in the circulating plasma as a result of tissue damage and is relatively organ-specific, occurring as three isoenzymic forms with an additional fourth variant that derives from mitochondria. Identification of the relative levels of isoenzymes present in the blood allows determination of the tissue that is the source and the relative extent to which damage has occurred. During exercise, there is increasing CK3 (the main isoenzyme present in muscle and also known as CK-MM) activity present in the blood as it leaks from the cells of skeletal muscle. Lactate dehydrogenase (LDH) has also been used as a measure of muscle damage; however, LDH activity is high in various tissues throughout the body and measurements cannot be so organ-specific.

During exercise, the main fuels for muscular contraction are glucose and fatty acids from the blood. However, any process that increases protein catabolism, such as strenuous activity coupled with reduced nutritional intake, will also tend to result in increased levels of plasma urea. Thus, levels of urea increase in response to stress, when levels of cortisol increase, and they will also rise as a result of food deprivation.

There is also an intramuscular carbohydrate reserve in the form of glycogen, and it is when muscle glycogen stores are depleted that exhaustion has been shown to set in. The main extramuscular carbohydrate source is glycogen in the liver. Reserves of muscle and liver glycogen may be measured by biopsy but, as most transport of animals is to slaughter, it is usually assayed in muscle and liver sampled immediately after slaughter. Metabolism of glucose can take place aerobically or anaerobically. In the latter case there may be a gradual build-up of lactate. Lipids can be metabolized only aerobically. At the start of fairly intense exercise, metabolism is mainly anaerobic. If the exercise is not too strenuous, aerobic metabolism of glucose and lipids takes over and lactate production decreases. The more intense the exercise is, the higher is the percentage use of glucose over lipid; thus lactate production is closely correlated with the intensity of exercise and may be seen as increased levels of lactate in muscle and in plasma. The degree to which the reserves of muscle glycogen are depleted at the time of slaughter has an effect on the post-mortem changes that take place in the muscle. If glycogen reserves have been depleted to any great extent, the muscle produces meat of an inferior quality, which looks dark, tends to have a less acceptable eating quality and is more prone to microbial spoilage, partly because it has a higher pH (is less acidic). Meat with this quality problem is commonly referred to as ‘dark, firm and dry’, or DFD, and is most prevalent among cattle and pigs, and less common with sheep. If glycogen reserves are intact before slaughter, an abrupt energy depletion, as, for example, in situations of distress, will lead to a higher rate of lactate production, which results in more rapid post-mortem pH decline. This process also provokes changes in carcass known as ‘pale, soft and exudative’, or

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PSE, meat, which is mostly prevalent in pigs. Numerous studies have used carcass-quality traits, including pH, colour and tenderness, as proxies of stress metabolism before slaughter (i.e. transport and pre-slaughter handling). Some examples are Correa *et al*. (2013) (pigs), Romero *et al*. (2013) (cattle), Miranda-de la Lama *et al*. (2012) (sheep) and Trocino *et al*. (2018) (rabbits), to mention but a few.

Immune Response

The capacity of animals to respond to health challenges (i.e. immunocompetence) can be altered during the stress response, with different consequences depending on the duration of the response (Dhabhar, 2014). Short-term stress may enhance innate and adaptive immune responses, whereas long-term stress suppresses or dysregulates innate and adaptive immune responses. Transport may well trigger a stress response that, depending on its duration and severity, can affect the animal's immune system and, sometimes, the health status of animals. The impact of transport on neonates can be more devastating because their immune system is not yet competent for many antigens. Evidence suggests that calves show higher respiratory and gastrointestinal morbidity after long transports (Chirase *et al*., 2004), which may well be attributable to a decreased immunocompetence coupled with exposure to novel pathogens in the transport container. However, in older animals, trials studying the effect of transport on immune function indicators have seen little evidence of immunosuppression (Earley *et al*., 2012).

The immune system changes suffered during transport are modified primarily by the increased levels of circulating corticosteroid hormones but also by other hormones such as vasopressin and oxytocin. These hormones can be measured in an effort to understand the stress status of an animal. At a superficial level, immunological changes may be seen in counts of circulating lymphocytes, neutrophils, leucocytes and eosinophils. Transport stress, typically, results in increased circulating concentrations of total leucocytes. Direct counts of these cells or ratios of counts have been commonly used to assess welfare during and after transportation. However, the changes that can be seen in immune status and their relationship with transport are too complex to describe here adequately. For a more comprehensive overview see Broom (2006), Hulbert (2010) and Mairead (2010). Recent research has shown that cattle with higher temperament scores, which showed excitable behaviour, had poorer immune function (Burdick *et al*., 2011).

Telomere Attrition as a Cumulative Stress Biomarker

Retrospective assessment of cumulative stress has been a challenge for animal welfare researchers. Most of the physiological variables mentioned so far are limited to a short period of time and are mainly capable of monitoring the effects of negative situations or emotions on welfare. However, cumulative welfare may also include the sum of all the events and effects that impact adversely and positively the welfare of an animal over its lifetime. Bateson (2016) argues that this cumulative welfare can be assessed through the biology of cellular ageing by measuring telomere attrition. Telomeres shorten with each round of DNA replication, reducing its replication capacity (von Zglinicki, 2002). Oxidative stress is an important modulator of telomere loss, meaning that organisms that have been exposed to stress will show a greater biological age. The contrast between biological age, monitored by telomere attrition, and chronological age, increases the hypothesis that the biological age of an animal could be used to determine its cumulative experience: 'Animals that are biologically old for their chronological age have had relatively more stressful lives compared with animals that are young for their chronological age' (Bateson, 2016). Despite the use of telomere attrition as an indicator of welfare in livestock being in its infancy, it has already been measured to successfully monitor stress in other species such as rodents (Kotrschal *et al*., 2007) and fish (Simide *et al*., 2016).

The Physiological Responses of Cattle, Sheep and Pigs to Transport

Cattle

Mortality rates among cattle transported by road are generally much lower than those of other forms of livestock. González *et al*. (2012a) reported a 0.011% mortality in a study of 6200 loads of fed cattle, feeder cattle, calves and cull cows. To a large extent, this is because the care with which animals are transported and the attention paid to their welfare is generally in proportion to the value of the individual animal (Hails, 1978).

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Marques *et al*. (2012) suggested that feed and water deprivation are major contributors to the acute-phase response and reduced performance during long-distance transports in cattle. Over the first 18–24 hours of transport, loss of bodyweight can range up to 11%. However, animals that lost more than 10% of their bodyweight during transport had a greater likelihood of dying or becoming non-ambulatory or lame (González *et al*., 2012b). Cernicchiaro *et al*. (2012b) reported that mean bodyweight loss associated with cattle transport to feedlots in the USA was 2.40 ± 0.02%. This is mostly due to loss of gut fill. Loss of carcass weight increases approximately linearly with transport time and has variously been reported to range from less than 1% to 8% over 48 hours.

Access to water can reduce both loss of bodyweight and loss of carcass weight (Warriss 1990; Vogel *et al*. 2010). After 24 hours of transport there is an increase in plasma levels of β-OHB, FFA and osmolality, total protein and albumin indicative of mobilization of food reserves and increasing dehydration (Tarrant *et al*., 1992; Warriss *et al*., 1995; Knowles *et al*., 1999a; Earley *et al*., 2012). After 24–31 hours of transport, levels of plasma cortisol, glucose and CK are elevated. In sheep these variables generally return to pre-transport levels after approximately nine hours of transport, but in cattle they tend to remain elevated or to steadily increase. Additionally, in cattle there is a gradual depletion of muscle glycogen (Knowles *et al*., 1999a) and an associated increase in the pH of the meat (Tarrant *et al*., 1992). These changes arise because cattle prefer to stand during transport as they are considerably heavy animals, and lying can produce considerable pressure on the parts of the body in contact with the floor of the vehicle, especially during a rough journey. The act of lying down and rising is difficult on a moving lorry at the stocking densities used for transport and there is a risk of being trampled or fallen upon. The changes seen in blood variables indicate that there is some physical effort involved in remaining standing and having to maintain balance against the motion of the vehicle. Despite the dangers and discomfort involved with lying, towards the end of the first 24 hours of transport some cattle do lie down (Tarrant *et al*., 1992; Knowles *et al*., 1999a). This could be because of the physical effort involved with standing, although, the physiological changes seen do not indicate excessive physical demand. Knowles *et al*. (1999a) hypothesized that the animals could possibly be in need of sleep as those animals that did lie down displayed higher levels of plasma cortisol. Raised levels of plasma cortisol are associated with sleep deprivation in humans (Leproult *et al*., 1997).

Knowles *et al*. (1999a) offered water to cattle on board lorries for one hour following 14 hours of transport within the UK. They found that fewer than 60% of animals drank – few drank fully – and that activity levels rose whilst the vehicle was motionless, leading them to conclude that the stop merely prolonged transport and further exhausted the animals rather than providing any recovery. Warriss *et al*. (1995) found that it took cattle five days to recover the liveweight lost during 15 hours of transport. Knowles *et al*. (1999a) found little difference in the pattern of recovery following either 14, 21, 26 or 31 hours of transport. Levels of plasma β-OHB, FFA, urea and glucose had recovered to pre-transport levels after 24 hours in lairage with food and water freely available, as had levels of plasma cortisol. Levels of indicators of hydration took up to 72 hours to return to pre-transport levels, whilst full pre-transport liveweight had not been recovered even after 72 hours of lairage.

Furthermore, after 30 hours on a truck, the likelihood of becoming non-ambulatory, lame or dead increased sharply (González *et al*., 2012c). The authors concluded that transportation durations exceeding 30 hours should be avoided during particular climatic conditions.

Based on both the physiological indicators of fatigue and dehydration and on the behaviour of the animals, both Tarrant *et al*. (1992) and Knowles *et al*. (1999a) suggest a maximum continuous transport time of no longer than 24 hours for cattle. Knowles *et al*. (1999a) and Earley *et al*. (2013) recommend a mid-transport lairage period of, ideally, 24 hours with food and water available to allow recovery from the physical demands of transport. They considered that short mid-transport stops were unlikely to provide reasonable opportunity for rest or recovery. Mid-transport stops may present additional environmental stress as the temperature inside transport lorries increases quickly when the lorry is not moving (Ritter *et al*., 2006). Air movement plays a significant role in thermal stress reduction, particularly when ambient temperatures are elevated (Mader *et al*., 2010). Cattle showing 'open-mouth breathing' are generally severely heat-stressed. A progression from open-mouth breathing to tongue extended is usually associated with increase in body temperature (Gaughan and Mader, 2012). In addition,

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heat tolerance varies between breeds of cattle. Gaughan *et al.* (2008) concluded that British breeds (Angus or Hereford, for example) had less heat tolerance than Brahman or Wagyu cattle.

The association between transportation and the occurrence of the bovine respiratory disease complex has long been recognized. The multiple stressors that calves experience during transportation result in an overall immunosuppression that allows the respiratory tract to be invaded by numerous opportunistic pathogens (Earley *et al.*, 2017).

The inclusion of rest stops during long transports without feed and water provision prevents increase in circulating cortisol and alleviates the NEFA and haptoglobin response elicited by transport, but does not improve performance of the transported cattle (Cooke *et al.*, 2013).

However, including a lairage stop of any length provides an opportunity for cattle from different sources to exchange pathogens. Experience in the USA has shown that 200–300 kg cattle will suffer fewer post-transport health problems if they are transported for a complete 32-hour journey, without any lairage stops. Whether the increased health problems are due to exposure to novel pathogens or to the inadequacy of the lairage conditions, extending the stress of transport, is not known (Grandin, 1997). Hulbert *et al.* (2011) reported that temperamental bulls were more likely to experience repressed neutrophil activity than were calm bulls, which demonstrated a potential interaction between cattle temperament and disease susceptibility as a result of transportation stress. Recently, workers have used measurements of the down-regulation of glucocorticoid and P-adrenergic receptors on the surface of lymphocytes to monitor the levels of stress suffered by young cattle (300 kg) during transport (Odore *et al.*, 2004). Using indices related to immune function in this way could also be useful in other species.

Tarrant *et al.* (1992) studied the effects of three stocking densities on 600 kg cattle that were transported for 24 hours. Following transport, they found that levels of plasma CK, cortisol and glucose had increased with increasing stocking density, as had the amount of bruising on the carcasses, indicative of increased physical and psychological stress and poorer welfare. They concluded that stocking densities above 550 $kg.m^{-2}$ were unacceptable for this size of animal on long journeys. These results run counter to the popularly held belief within industry that packing animals in tightly helps support them and prevents them from being jolted and bruised. Too high a stocking density was found to prevent the animals from holding a proper footing, by overly restricting their movement. The highest stocking density, and the one that was found to be unacceptable, was that which would normally be considered to represent a full load – the maximum number of animals that could be held in a pen and the gate still easily closed.

Poor driving or stop-start driving is another major factor contributing to animal stress, increased falls and injury during transport and reduced meat quality (Stockman *et al.*, 2013). The lesions are mainly associated with mishandling during loading and unloading or the use of poorly designed or maintained trailers, ramps and alleys (Miranda-de la Lama *et al.*, 2012).

Young calves (cattle less than one month of age)

Age and weight are among the most important factors contributing to the ability of an animal to manage transport stress. Neonatal animals are generally less well adapted to cope with transport and are more vulnerable than the adult animal. Because calves of this age are unweaned, the transport process effectively involves the withdrawal of both feed and water. This results in an increased incidence of morbidity and mortality when calves enter the feedlot (Fike and Spire, 2006; González *et al.*, 2012c) and an increased risk of bovine respiratory disease (Cernicchiaro *et al.*, 2012b).

The long-distance transport of very young cattle is common and usually takes place within days or weeks of birth, whilst the animal is still unweaned and is fully dependent on milk. Calf mortality during transport tends to be low; however, mortality rates following transport can be high, usually as a result of disease (Knowles, 1995).

In a large-scale survey of calf mortality and husbandry within the UK, Leech *et al.* (1968) estimated the mortality of transported calves to be 160% that of calves that remained on their farm of birth. Mortality of calves transported below one month of age remained markedly above that of home-bred calves until two months after purchase. In calves under one month old, various authors have reported a strong negative correlation between mortality/morbidity and age when first transported (Knowles, 1995). In addition to the age at which calves are transported, the length of time that marketing takes

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is also important. Mormede *et al.* (1982) found less post-transport disease among calves whose marketing took only 13 hours rather than 37 hours.

The reactivity of the adrenal glands to adrenocorticotrophic hormone (ACTH) increases with age and is not fully developed in the calf (Hartmann *et al.*, 1973). Several authors report that the increase in plasma cortisol usually seen in response to transport is not present in young calves (Knowles, 1995); neither do calves show the usual increase in heart rate and plasma glucose levels (Knowles *et al.*, 1997). These authors concluded that calves were unable to respond to the stress of transport because of their immaturity, and that the lack of a cortisol response was not because they were relatively 'unstressed' by the process of transportation. Using measurements of rectal temperature, Knowles *et al.* (1997, 1999b) found that when transported during cold weather, calves found difficulty in maintaining body temperature during transport and regulating it afterwards. Loss of liveweight was greater in the cold.

Fisher *et al.* (2014) assessed the impact of transport duration and feed (milk) withdrawal on 5–9-day-old calves. Apart from increases in serum creatine kinase in calves transported for 12 hours, transported calves generally did not differ in blood concentrations of glucose, beta-hydroxybutyrate, lactate, total protein or packed cell volume compared with untransported calves. Withdrawal of feed for 30 hours caused calves to lose 6% of bodyweight; blood glucose varied from 3.96 mmol/l immediately before daily feeding to 5.46 mmol/l at 3 hours post-feeding, and then declined to 3.43 mmol/l at 30 hours. Calves lay down for 22–32% of the time during transport and did not show a rebound effect in lying behaviour post-arrival in comparison with controls.

During and immediately after long-distance transport, calf hauliers within Europe prefer to feed a glucose and electrolyte solution rather than a milk replacer, as they report that this reduces the incidence of diarrhoea. Knowles *et al.* (1997, 1999b) found that feeding electrolyte during transport of 19–24 hours provided only little benefit in terms of rehydration and improvements in levels of plasma metabolites, and so recommended that it was best to complete the journey without the disruption and stress of feeding. Liquid feeding of unweaned calves requires the observation, and often the handling, of each individual animal. It also requires attention to hygienic presentation of the feed, which has to be made up to the correct temperature and solution strength in order to avoid digestive problems. There was some evidence from the study of Knowles *et al.* (1999b) that feeding just cold water during transport was detrimental to the calves.

If there is sufficient room for them to do so, calves spend much of the time lying down during road transport. Knowles *et al.* (1997) found that calves spent approximately 50% of the time lying down during 24 hours of transport. During cold weather the amount of the journey spent lying down increased to 80–90% (Knowles *et al.*, 1999b). Following transport for 24 hours, Knowles *et al.* (1999b) reported that most of the commonly measured physiological variables had returned to pre-transport values after 24 hours of lairage and feeding, except for liveweight and levels of plasma CK, which took up to seven days to recover.

Overall, present evidence indicates that young calves should not be transported until they are at least over the age of 1 month, but further work is required to confirm that this age limit should not be further extended. If they are to be transported, then it is best to keep the marketing time to a minimum, to avoid feed/rest stops if transport is for no longer than 24 hours, to avoid exposing the calves to cold and to avoid cross-contamination of animals from different sources. The animals should be well bedded, especially in cold weather, and transported at a stocking density that allows enough space for them all to lie down.

Sheep

The mortality rate among slaughter lambs transported by road within the UK has been estimated as 0.018% (Knowles *et al.*, 1994a), as 0.10% within South Africa (Henning, 1993) and as between 0.74% and 1.63% within Queensland, Australia (Shorthose and Wythes, 1988). In the UK, those lambs that go direct from farm to slaughterhouse have an estimated mortality rate of 0.007% compared with 0.031% for those that pass through a live auction market (Knowles *et al.*, 1994a). Occasionally, mass deaths within single loads of sheep are reported. These are most often associated with a combination of high ambient temperatures and reduced ventilation on a stationary lorry. In many countries there is a trade in cull sheep. There is anecdotal evidence that the mortality rates among these relatively infirm, low-value animals can be high during transport.

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The loss of liveweight during transport has been well documented in lambs. Wythes and Morris (1994) averaged the results from eight pieces of work and found liveweight losses of 3, 5, 7.5, 11, 12 and 14% over 6, 12, 24, 48, 72 and 96 hours, respectively. With food withdrawal alone, however, losses as high as 20% after just 72 hours have been reported by Horton *et al.* (1996) when also deprived of water. They also found that, following transport, food intake was depressed. Combining data from various sources, Wythes and Morris (1994) found the average rate of loss of carcass weight to be 1.7% per day over four days when lambs were deprived of only feed and not transported, with a range of 1.3–2.3% per day. During periods of fasting and transport of up to 72 hours, plasma levels of β-OHB have been found to increase linearly at a rate of approximately 0.006 $mmol.l^{-1}.h^{-1}$ (Warriss *et al.*, 1989a; Knowles *et al.*, 1995). Levels of plasma FFA tend to rise linearly with periods of fasting and transport at a rate of approximately 20 $\mu mol.l^{-1}.h^{-1}$ but peak and flatten out, with no further increase, between 18 and 24 hours, whilst levels of plasma urea increase approximately linearly by 30–50% during 24 hours of transport (Knowles *et al.*, 1995, 1998).

Water deprivation is one of the major concerns when transporting animals for long periods (Nielsen *et al.*, 2011). However, Dalmau *et al.* (2013) reported that lambs do not use the drinkers of the truck during a 24-hour transport. Sheep are known to be particularly resilient to dehydration (Knowles *et al.*, 1995; Parrott *et al.*, 1996; Cockram *et al.*, 1997). Healthy untransported sheep can tolerate feed and water withdrawal for up to three days (Cole, 1995), while if transported without feed availability, they remain in water balance for two days. When sheep were held without food or water for 48 hours at temperatures up to 35°C, Parrott *et al.* (1996) found little evidence of dehydration from measurements of plasma osmolality, but they did find evidence that the sheep were unable to maintain water balance if they consumed feed. Sheep transported for up to 24 hours in the summer in the UK showed no signs of dehydration as measured by plasma total protein, albumin and osmolality. However, sheep transported across France for 24 hours, during which daytime temperatures rose above 20°C, showed signs of dehydration, with increases in plasma total protein, albumin and osmolality of approximately 10%, 12% and 5%, respectively (Knowles *et al.*, 1996). In accordance with Parrott *et al.* (1996), Knowles *et al.* (1996) noted that feeding during and after transport tended to disrupt water balance. This has important implications for the length of mid-transport lairage stops as after short periods of food and water deprivation sheep are primarily interested in eating and do not drink readily or immediately (Knowles *et al.*, 1994b). A lairage stop of just one hour, as is presently required for transport of over 14 hours within Europe, is sufficient for the animals to eat but not to drink, so animals may be reloaded after having consumed a high dry-matter feed, but no water. A minimum mid-transport lairage time of eight hours has been recommended (Knowles, 1998).

Measurements of heart rate, plasma cortisol, glucose and CK have shown that it is the initial stages of transport that are most stressful to sheep (Knowles *et al.*, 1995).

Even four-hour journeys by road can induce behavioural, physiological and thermophysiological responses indicative of significant stress in adult ewes, leading to liveweight shrinkage (Pascual-Alonso *et al.*, 2016). Transported ewes lost approximately 1 kg live weight compared to non-transported animals and had higher body temperatures until 12 hours post-transport. Cortisol, glucose, non-esterified fatty acid (NEFA) concentrations as well as the neutrophil–lymphocyte ratio (N/L) and other physiological indicators are higher immediately after unloading in transported ewes but mostly returned to normal after four hours, with complete recovery after 24 hours. The increased physical activity is associated with vehicle movements and vibrations during transport (Miranda-de la Lama *et al.*, 2011).

Cockram (2007) observed that sheep lie down during transport and consequently assumed that the animals are able to rest on a moving truck. However, sheep do not lie down during the transport as much as they would in a static pen (Cockram *et al.*, 1997; Knowles, 1998). Dalmau *et al.* (2013) found higher concentration of salivary and faecal cortisol metabolites in lambs aged between 14 and 16 weeks and transported for 24 hours in comparison with lambs transported for one hour, suggesting that an accumulative stress exists in lambs transported for long periods. Nevertheless, high cortisol levels may reflect the reaction to emotional stress, due to a novel environment and stimuli, and do not necessarily underlie transport stress response (Napolitano *et al.*, 1995).

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Heart rate peaks at loading and there is a rise in cortisol, glucose and CK levels at loading, but after nine hours of transport these variables have generally returned to approximate basal levels and the only measurable changes seen are then due to the effects of feed and water deprivation, which can be exaggerated by the conditions of transport. However, the conditions of transport are important. Sheep that are loaded at too high a stocking density to be able to lie down easily show elevated levels of plasma CK, indicative of physical fatigue caused by having to remain standing (Knowles *et al*., 1998). No detectable muscular damage to sheep was reported after 24 hours transport in lambs (Dalmau *et al*., 2013) and 29-hour transport in ewes (Messori *et al*., 2015). When transported under good conditions, sheep can tolerate transport durations of up to 29 hours without undue impairment of their welfare.

High temperatures during transport stimulate evaporative heat loss in the animals by panting and sweating, creating a microclimate that favours dehydration (Caulfield *et al*., 2014).

As long as they are fit, loaded at an appropriate stocking density, the ambient temperature is not extreme and the load is properly ventilated, sheep appear to cope reasonably well during transport. However, Horton *et al*. (1996) reported that, after passing through a live auction market, lambs transported for 72 hours without food or water, whilst not differing in terms of performance or blood metabolites from animals simply deprived of food and water for 72 hours, suffered in terms of compromised general health. This was probably a result of confinement on the lorry and exposure to unfamiliar animals and pathogens, combined with the effects of deprivation and transport *per se*. After transport, the recovery of physiological variables to pre-transport levels appears to take place in three stages (Knowles *et al*., 1993). After 24 hours of lairage, with food and water, variables usually associated with short-term stress and the variables associated with dehydration had returned to normal levels. After 96 hours there had been a well-defined recovery in liveweight and levels of most of the metabolites measured had returned to normal levels. At 144 hours of lairage, a fuller recovery had taken place, levels of creatine kinase had fallen and all variables had stabilized.

Studies on stop duration in sheep during travel provide divergent results. Liu *et al*. (2012) suggested that a resting period of 6–12 hours with feed and water allows lambs to recover their homeostasis after an eight-hour journey. Shorter resting periods seem to be detrimental rather than beneficial for lambs (Cockram *et al*., 1997), even if Miranda-de la Lama *et al*. (2012) found that, in lamb transport, a logistic stopover system of one hour was less stressful than a direct transportation. Messori *et al*. (2017) compared 8 hours, 16 hours and 24 hours resting in a control post after a 29-hour journey on adult sheep and concluded that a 16-hour stop was sufficient to recover. In contrast, stop times of eight hours seem to have detrimental effects on muscle indicators, probably due to the shorter times between unloading and loading procedures. At control post, sheep invest the first hours after arrival mainly eating (Knowles *et al*., 1995; Cockram *et al*., 1996, 1997) and wait for a considerable period of time before resting (Knowles *et al*., 1994b). They only begin to drink 40 minutes after eating and spend less time resting than controls in the first 3 hours after unloading (Pascual-Alonso *et al*., 2016). Afterwards, the sheep will rest to restore from the reduced amount of lying behaviour imposed by the transport (Cockram *et al*., 1997). Therefore, if the stop is too short, they will not have time to drink and rest (Krawczel *et al*., 2007).

Messori *et al*. (2015) compared the effect of an eight-hour rest stop on the truck and in the control post, and concluded that there are no clear advantages in terms of animal welfare for avoiding the unloading and loading of the animals in the control post after long journeys. On the truck, the feeding and lying behaviours are restricted by the limited space allowance. Therefore, although leaving the sheep on the truck might reduce the management stress of unloading and loading, it also prevents the animals from resting, at least in the same way they do it in their housing pens. Also, the novelty of the rest pen, feeders or watering buckets did not appear to affect the behavioural response of sheep resting in the control post pen (Krawczel *et al*., 2007).

Where appropriate, it is always preferable, and generally makes better economic sense, to transport carcasses rather than live animals. Transport is stressful and transport times should be kept to a minimum. After nine hours of transport the changes in physiological variables with time tend to be linear and are of little help in determining a maximum acceptable transport time. Behavioural studies of motivation to feed have shown that sheep will begin to work for food after 10–12 hours of deprivation. At present, all the evidence taken together

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points to an acceptable maximum journey time in the region of 24 hours when transport is continuous and when food and water are not available. If a lairage stop is included in a journey then it should be for a minimum of eight hours with both food and water continuously available. However, a lairage stop does increase the chance of cross-infection between animals from different sources and animals stressed by the process of transport will tend to already be immunologically compromised and vulnerable.

Pigs

Most studies on the physiological responses of pigs to transport have dealt with market-weight pigs sent to slaughter, but more recently, some interest has been shown in the transport of weaners. Weaning is a stressful period, particularly if separation from the sow is compounded by transport to the fattening facility. Sutherland *et al*. (2010) showed that transport of weaners for about 2.5 hours reduced bodyweight and plasma glucose and increased total white blood cell count and plasma cortisol. The stocking rate used did not affect the pigs' physiology but influenced their behaviour. In a study of 109 journeys using 58,682 weaned piglets transported at 85–100 days of age, Averós *et al*. (2010) recorded 0.07% of all the transported piglets as dead on arrival, with deaths recorded in 13.8% of journeys. There was a significant interaction effect between the duration of the journey and the outside temperature. There was a gradual increase in mortality with increasing journey duration as the outside temperature increased. Factors that appeared to decrease mortality were provision of drinking water, having mechanically assisted ventilation and fasting before transport. Zhao *et al*. (2016) reported overall higher mortality rates for weaner piglets compared to feeder pigs and a higher susceptibility to unfavourable temperatures (both cold and hot).

The worst physiological outcome for transported pigs is that the animal dies during, or as a result of, transport. Ritter *et al*. (2009) have reviewed much of the work that has been done on slaughter pig mortality, particularly in North America. They summarized a large number of studies on the prevalence of dead and non-ambulatory pigs collected historically and recently in the USA, and also from Canada and several European countries. More recently, Zhao *et al*. (2016) evaluated a total of 7054 transportation records (3172 of weaners and 3882 of feeders) and concluded that mortality on arrival was affected by pig type, temperature and distance interactively. Non-ambulatory pigs are those that are unable to move or to keep up when moved with their congeners. In the USA, meat from non-ambulatory pigs cannot be used for government-related food systems, such as school meals, or for feeding the armed forces. The pork is often of poor quality. Cold weather is a factor in increasing the incidence of non-ambulatory pigs. At temperatures below 5°C, the number of pigs that could not walk increased (Sutherland *et al*., 2009). Another factor that may increase non-ambulatory pigs is use of high doses of the β-adrenergic agonist ractopamine (Marchant-Forde *et al*., 2003; Grandin, 2010). Ritter *et al*. (2009) concluded that, overall, 0.25% of pigs die in transit in the USA with an additional 0.44% classed as non-ambulatory on arrival. This has significant animal welfare and economic implications. Of the non-ambulatory pigs, 0.37% were classified as fatigued but not injured. Fatigued pigs often showed signs of acute stress with open-mouthed breathing, skin discolorations and muscle tremors, indicating that they were suffering from metabolic acidosis. Furthermore, according to Grandin (2017), two new studies clearly show that high doses are likely to cause problems. Peterson *et al*. (2015) fed pigs ractopamine for 28 days at doses of 0 mg/kg, 5 mg/kg and 7.5 mg/kg, and a significant increase of non-ambulatory pigs was found for the highest dose. Noel *et al*. (2016) compared handling of pigs fed 10 mg/kg of ractopamine versus 0 mg/kg for 32 days and found that pigs receiving no ractopamine could walk a further distance before they became exhausted.

Fitzgerald *et al*. (2008) and Ritter *et al*. (2009) described the problem of transport losses as multifactorial. However, two key factors influencing prevalence would appear to be the genetic make-up of the pig and the ambient temperature during transport. The mortality rate among pigs transported to slaughter within the UK had changed little over 20 years and was estimated to be 0.061%, with a further 0.011% of pigs dying in the lairage pens before slaughter (Warriss and Brown, 1994). However, there are marked differences in mortality rates between different countries. Averós *et al*. (2008) carried out a survey of 739 journeys to 37 slaughterhouses in five EU countries and found

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that the average mortality ranged from 0% to 11%, the average proportion of injured pigs ranged from 0% to 36%, and these figures correlated significantly. The rates are particularly higher in countries where the slaughter pig population contains a large proportion of genes from stress-susceptible breeds such as the Pietrain and Belgian Landrace. Estimates range from 0.3% to 0.5% in Belgium and Germany (see Warriss, 1998a). Murray (2000) and Haley *et al.* (2008) give a mortality figure for pigs transported in Alberta, Canada, in 1996 and 2004 of 0.14% and 0.12%, respectively, of which half was attributed to the presence of the halothane gene. Fàbrega *et al.* (2002) reported an 11-fold reduction in pre-slaughter mortality if both nn and Nn genotypes could be removed. In Denmark, total mortality was reduced eight-fold during the period that the halothane gene was being removed from the pig population, from 0.12% in the early 1980s to 0.016% in 2002 (Barton-Gade *et al.*, 2007). Since the publication of the third edition of this book (2007), many US breeders have eliminated the halothane gene. A similar strategy has been followed in Europe, and this probably explains the tendency for an overall decrease in mortality over the last decades. For example, in Germany, the percentage of animals dying during or after transport clearly decreased between 1999 and 2003 (Werner *et al.*, 2005). At present, some studies have presented results on the effect of the implementation of the new EU regulation in 2005. Voslarova *et al.* (2017) presented data on pig mortality during transport of Czech pig abattoirs from 2009 to 2014, reporting a decrease from 0.08% to 0.06%. However, these authors suggested that their study revealed that welfare of pigs in long distances and under extreme weather conditions was still compromised.

The other major factor influencing the mortality of pigs during transit is ambient temperature. Pigs are sensitive to high temperatures because they are poorly adapted to lose heat unless allowed to wallow, a behaviour not possible during transport. The relationship between mortality and ambient temperature is curvilinear. This is illustrated in Fig. 3.3, with data for the UK from Warriss and Brown (1994), which shows that there was a marked increase in mortality when average monthly temperatures rose above 15°C. Haley *et al.* (2008) showed a correlation between temperatures inside the vehicle and mortality rate. Because pigs find it hard to thermoregulate when confined in vehicles during transport, they are susceptible to heat stress. Measuring animals' temperature is therefore a potential way to monitor stress suffered during transport.

Warriss *et al.* (2006) used a thermal-imaging camera to record the temperature of the ears of transported pigs at slaughter. Ear temperature was significantly correlated with the pigs' core temperature, measured as the temperature of the blood lost at exsanguination. Moreover, ear temperature was positively correlated to serum creatine kinase activity, and blood temperature was positively correlated to serum cortisol concentration. Thermal images could therefore be useful to assess the physiological

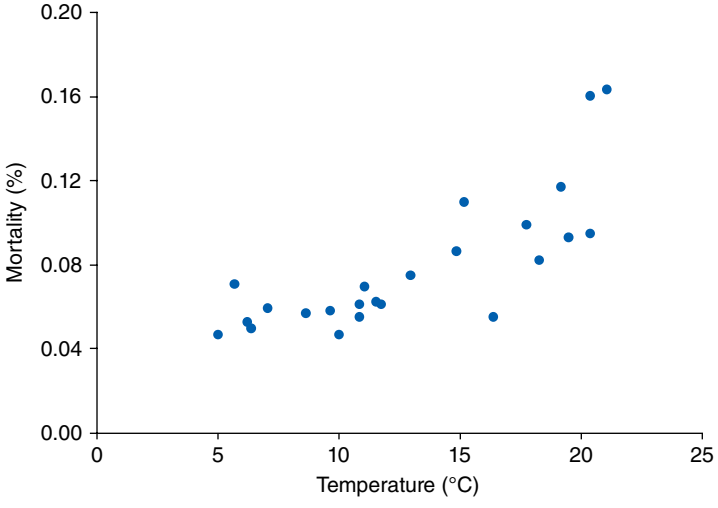


Fig. 3.3. The relationship between average monthly ambient temperature and the mortality of pigs transported to slaughter. (From Knowles *et al.*, 1999a)

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state of pigs non-invasively and so monitor their welfare. Schmidt *et al*. (2013) suggested that the more promising areas to evaluate temperature with infrared thermography were either behind the ears or the eyes; however, Brandt and Aaslyng (2015) considered the automation of such measurement a challenge. Similarly, ocular infrared thermography was found to significantly correlate with blood lactate levels (r = 0.20), with pH taken one hour post mortem (pH1: r = –0.18) and drip loss (r = 0.20) in the LD muscle, and with pH1 in the SM muscle (r = –0.20); and the authors suggested that it could be a potential tool to assess the physiological conditions of pigs at slaughter, but further improvements in the technique were required to increase the magnitude of the correlation (Weschenfelder *et al*., 2013). Nanni Costa (2013) reviewed the use of thermography to assess pre-slaughter stress in pigs and other species. Other factors of importance in determining mortality are the time of last feed before loading, vehicle deck, stocking density and possibly journey time. Pigs fed too soon (less than four hours) before transport are more likely to die, as are those carried on the bottom deck at higher densities and for longer. However, the evidence for the latter is contradictory and may be dependent on the interaction with age of pigs and climatic conditions as reported by Zhao *et al*. (2016).

Pigs find simulated transport aversive (Ingram *et al*., 1983), particularly the vibration associated with it (Stephens *et al*., 1985) and if they have recently eaten a large meal. Because pigs may vomit during transport (Riches *et al*., 1996; Bradshaw and Hall, 1996) and show increased circulating levels of vasopressin, a hormone associated with feelings of motion sickness in humans, part of their aversion may be attributable to similar feelings of sickness. A measurement of the G-force taken during the transport simultaneously with video surveillance showed that when travelling at 70 km/h and fully applying the brakes, triggering the ABS anti-blocking system, the G-force in the forward direction was 0.6G. With a loading density of 100 kg per 0.42 m^2, this braking forced the pigs forward in the pen, and those not leaning against anything lost their balance. This happened again when the brakes were released or when the truck came to a complete stop (Nøddegaard and Brusgaard, 2004). Santurtun and Phillips (2015) reviewed the impact of vehicle motion on animal welfare and concluded that despite the paucity of data and the gaps of knowledge with regard to the underlying mechanisms, there was sufficient evidence to believe that motion sickness was affecting welfare when pigs are transported by road.

That pigs find at least some aspects of transport psychologically stressful is evidenced by increases in plasma adrenalin (Dalin *et al*., 1993), indicating stimulation of the sympatho-adrenal system, and of cortisol (see, e.g., Dantzer, 1982) with corresponding depletion of adrenal ascorbic acid (Warriss *et al*., 1983) indicating stimulation of the hypothalamo-adrenal axis. They may also find it physically stressful, based on elevations of circulating activities of the enzyme CK (Honkavaara, 1989). For that reason, the blood concentration of certain metabolites, such as glucose, lactate and creatine kinase have been said to be promising indicators of overall pre-slaughter stress (Brandt and Aaslyng, 2015).

The physical stress they experience will be determined by the comfort and length of the journey. It is likely to be greater if vibration levels are higher. Modern vehicles with air suspension and driven on smooth roads will provide more comfort than older vehicles with traditional spring suspension systems driven on poorer road surfaces. Physical stress and the associated fatigue are likely to be higher if pigs stand, rather than lie down, during the journey. There is some debate about whether pigs prefer to stand or lie down. The available evidence has been reviewed by Warriss (1998b) who suggested that it pointed to the view that pigs preferred to stand on short journeys in which the conditions made it uncomfortable to lie down. These conditions could be excessive vibration or uncomfortable flooring, perhaps because of inadequate bedding. But, under comfortable conditions, many, if not all, pigs would lie down if given sufficient space, especially on longer journeys. Temperature may also affect the lying behaviour in pigs, since Fox *et al*. (2014) found that water sprinkling during transport at an ambient temperature below 23°C in a pot-belly trailer resulted in more pigs standing, whereas non-sprinkled pigs spent more time lying down during transport and drinking at lairage.

What is sufficient space was also discussed by Warriss (1998b). It is equivalent to a stocking density of not higher than about 235–250 $kg.m^{-2}$ for normal slaughter pigs weighing between 90 kg and 100 kg. For smaller pigs, the space requirement would be expected to be slightly greater, and for larger pigs slightly less. Council Regulation (EC) 1/2005 requires that the loading density for pigs of around 100 kg should not exceed 235 $kg.m^{-2}$. Also,

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the Regulation recognizes that this density may be too high under certain conditions. Breed of pig, size and physical condition of the animals, or weather and journey time, may mean that the space allowed has to be increased by up to 20%. Pigs carried at very high stocking densities show increased circulating levels of CK (Warriss *et al*., 1998). The provision of appropriate amounts of space is especially important with longer journeys.

The physiological state of an animal at slaughter often affects subsequent lean meat quality. Thus muscle glycogen depletion can lead to elevated ultimate muscle pH in the meat. Longer transport sometimes results in muscle glycogen depletion and more meat with high ultimate pH (Malmfors, 1982; Warriss, 1987). This is seen as a higher prevalence of DFD pork. Rigor mortis occurs when the levels of adenosine triphosphate (ATP) in the muscles after death are exhausted because of failure to be regenerated from creatine phosphate, adenosine diphosphate and glycogen. Transport durations of eight hours resulted in an increased number of pigs with pH_{45} below 5.7 compared to transport duration of 16 hours and 24 hours and an increased number of pigs with a ultimate pH above 6.3 when transported for 24 hours compared with 8 hours in Pietrain LY crosses (Mota-Rojas *et al*., 2006). Furthermore, journeys lasting 8 hours and 16 hours resulted in significantly increased blood glucose, lactate and haematocrit levels compared to the baseline levels (Becerril-Herrera *et al*., 2010). Nannoni *et al*. (2014) also reported an effect of sprinkling pigs during transport on higher pH one hour post mortem and lower blood lactate, which were attributed to less physical activity, although ultimate pH was not significantly affected in this study. Factors that affect the concentrations of glycogen and creatine phosphate in the muscles at death can therefore influence the rate of development of rigor in carcasses. These factors are often associated with pre-slaughter stress. Warriss *et al*. (2003) showed that earlier rigor development in commercially slaughtered pigs was associated with higher concentrations of cortisol, lactate and CK in the blood lost at exsanguination. This suggested that the average rates of rigor development, or the proportion of carcasses in full rigor at a particular time after exsanguination, could be used to monitor pre-slaughter stress, including that caused by transport, in groups of slaughter pigs. Similar results have been reported by Shiang Liang *et al*., (2009) and Dokmanovič *et al*. (2014). Blood lactate concentrations have been shown to be very useful in assessing stress levels in pigs subjected to the handling associated with transport and slaughter. Warriss *et al*. (1994) showed that pigs killed in UK slaughter plants that were subjectively judged to have poor pre-slaughter handling systems, and to produce subjectively assessed high levels of stress in the animals, had significantly higher levels of CK and lactate in their blood, collected at exsanguination, than those killed in plants subjectively assessed as having well-designed systems. The pigs also exhibited more meat showing poor quality. The levels of noise in the plants with poor handling systems were also higher, largely attributable to the pigs' increased vocalizations. In the USA, Edwards *et al*. (2010a) also found higher blood lactate levels in pigs whose carcasses showed a lower initial pH and poorer water-holding capacity, indicative of poorer meat quality. In a subsequent paper (Edwards *et al*., 2010b), the occurrence of specific behaviours of the pigs during handling at the slaughter plant, which led to problems in moving the animals, such as jamming or backing up the handling races, were correlated to higher lactate concentrations. Lactate can be easily measured with a handheld meter (Edwards *et al*., 2010b) and could therefore become a useful technique in future studies. Along that line, Brandt and Aaslyng (2015) have suggested that the development of automatic blood sample collection and automatic analysis of lactate, glucose and/or CK would be beneficial in the continuous monitoring of animals on the day of slaughter. These authors pointed out that each of those metabolites would be probably indicating different stages of stress. Since serum concentrations of CK increase and reach their peak six hours after stressful situations and return to basal levels after 48 hours (Anderson, 2010; Correa *et al*., 2013), CK measured in exsanguinated blood could be used as an indicator of events mostly taking place from the farm until sticking, even with long lairage times. On the other hand, plasma lactate increases to its maximum level within four minutes of physical exercise and returns to basal level in 2 hours (Anderson, 2010; Correa *et al*., 2013); therefore, Brandt and Aaslyng (2015) suggested lactate as an indicator of events taking place closer to slaughter. Glucose could be used as an indicator of energy metabolism and exhaustion.

During transport, pigs are deprived of food. They are often also deprived of water, although current

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EU legislation (EC Directive 95/29/EC) prescribes that pigs transported for more than eight hours must have continuous access to drinking water. There is, however, evidence that pigs drink only very small amounts of water (Lambooy, 1983; Lambooy *et al*., 1985). Some studies (Warriss *et al*., 1983) have indicated that pigs can become dehydrated after only short journeys, but data from other work (Becker *et al*., 1989) have not supported this. Dehydratation can be assessed by measuring the osmolarity of the blood or by using the blood concentration of albumin as indicator; thus the latter measurement has been suggested to be included in an automated blood sampling at exsanguinations (Brandt and Aaslyng, 2015). Food deprivation leads to losses in live and carcass weight (Warriss, 1985), liver weight and liver glycogen (Warriss and Bevis, 1987) and muscle glycogen (Warriss *et al*., 1989b). These responses are undesirable. However, some period of food withdrawal before transport is desirable to minimize mortality; and, in the case of slaughter pigs, to facilitate hygienic carcass dressing and minimize the risk of contamination. Four hours has been recommended (Warriss, 1994) but this may be too short a time, based on observations of vomiting during transport, although the ideal period of withdrawal is not clear (Warriss, 1998a). Most recommendations provided to farmers have 12 hours as mean optimal time (e.g., AHDB, 2011 recommendation is from 8 to 12 hours fasting prior to loading, whereas Ontario Ministry of Agriculture, Food and Rural Affairs, 2016 recommended 12 to 18 hours). The real timing of feed withdrawal is not easy to assess, especially on an individual basis, since it may depend on the housing conditions. Pigs in a non-crowded environment eat little feed overnight, but those kept at high stocking densities are more likely to continue feeding throughout the night. Several slaughterhouses in Spain have demanded research on indicators such as stomach weight to assess the timing of feed withdrawal and correlate it with meat-quality parameters.

Many slaughter pigs are mixed with unfamiliar animals when they are assembled for sending to slaughter. This usually leads to fighting, particularly between dominant individuals. Aaslyng *et al*. (2013) found that the pick-up facilities are one of the main stages on the day of slaughter at which skin damage occurs as a consequence of fighting in finishing pigs. The practice of split-marketing, consisting in the removal of the heaviest 25–50% of pigs from a pen to market them one to two weeks earlier than the other penmates, increases the risk of fighting both in the marketed group (Goumon and Faucitano, 2017) and within the pigs remaining at the pen (Fàbrega *et al*., 2013).The consequences are elevations in circulating cortisol, CK and lactate, and depletion of muscle glycogen (Warriss, 1996). Mixing pigs is undesirable from the point of view of both welfare and meat quality. Nevertheless, in the UK, about 40% of pigs show some evidence of fighting, and between 5% and 10% evidence of severe fighting. A complicating factor in the interpretation of changes in the levels of stress indicators in the blood of pigs may be the social status of different individuals. Hicks *et al*. (1998) measured the effects of a four-hour transport, heat stress and cold stress on weanling pigs (4 weeks old). There were interactions between the effects of treatment and social status on albumin/globulin ratio, natural killer cell cytotoxicity, lymphocyte proliferation and cortisol concentrations. After transport, subordinate piglets tended to have higher serum cortisol and lower albumin/globulin ratios, compared with piglets of higher social status. Physiological measurements of the consequences of mixing could be accompanied by animal-based indicators of skin damage, which can be assessed in live animals or in the carcass. Three-, four- and five-level scales have been developed (Aaslyng *et al*., 2013). However, it has to be taken into consideration that in supply chains where loading on the farm and transport to the abattoir occurs within 12 hours, it may be difficult to tell the age of the bruise/lesion, and, therefore, proper training is required to identify when and who/what inflicted the lesion.

Table 3.2. Commonly used physiological indicators of stress during transport.

Stressor	Physiological variable
Measured in blood	
Food deprivation	↑ FFA, ↑ β-OHB, ↓ glucose, ↑ urea
Dehydration	↑ osmolality, ↑ total protein, ↑ albumin, ↑ PCV
Physical exertion	↑ CK, ↑ lactate
Fear/arousal	↑ cortisol, ↑ PCV
Motion sickness	↑ vasopressin
Other measures	
Fear/arousal and physical exertion	↑ heart rate, ↑ respiration rate
Hypothermia/hyperthermia	body temperature, skin temperature

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4 The Effects of both Genetics and Previous Experience on Livestock Behaviour, Handling and Temperament

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Summary

Both genetics and previous experiences with handling will have an effect on the behaviour of cattle, sheep, pigs and other livestock. Cattle that become agitated in squeeze chutes or run out quickly (exit speed) have lower productivity and higher physiological measures of stress. There are significant breed differences. *Bos indicus* breeds are generally more fearful than *Bos taurus* English/European cattle. Agitated behaviour is more likely to occur in high fear genetics when the animals are confronted with sudden novelty. Young calves should be gently acclimatized to quiet contact with people and moving calmly through handling facilities. This will help produce calmer adult cattle. Rewarding with feed is strongly recommended when animals are being acclimatized to handling facilities. This is especially important if they are moved through the facility multiple times. Animals have specific sensory-based memories. An animal with flighty genetics that is acclimatized to handling may have a violent reaction when it is suddenly confronted with novelty. Livestock with calmer genetics may have a milder reaction to a sudden novel event. Fearfulness is only one temperament trait. Inherited traits such as guarding the calf or seeking further grazing may be separate traits that are not related to fear. Fear-motivated traits such as exit speed score are not related to calf guarding. The Jaak Panksepp emotional traits of FEAR, RAGE, PANIC, separation distress, SEEK, LUST, NURTURE and PLAY may be useful for sorting out conflicting data from temperament research. The most common mistake is mixing up fear-motivated behaviour and aggression. Genomic analysis of temperament should be conducted on single temperament tests such as exit (flight) speed chute/crush score, or isolation tests. Composite scores of more than one temperament test may result in mixing up emotional systems and confounding genomics tests. There is starting to be some evidence that some British and European Continental genetic lines of cattle may have been over-selected for calmness.

Introduction

The behaviour of cattle, sheep, pigs and other livestock during handling is affected by both genetic factors and experience. Cattle with a calm temperament are more productive. Animals that stand calmly in a squeeze chute or exit more slowly gain more weight and have lower cortisol levels (Voisinet *et al*., 1997; Burrows and Dillon, 1997; Petherick *et al*., 2002; King *et al*., 2005; Curley *et al*., 2006). Both older studies and more recent ones show that calm cattle have better meat quality (Voisinet *et al*., 1997). In the Brazilian Nelore breed, calmer animals also have better meat tenderness (Coutinho *et al*., 2017). This research motivated producers to select livestock that would remain calmer and be

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easier to handle during routine vaccination, pregnancy testing and other husbandry procedures. When the first studies were published 20 years ago (Voisinet *et al*., 1997 and Burrows and Dillon, 1997) US ranchers started culling cows that became highly agitated or dangerous to handle. Below are some anecdotes from the author's experience, after which the scientific literature is explored.

Twenty years of temperament selection in the USA for calm cattle caused dramatic changes in behaviour

I did not realize how much Angus cattle had changed at our own experiment station until we bred a steer I called the Time Machine. In 2017 they tried some new bull semen. A steer sired with this semen was completely crazy compared to our other Angus steers. Observing this steer was like being transported by a time machine back to the early 2000s before temperament selection became a common industry practice. During the last 20 years our herd has been selected for calm behaviour during handling. I did not realize how calm our Angus herd had become until I saw this highly agitated steer. His flight zone was three times larger than the other cattle's. While he was waiting in the single-file race, he tried to break through the bars when I got too close. The rest of our cattle stood calmly while he became extremely agitated. The student operating the squeeze chute failed to catch him and his exit speed was at a run. All the other cattle walked calmly when they exited. This steer's behaviour was definitely influenced by genetics. All the steers in our Angus herd lived in the same environment and were handled by the same people.

Striking differences between breeds when viewed beside each other

On a trip to Brazil in 2017 we had to do the same cattle-handling demonstration four times in one day. This required running cattle through the handling facility and locking each cow in the headgate. For each demonstration we used a new group of Nelore cows. Due to their more excitable temperament, handling the same Nelore cows four times in one day would have been really dangerous for both us and the cattle. However, there was a single Nelore dairy cross-cow who always remained calm. She calmly participated in all four demonstrations. She lived with the Nelore cows in the same pasture and had all the same previous experiences. The genetic effects which influenced her calm behaviour became obvious. Many people may not realize the large effect that genetics has on behaviour. Observing animals from different genetic lines beside each other during handling makes observation of differences in behaviour easy. To separate genetic from environmental effects, the livestock must all be raised in the same environment.

Deer much calmer 30 years later

When I visited deer farms in New Zealand in the 1970s, deer were much more flighty. Handling facilities had to be in a dark building and have high, solid fences. In 2016 I visited a New Zealand deer farm and it was now possible to handle deer in an open outdoor pen (Fig. 4.1). We were also able to be in the pen with the deer. If we had tried to do this in the 1970s, we would have had deer crashing against the walls.

Changing the Level of Fearfulness

In all of the above observations, the genetic trait that had been changed was fearfulness. When animals become agitated during handling, it is usually due to fear. In the early 90s, when I started doing studies on temperament, the reviewers made me change the word 'fear' to 'agitation' (Grandin, 1993). Using the word fear was considered as attributing human emotions to animals. Australian researcher Paul Hemsworth was one of the first farm-animal scientists to use the word fear in the title of a scientific journal article (Hemsworth and Barnett, 1990). He reported that sows that were fearful of people had fewer piglets (Hemsworth *et al*., 1981). Fear has been extensively described in the neuroscience literature. The fear circuits in animal brains have been completely mapped (LeDoux, 1996; Rogan and LeDoux, 1996; Panksepp, 2011; Morris *et al*., 2011). Other indications that animal emotions have similarities to humans is that psychiatric drugs such as clomipramine and fluoxetine (Prozac) have the same effect on animals (Overall and Dunham, 2002).

Detrimental Effects of Fear

Cattle , horses, sheep and other grazing and herding animals are all prey species. Fear motivates them to be constantly vigilant so that they can escape from predators. Fear is a very strong stressor (Grandin,

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Fig. 4.1. Over the years deer have become calmer. Thirty years ago, handling deer in this open corral would have been very dangerous. Gradually, fearfulness was reduced. (Photo: Courtesy of Temple Grandin)

1997). Calm animals are easier to handle and sort than agitated, fearful cattle. Fearful cattle bunch tightly together and handling becomes more difficult. The secret to low-stress cattle handling is to keep them calm. If cattle become frightened after severe handling stress, it takes 30 minutes for them to calm down and have their heart rate return to normal (Stermer *et al*., 1981). Feedlot operators who handle thousands of extensively raised cattle have found that quiet handling during vaccination enabled the animals to go back onto feed more quickly.

Voisinet *et al*. (1997) reported that cattle that became highly agitated during restraint in a squeeze chute (high chute score) had lower weight gains than calm cattle that stood quietly. Similar results have been found in sheep. Sheep that remained calmer during weighing gained more weight (Gavojdian *et al*., 2015). Further research has shown that cattle that run rapidly out of the chute are more susceptible to pre-slaughter stress, yield tougher meat and have lower weight gain and reproductive performance (Petherick *et al*., 2002; Vann *et al*., 2017; Cooke *et al*., 2009; Hall *et al*., 2011; Burrows and Dillon, 1997; Coutinho *et al*., 2017). King *et al*. (2005) reported that extensively raised cattle with an excitable temperament had higher cortisol levels after handling. Cattle that had higher cortisol levels also exhibited more resistance to entering a squeeze chute, more vocalization and an absence of rumination compared with undisturbed cattle on a pasture (Bristow and Holmes, 2007). In Lacaune ewes, animals that remained quiet during milking had lower (better) somatic cell counts (Toth *et al*., 2017). Sheep and cattle may also have an innate fear of dogs. Sheep were more willing to approach a goat than an unfamiliar human or a quiet sitting dog (Beausoleil *et al*., 2005). The unfamiliar goat may be perceived as a herd mate rather than as a threat.

Other Behavioural Indicators of Fear and Stress

When grazing animals see novel or potentially threatening things, they will raise their heads in a vigilant posture (Welp *et al*., 2004). The eyes also provide an indicator of bovine stress level. Frightening cattle by suddenly opening an umbrella caused a greater percentage of the white portion of the eye to show (Sandem *et al*., 2004). Cattle with a more excitable temperament that became more agitated in the squeeze chute also had a higher percentage of visible eye white (Core *et al*., 2009). The percentage of visible eye white also increases

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when a calf is separated from its mother, and the tranquilizer diazepam reduces this (Sandem and Brasstad, 2005; Sandem *et al*., 2006). Under practical conditions, a bovine should be classified as either showing eye white or not showing it.

In most mammals and birds, the left eye, which is connected to the right side of the brain, is used for monitoring potentially threatening or novel stimuli and the right eye is used when approaching familiar safe things. Robins and Phillips (2010) and Phillips *et al*. (2016) found that this principle is true in cattle. When a novel stimulus becomes safe and familiar, the eye preference for viewing the stimulus switches (Robins *et al*., 2018) Dairy cows that were more anxious passed a novel person standing in the exit alley so that they could view him with their left eye (Gomaz-Amira *et al*., 2018).

Another sign of fear and agitation in cattle is tail swishing (Grandin, 2015). Cattle will often swish their tails at a steadily increasing frequency before they do something violent such as kicking people or attempting to jump out of a race. Another indicator of stress is defecation during handling. When cattle remain calm during handling there will be less manure to clean up (Joe Stookey, personal communication, 2018).

Differences between Breeds and within Breed Variation

There are large differences in temperament, both between and within breeds of cattle and sheep (Tulloh, 1961; Fordyce *et al*., 1988; Uetake and Kudo, 1994; Baszczak *et al*., 2006; Zambra *et al*., 2015; Littlejohn *et al*., 2016; Chase *et al*., 2017). Crossbred cattle with visible *Bos indicus* genetics have higher exit speed scores compared to *Bos taurus* (Bazczak *et al*., 2006; Littlejohn *et al*., 2016). In Holstein calves, the sire had an effect on cortisol response to transportation stress (Johnston and Buckland, 1976). The sire also has an effect on learning ability and activity levels in Holstein calves (Arave *et al*., 1992). Holstein steers balked more and were more likely to refuse to move through a race than Angus steers (Thomas, 2012). In sheep, Carriedale lambs became more agitated in an isolation box compared to Merinos (Zambra *et al*., 2015).

Breed has a definite effect on bovine temperament. Brahman cross-cattle became more behaviourally agitated in a squeeze chute compared to Shorthorns (Fordyce *et al*., 1988). Both Hearnshaw *et al*. (1979) and Fordyce *et al*. (1988) reported that temperament is heritable in *Bos indicus* cattle. Stricklin *et al*. (1980) reported that Herefords were the most docile British breed and Galloways the most excitable. The continental European breeds of *Bos taurus* were generally more excitable than British breeds. Within a breed, the sire was found to have an effect on temperament scores. Several studies show that a more agitated temperament score is related to the proportion of *Bos indicus* breeding (Baszczak *et al*., 2006; Littlejohn *et al*., 2016). Cattle with *Bos indicus* genetics will also have higher cortisol levels (Zavy *et al*., 1992; Chase *et al*., 2017; Vann *et al*., 2017). The association of chute score and average daily gain is weaker in Angus cattle compared to Brahman cattle (Café *et al*., 2010).

Hair Whorl Temperament

Grandin *et al*. (1995a) and Randle (1998) both found that cattle with spiral hair whorls above the eyes had a larger flight distance and were more likely to become agitated during restraint than cattle with hair whorls below the eyes. Red Angus cows with hair whorls above the eyes were more vigilant when defending their calves from threats in their environment (Florcke *et al*., 2012). The cows with high hair whorls raised up their heads sooner when a strange vehicle approached them (Florcke *et al*., 2012). In the Holstein and the German Black Pied breeds there was no effect of hair whorl height (Broucek *et al*., 2007; Ebinghaus *et al*., 2016). This may be due to less genetic variation in these breeds. In the area where the author is located, in Colorado, extensive temperament selection of British and European continental breeds has been occurring for 20 years. The Angus cattle at our experiment station have hair whorls either between the eyes or below them. It is difficult to find an animal with a hair whorl high above the eyes. However, if I look at 30-year-old photos, I can find lots of beef cattle with high hair whorls high in the middle of their foreheads. In *Bos indicus* purebreds, the hair whorl may be behind the poll. There is none on the forehead. There needs to be research done with poll hair whorls.

Body Type and Temperament

Observations of cattle, horses, dogs and other animals indicated that animals with a slender body and fine bones were more nervous and flighty (Grandin and Deesing, 2014). Lanier and Grandin

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(2002) found that cattle with a smaller diameter cannon (foreleg) bone were more nervous and ran out of the squeeze chute more quickly than those with larger cannon bones. Cannon bone diameter was confirmed by post-slaughter measurements. Hansen *et al.* (2001) reported that the lighter sheep breeds flocked more tightly and had a bigger flight zone. Leaner pigs became more agitated when they were put on a scale for weighing (Holl *et al.*, 2010). In the late 1980s, when lean hybrid pigs were first introduced, the author observed an increase in problems with tail biting and excitability. These pigs had been bred for three traits – rapid weight gain, large loin size, and leanness (low fat). Observations at the abattoir clearly showed that they were more excitable than other pigs. When I shook the pen gate, the new hybrids squealed and jumped. A pen of an older genetic line of Yorkshire-type pigs did not even get up when the gate was rattled. The difference in temperament was obvious when pigs from different genetic lines were beside each other in adjacent lairage pens.

Sudden Novelty Separates Genetic Factors from Previous Handling Experiences

One study showed that the single most effective test for differentiating different genetic lines of pigs was a sudden stomping of a boot (Lawrence *et al.*, 1991). Le Neindre *et al.* (1996) discussed problems associated with taking breeds that had been developed for an intensive system and putting them out on an extensive range. For example, a bull can produce daughters that are gentle in an intensive system where they are raised in continuous contact with people. When these cattle were raised away from people on the range, they were more likely to attack people. The author observed that these problems are most likely to occur in excitable, flighty cattle that become highly agitated when suddenly confronted with novelty. Some genetic lines of Saler cattle are calm and easy to handle when they are with familiar people, but they panic, kick and charge people when confronted with the noise and novelty of either an auction or slaughter plant. These problems are most likely to occur in high-fear breeds such as the Saler. Younger animals may be more strongly affected by sudden novel experiences because they have had fewer life experiences.

Environmental Enrichment Reduces Startle Response

Hens that lived in an enriched environment that had perches and substrates for dust bathing had a weaker startle response to a sudden xenon flash compared to hens housed in a more barren environment (Ross *et al.*, 2018). Grandin (1989a) also found that enriching a pig's environment reduced the tendency to startle. In horses, older animals had less heart rate response to a balloon suddenly inflating (Baragli *et al.*, 2014). Reactions to sudden novelty will be stronger in animals with a flighty (fearful) temperament (Grandin and Deesing, 2014). It appears that long-term living in a varied stimulating and non-threatening environment will reduce an animal's reactivity to a sudden novel startling event. Possibly this long-term experience down-regulates the nervous system. Short-term positive associations with a particular place do not reduce the startle response. Training hens to enter a chamber with reward conditioning failed to reduce their startle response to a novel xenon flash (Ross *et al.*, 2018).

Some animals are more excitable and have a higher startle response when they are suddenly introduced into a new and novel environment (Grandin and Shivley, 2015; Grandin, 1997). Deiss *et al.* (2009) and Bourquet *et al.* (2010, 2015) conducted studies with cattle and sheep that showed that the novelty of the new environment at a slaughter plant caused greater stress in the animals that were more excitable when their temperament was tested on the farm. Agitation in these animals during handling is caused by fear. There were definite breed differences in their responses (Bourquet *et al.*, 2010).

Animal Memories are Specific

Animal memories of previous experiences are very specific. If a horse becomes habituated to a blue-and-white umbrella, that learning will not transfer to an orange tarp (canvas) (Leiner and Fendt, 2011). Taming ewes to people did not generalize to other procedures, such as handling, shearing or movement through a race (Mateo *et al.*, 1991). If an experience that an animal has in the future is similar to a previous experience, the animal may be able to generalize. This could reduce stress during future handling.

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An animal is a sensory-based thinker. Memories are stored as pictures, sounds or other sensory impressions (Grandin and Johnson, 2005). If animals are exposed to novel things that they may see in the future, they are less likely to become fearful. Lewis *et al.* (2008) found that stress caused by a novel loading ramp could be reduced by training the pigs to go through it. Cockram (1990) found that previous experiences of going through an auction market produced cattle that settled down more quickly at an abattoir.

Further studies with cattle showed that carefully acclimatizing cattle by moving them through yards and corrals reduced stress at the slaughter plant (Petherick *et al.*, 2009). The reaction of the animals indicates that their memories are sensory-based and stored as specific images or sounds (Grandin and Johnson, 2005). Cattle differentiate between a person on a horse and a person walking. Extensively reared cattle that have been handled exclusively on horseback may have only a 1 m flight zone, but when they first encounter a person walking at an auction or slaughter plant, their flight zone may expand to 10 m. This can be dangerous for a handler in a small pen because the animal may run wildly back and forth or attempt to jump the fence to get away from the person. The cattle perceive the man on foot as novel and frightening and the man on the horse as familiar and safe. Ideally, cattle should be acclimatized to being moved on foot before they arrive at markets and slaughter plants (Grandin and Deesing, 2014).

A similar problem can occur in pigs or cattle that are raised indoors. The animals differentiate between a person in the alley and a person walking through their pens. To produce calm animals that will be easy to load onto trucks and handle at their destination requires people walking through their pens during the entire fattening period. This will get the animals accustomed to moving quietly away when a person walks through them. Pigs that first experience a person in their pens on the day they are shipped are more likely to be difficult to handle. They may bunch together and squeal. Acclimatization to a person walking through them is especially important with more excitable genetic lines. In the USA, the large integrated pork companies have a standard procedure that instructs people to walk through the finishing (fattening pens) every day. This teaches the pigs to calmly move away from the walking person.

Novelty Is Both Attractive and Scary

The paradoxical aspect of novelty is that it is both frightening and attractive (Grandin and Deesing, 2014). A clipboard on the ground will attract cattle when they can voluntarily approach it, but they may balk and refuse to step over it if they are driven towards it. Cattle on a pasture will often approach novel objects that are left on the ground (Fig. 4.2). Even fish will seek out and approach a novel object, such as a stationary toy vehicle (Franks *et al.*, 2018). The tendency to be attracted



Fig. 4.2. This cow is attracted to a novel box that held camera equipment. Novelty is both scary and attractive. When the wind moved the tag, the cows jumped back and then they slowly reapproached. In this situation, the emotional systems of both the SEEK trait and FEAR may be alternating. (Photo: Courtesy of Temple Grandin)

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to non-threatening novelty may be a trait in all animals. A prey species may be wary of novelty because novelty can mean danger. For example, nyala (antelope) in a zoo have little fear of people standing by their fence, but the novelty of people suddenly appearing on their barn roof provoked an intensive flight reaction (Grandin *et al*., 1995b; Philips *et al*., 1998). Small objects that do not move may be attractive to antelopes at the zoo. A small stationary snowman built in their yard elicited cautious curiosity according to zookeepers who worked with them. Large novel moving objects were more likely to provoke a flight reaction.

Studies by Stephens and Toner (1975) and Dantzer and Mormède (1983) both reported that sudden novelty is a strong stressor. Putting a calf in an unfamiliar place is probably stressful (Johnston and Buckland, 1976). In tame beef cattle, throwing a novel-coloured ball into the pen caused a crouch-flinch reaction in 50% of the animals (Miller *et al*., 1986). Ried and Mills (1962) were the first researchers to suggest that sheep could be trained to accept some irregularities in management, to reduce violent reactions to novelty. Exposing animals to reasonable levels of music or miscellaneous sounds will reduce fear reactions to sudden, unexpected noises. When a radio is placed in a pig barn, pigs have a milder reaction to a sudden noise such as a door slamming. Playing instrumental music or miscellaneous sounds to 75 decibels improved weight gain in sheep (Ames, 1974). Louder sound reduced weight gain. Zebu cattle reared in the Philippines are exposed to so much novelty that new experiences seldom alarm them. Halter-broken Zebu cows and their newborn calves are moved every day to new grazing locations along busy roads full of buses and cars.

Beneficial Effects of Calm Livestock Handling and Transport

There is an old saying, 'You can tell what kind of a stockman a person is by looking at his cattle.' Many cattlemen and cattlewomen believe that early handling experiences have long-lasting effects (Hassall, 1974). Cattle with previous experience of gentle handling will be calmer and easier to handle in the future than cattle that have been handled roughly (Grandin, 1981). Calves and cattle accustomed to gentle handling at the ranch of origin had fewer injuries at livestock markets because they had become accustomed to handling procedures (Wythes and Shorthouse, 1984). Nelore cattle that were calmly handled were less reactive during handling in the future than cattle handled with yelling, electric prods and sticks (Tirloni *et al*., 2013). Lima *et al*. (2018) and Bauer *et al*. (2012) both reported that improving cattle handling reduced cortisol levels. The improved treatment was NO yelling, NO dogs, and NO electric prods.

Benefits of Acclimatization to Calm, Careful Handling

Rough handling can be very stressful. In a review of many different studies, Grandin (1997) found that cortisol levels were two-thirds higher in animals subjected to rough treatment. Petherick *et al*. (2009) reported that cattle that were handled carefully, with good handling methods, had lower cortisol levels. Heifer calves carefully acclimatized by walking them through handling facilities and races had improved reproductive performance and lower cortisol levels when handled in the future (Cooke *et al*., 2009, 2012). It is important to acclimatize young heifers. Acclimatization is much less effective on older mature cows. Further experiments by Francisco *et al*. (2012) showed that acclimatizing Angus and Hereford cross calves to handling at the ranch resulted in lower cortisol and calmer temperament scores at the ranch. However, when these animals went to a feedlot, their weight gains were lower and cortisol levels were higher than those of control animals. A possible explanation for this disturbing finding is that the acclimatized cattle may have been handled more roughly at the feedlot because they would have been calmer and may have moved more slowly. Another possibility is that the acclimatized cattle may have reacted more strongly to the novelty of being mixed with wild cattle. Rough handling and sorting in poorly designed facilities results in much greater increases in heart rate than handling in well-designed facilities (Stermer *et al*., 1981).

Use Feed Rewards to Facilitate Repeated Restraint and Handling

When animals are acclimatized by being moved through handling systems multiple times, they must be rewarded with feed. This is especially important for tame cattle that have had years of selection for a calm temperament. Hutson (1985) found that barley feed rewards were effective for sheep.

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Ceballos and Weary (2002) have also documented the beneficial effect of feeding small amounts of grain in the milking centre. Dairy heifers with an excitable temperament failed to acclimatize to practice runs through the milking parlour that had no food reward (Sunderland and Huddart, 2012). The heifers with the calmer temperament did acclimatize. One must remember that Holsteins as a breed are much calmer than Nelore or Angus. An excitable Holstein would probably be similar to the calmest Angus. Ranchers in Kansas have reported that Angus and other *Bos taurus* cattle that have undergone intensive selection for a calm temperament have become reluctant to put their heads in the headgate. To encourage them, feed rewards specifically associated with the headgate should be used. After they have been locked in the headgate, they should be immediately rewarded with a small handful of feed. Use feed that is a special treat, not their regular hay.

In the 1970s, it was a common practice to feed dairy cows grain in the milking centre. This practice was phased out to save money. This may have been a big mistake. In Brazil, Nelore cattle are restrained in the headgate up to eight times for oestrus synchronization. Ranchers have reported that after the fifth time through the chute, they start balking and refusing. There is a point where acclimatization alone will stop working and feed rewards must be used. Mateus Paranhos de Costa, a cattle-handling specialist in Brazil, is now handling Nelore cows in 25 head groups. Feed rewards are given after they exit from the squeeze chute. Sheep can be easily trained to line up at the entrance gate to a tilt table to get feed rewards (Grandin, 1989b). They were willing to do this multiple times in a row.

Previous Experience Reduces Transport and Handling Stress

Cattle can also be acclimatized to being transported as a method to reduce stress. Angus steers were more behaviourally agitated and had higher heart rates and glucose levels during their initial trip compared to their ninth trip (Stockman *et al*., 2011). Schwartzkopf-Genswein *et al*. (2007) found that beef cattle that had previous experiences with being transported had lower cortisol levels when they arrived at a feedlot. Training calves to loading procedures is also beneficial. Five training sessions made calves easier to load with less balking, and their heart rates were lower than controls (Fukasawa, 2012). Sheep that were transported were more stressed during their first trip compared to their seventh trip (Wickham *et al*., 2012). There is an interaction with temperament. Brahman cows with high temperament scores (more excitable) have a greater cortisol response before being transported (Price *et al*., 2015). Body temperature and glucose decreased with repeated transport.

Animals will adapt to repeated non-painful procedures, such as moving through a race or having blood samples taken through an indwelling catheter when held in a familiar tie stall (Alam and Dobson, 1986; Fell and Shutt, 1986). Peischel *et al*. (1980) reported that daily weighing of extensively raised beef calves did not affect weight gain. Acclimatizing heifers with four handling sessions through the races (chute), spaced a week apart, had no effect on weight gain on the home ranch (Cooke *et al*., 2012), but when heifers had to walk almost 2 km to be handled, weight grain was lowered (Cooke *et al*., 2009). Ferguson *et al*. (2013) found that crossbred Longhorn calves could be acclimatized to being used for cowboy roping events.

Calves on an experiment station where they were petted by visitors had significantly lower cortisol levels after restraint and handling than calves that had had less contact with people (Boandle *et al*., 1989). Piglets that are handled early in life are less fearful of a novel environment (Oliveira *et al*., 2015).

Binstead (1977), Fordyce *et al*. (1985), Fordyce (1987) and Roche (1988) reported that training young *Bos indicus* heifer calves produced calmer adult animals that were easier to handle. Training of weaner calves involves walking quietly among them in the corrals, working them through races and teaching them to follow a lead horseman (Fordyce, 1987). These procedures are carried out over a period of ten days. Becker and Lobato (1997) also found that ten sessions of gentle handling in a race made Zebu crossbred calves calmer and less likely to attempt to escape or charge a person in a small pen. Training bongo antelope with food rewards to voluntarily co-operate with injections and blood sampling resulted in very low cortisol levels that were almost at baseline (Phillips *et al*., 1998). Ceballos *et al*. (2016) reported that cattle that are frequently moved for rotational grazing had calmer temperament scores.

All training procedures must be done gently. Burrows and Dillon (1997) suggest that training may provide the greatest benefit for cattle with an excitable temperament. There are great individual

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differences in how animals react to handling and restraint. A mother animal's previous experiences can have a beneficial effect on its offspring's reaction to a novel object. Mares which were habituated to novel moving objects before foaling trained their foals to be less afraid of new things (Christensen, 2016).

Introduce New Things in Small Increments to Flighty Wildlife

If the animal has an extremely flighty temperament, each new step of the procedure must be introduced more gradually. When nyala antelope were trained, it took ten days to slowly habituate them to a sliding door opening (Grandin *et al*., 1995b). Bongo antelope trained to stand quietly in a box for blood sampling had almost baseline levels of cortisol (Phillips *et al*. 1998). To prevent a catastrophic flight reaction, introduction of something new, such as a moving sliding door, was immediately stopped when the animal oriented towards the stimulus. When the animal orients, the brain makes a decision to either keep watching or have a big fear reaction.

Animals Will Not Habituate to Extremely Painful or Frightening Experiences

Cattle will not readily adapt to severe procedures that cause pain or to a series of rapidly repeated procedures where the animal does not have sufficient time to calm down between the procedures. Fell and Shutt (1986) found that cortisol levels did not decrease after repeated trips in a truck in which some animals had fallen down and lost their footing. Tame animals are likely to have a milder reaction to an aversive procedure than wild ones.

If an experience is really painful, animals will not habituate to it (Fell and Shutt, 1986). The author observed that cattle that had too many students practise palpating them absolutely refused to enter the cattle-handling facility. Dairy cows were more reluctant to enter a hoof-trimming restrainer compared to the milking parlour (Lindahl *et al*., 2016). They refused to enter the single-file chute that led to the hoof-trimming restrainer. Sometimes refusal to enter will happen further back in the handling system (Pollard *et al*., 1992). Cattle that have been bitten by dogs in the single-file race may run fast through the race in an attempt to avoid bites. This may be more likely to occur in animals with more fearful genetics. These studies show that there are several different ways that an animal may attempt to avoid an aversive experience. It may either refuse to enter a handling facility or run quickly through it.

Reactions to Highly Aversive Events

The use of highly aversive methods of restraint, such as electro-immobilization, is not recommended (Lambooy, 1985). An electronic immobilizer restrains an animal by tetanizing the muscles with electricity. There is no analgesic or anaesthetic effect (Lambooy, 1985). Application of the immobilizer to the author's arm felt like a disagreeable electric shock. Cows that had been immobilized had elevated heart rates six months later when they approached the chute where they had received the shock (Pascoe, 1986). Piglets that had been treated positivity by a handler were more likely to touch the handler than those that were handled roughly. These effects lasted for five weeks (Brajon *et al*., 2015).

A choice test in a Y-shaped race indicated that sheep preferred the tilt-squeeze table to electro-immobilization. After one or two experiences, sheep avoided the race that led to the immobilizer (Grandin *et al*., 1986). When a choice test is used to test the aversiveness of restraint methods, naïve animals that have never been in the testing facility should be used. New cattle should be used for each test. Cattle that have developed a strong preference for one of the races would often refuse to switch races to avoid mildly aversive treatment, such as being gently restrained in a squeeze chute (Grandin *et al*., 1994). Initially, they quickly learned to avoid the aversive side, but they often refused to switch when a mildly aversive treatment was switched to the other side. When the treatments were switched, the animal's brain registered the switch because the amount of looking back and forth at the decision point increases. However, cattle that had been accidentally struck on the head by the headgate were more likely to avoid the squeeze chute in the choice test (Grandin, 1993).

From a species survival standpoint, it makes sense to continue using a previously learned safe path even if something mildly aversive happens, such as being restrained gently by the headgate. However, when something severely aversive happens, such as being struck on the head or electrically immobilized, the animal would immediately switch paths to avoid a painful experience. Deer show a similar reluctance to change. After eight training sessions with no aversive treatment, deer still quickly entered a race after the first aversive treatment (Pollard *et al*., 1992).

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Cattle and Sheep Have Excellent Memories

Cattle will learn to differentiate between a head stanchion that strikes them on the head and a scale that causes no discomfort. Cattle that were handled five times became progressively more willing to enter a single-animal scale and somewhat less willing to enter a squeeze chute (Grandin, 1993). Many of the animals that refused to enter the squeeze chute entered the squeeze section willingly, but then refused to place their heads in the head stanchion. They had learned that pressure on the body does not cause discomfort, but that the head stanchion hurts when it slams shut. Cattle were also more likely to become agitated in the squeeze chute. Two per cent of the animals became agitated on the scale but 13% became agitated in the squeeze. Hutson (1980) found that sheep remembered aversive handling for a year.

Research by Virginia Littlefield in the author's laboratory has shown that *Bos taurus* cattle will habituate to repeated daily restraint in a squeeze chute if they are handled gently. The animals balked less on each successive day and became less and less agitated in the chute. However, they became harder and harder to drive into a squeeze chute if electric prods were used (Goonewardene *et al*., 1999). Animals can easily learn to stay away from something painful or frightening. Cows with GPS electronic collars quickly learned to stay away from a virtual fence when they heard a warning sound (Campbell *et al*., 2017). Pigs and sheep were less likely to be startled by a sudden novel stimulus if they got a warning tone first (Boissey and Lee, 2014). A warning tone enables the animal to learn when it is safe and when it is not. These same principles work with standard electric fencing. The animal can either see the fence or hear the fence charger and then learn to stay away.

Avoidance of Giving Human Emotions to Animals

In studies done by agricultural animal scientists, veterinarians and developmental biologists, the word 'temperament' is preferred (Mackay and Haskell, 2015). The biologists and the psychologists will use the word 'personality' in their papers (Mackay and Haskell, 2015). Rauw *et al*. (2017) states that an animal's coping style 'should not be equated with personality'. The authors of this paper specifically avoid equating human and animal emotions. Neither one of these extensive review articles cited the work of Panksepp on emotional systems (Panksepp, 2011). The author proposes that acknowledging some similarity between animal and human emotion will help sort out confusing results in the scientific literature.

Fear Is Not the Only Temperament Trait

Many of the studies discussed in this chapter were based on an animal's reaction to either fear or pain. Fear is only one temperament trait. Variable results from different studies may be due to mixing up fear with other temperament traits such as anger or separation stress. The most common mistake is mixing up fear-based behaviour with true aggression. There is a need for more research on temperament traits that may be unrelated to either chute score or exit speed (Haskell *et al*., 2014). In pigs, researchers have also found that different behaviour tests measure different traits (Scheffler *et al*., 2014). The author hypothesizes that these other traits may become more obvious in cattle that have been bred for lower fearfulness.

Confusing results from different temperament studies may be able to be sorted out by using the framework of the Panksepp emotional systems (Panksepp, 2011). Panksepp was not cited in any of the previously discussed livestock studies because his papers were published in neuroscience literature. The emotional systems are:

FEAR – motivates animals to avoid danger
RAGE – aggression-anger
PANIC – separation distress – isolation of a single animal or separation of the mother and baby
SEEK – exploration trait – novelty-seeking
SEX – reproduction
NURTURE – mother–young behaviour such as licking the calf
PLAY

Fear

Neuroscientists have been using the word 'fear' since the 1950s. The amygdala is the brain's fear centre. Stimulation of the amygdala elicits both behavioural and physiological responses of fear in animals (Redgate and Faringer, 1973; Davis, 1992). When an electrode is used to stimulate the amygdala in a person, there are feelings of fear (Chapman

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et al., 1954; Gloor *et al*., 1981). If the amygdala is completely destroyed it will cause wild rats to have tame behaviour (Kemble *et al*., 1984). Destroying the amygdala will prevent an animal from learning to fear a new stimulus that startles it (Antoniadis *et al*., 2007; Scheonbaum and Setlow, 2003). However, its destruction does not eliminate a previously learned fear response. This information has been in the neuroscience literature for decades. One of the first introductions of the neuroscience fear literature to animal scientists was in Grandin (1997).

A fearful animal can either flee, fight or freeze. Fear-motivated reactions can be behaviourally different (Franceschi *et al*., 2016). Some animals freeze when they get scared and others will fight or flee. Severely stressed Brahman or Nelore cattle in a single-file chute may become immobile and lay down (Fraser, 1960; Grandin, 1980; Fraser and Broom, 1990). This can confound assessing temperament with a chute score. *Bos taurus* cattle are less likely to do this. The author has observed Saler cattle that became so frightened when they fell down that they had difficulty getting up. This was due to frenzied thrashing.

Other Temperament Traits

The literature where fear was the main temperament trait has already been reviewed.

Rage

There were two papers that clearly showed that when a cow defends her calf, it is a trait that is separate from fear. Both exit speed score and hair whorl position had no effect on a cow's protective behaviour towards her calf (Turner *et al*., 2013; Perez-Torres *et al*., 2014). Defensiveness, which was measured as the cow's aggression behaviour when her calf was handled, was not related to exit speed score or chute score. Turner *et al*. (2013) conclude that temperament and defensiveness are independent traits. In dairy cows, stepping during milking-machine attachment and kicking the person during milking may be separate traits. Hedlund and Lovlie (2015) found that a variety of behavioural tests had consistent effects on milk yield.

Panic/separation distress

Separation distress is a separate trait from fear. It is controlled by a separate brain system (Panksepp, 2011). Separating a mother and offspring or separating an animal from its social group can trigger panic (Herman and Panksepp, 1978). Faure and Mills (2014) and Mills and Faure's (1991) research with quail showed that separation distress and fear are truly independent. They bred separate genetic lines of high fear and low fear and high separation and low separation. They used the term 'social reinstatement' for separation distress. There are many studies on isolation from herd mates. Sheep will vocalize loudly when they are isolated (Hazard *et al*., 2016). Sheep breed had an effect on both the intensity of the reaction to isolation and the number of vocalizations (Boissey *et al*., 2005; Wolf *et al*., 2008; Barnhard *et al*., 2015). Sheep seldom vocalize when they are hurt.

Reactions to being socially isolated in sheep have a stronger genetic basis than flight distance or willingness to approach a person (Hazard *et al*., 2016). A sheep's reaction to isolation is stronger compared to cattle. In the wild, isolated sheep got eaten by predators. Learning has a bigger effect on traits such as flight distance. In tame sheep, isolation was more stressful than shearing and restraint (Fazio *et al*., 2016). A common mistake in the sheep literature is to confuse separation distress with fear.

There are differences in vocalization between individual cows when their newborn calf is threatened. Some mothers will call their calf and others will not (Florcke *et al*., 2012). If the cow and calf can touch each other, vocalization is reduced (Johnsen *et al*., 2015). Separation distress is controlled by the oxytocin system. When the oxytocin systems in the brain are impaired, mice were more likely to abandon their pups (Rich *et al*., 2014).

Some animals are more independent than others and seek less social contact. Stephenson and Bailey (2017) used GPS trackers to determine that some grazing cows are more independent. Reser (2014) wrote a fascinating article that solitary mammals that seek less social contact with their own kind may be a model for autism. The more solitary animals, such as panthers or tigers, may have diminished oxytocin compared to more social animals such as lions. People with autism are less social. Von Holdt *et al*. (2017) have discovered a genetic link between friendliness in dogs and William's Syndrome in people. Humans have bred dogs to be more social compared to wolves.

Seek – exploration – novelty-seeking

The motivation to explore the environment is driven by the dopamine system. Pharmacological

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manipulation of a monkey's dopamine system will increase approach to novel new things (Costa *et al*., 2014). In pigs, measurement of fear by restraining a pig on its back did not reduce exploration (Spake *et al*., 2012). In an earlier part of this chapter, the author discussed the specificity of animal memory. It is likely that exploration would have been reduced if the restraint test had been conducted in the same place where the pigs were allowed to explore. Experiments with rats clearly show that animals can be selected for either high or low novelty-seeking (Cuenya *et al*., 2013).

SEEK trait may change cattle grazing patterns

Tracking of beef cows with GPS units indicated that some cows have a 'go-getter' grazing pattern and others are 'laid back' (Goodman *et al*., 2016). The go-getters would go out and eat more pasture, and the laid back animals preferred to lie near the water. There are individual differences in which heifers will be the leaders of group movements during grazing (Dumont *et al*., 2005). In water buffalo, the distance walked on pasture was measured with GPS units. The distance the cows walked was not related to behavioural reactivity during milking (Carvahal *et al*., 2017). Cows that were more reactive gave less milk (Carvalhal *et al*., 2017). Walking distance and behaviour during milking appear to be separate traits. Maybe this is due to fear-induced inhibition of the SEEK trait. Buiji *et al*. (2018) found that chickens have differences in how far they will range away from the coop. New experiences may also reduce expression of the SEEK trait. Bailey *et al*. (2010) found that Brangus cows that had lived in the region for at least three years grazed pasture further from the water source than cows that had recently been brought in.

Some cattle prefer to graze on the low flatlands and others prefer hills (Bailey, 2004; Bailey *et al*., 2004, 2005). Terrain preference may be inherited. Within a breed of cattle, the sire had a significant effect on terrain preference. Breeds developed in the mountains tend to prefer grazing on the hills, but there is also a lot of variation within a breed. Cows sired by Piedmontese bulls, a breed developed in the mountains, preferred steeper rougher terrain than cows sired by Angus bulls, a breed originating from the lowlands (VanWagoner *et al*., 2006). Keeping animals in the right grazing location will be easier if the animal has a preference for the type of terrain you want them to stay on. To determine the terrain preference for a cow, check her location at 7 o'clock in the morning (Bailey *et al*., 2004). Further research has confirmed that a cow's preference for either flatlands or hills is inherited (Bailey *et al*., 2015). Genomic analysis indicated that a gene associated with motivation, locomotion and spatial memory accounted for 24% of the variation in preference for sloped versus flat terrain (Bailey *et al*., 2015). Ranchers report that cattle can learn to become lazy when feed is always brought to them. Some animals may become lazier than others. Both genetics and learning will affect their behaviour.

Bucking bulls – FEAR or SEEK?

Rodeo bulls from a reputable stock contractor can become habituated to being handled. Seventy per cent appeared to be calm and made no attempt of aggression or escape while held in the chutes (Goldhawk *et al*., 2016). Thirty per cent of the bulls did have some distress behaviour such as rearing. None of the behaviours in the chute were associated with bucking performance. The question that might be asked is: Does SEEK get turned on for some bulls?

Early Environment Affects Exploratory Behaviour

Pigs raised in a barren pen with a plastic floor were compared to littermates reared in a straw-filled pen that had many enrichment objects and positive contact with people. The pigs in barren pens startled more easily (Grandin, 1989a). Initially, they were afraid of new things such as a water hose, but after several pen cleanings, they actively sought the hose. They bit the water stream and appeared to be seeking stimulation (Grandin, 1989a). Animals that are exposed to many new things may be less afraid to explore something new.

Pigs that were handled early in life were more likely to engage in exploratory behaviour (Zupan *et al*., 2016). Piglets that were handled gently by people were less fearful when they were put in a human approach test (de Oliveira *et al*., 2015). Similar results were found in sheep. Lambs that had daily gentle contact with people were less behaviourally reactive and the physiological indicators of stress were lower (Pascal-Alonso *et al*., 2015).

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SEEK and FEAR Alternate

There is a neurological mechanism in the brain that can switch back and forth between fear and seek (Reynolds and Berridge, 2008). When a metal box was put in the middle of a field, Angus cows approached it. When the tag on it blew in the wind, they backed away (Fig. 4.2). When the tag stopped moving, they approached it again. There is a hilarious video online of cattle reacting to a remote-controlled model car. At first they ran away from it and then they started to chase it. When the car stood still, they all approached it and when it moved slightly, the cattle jumped away.

Nurture

The trait of a mother animal licking her young is separate from the trait of defensive aggression when a cow attacks a person. Turner *et al*. (2013) assessed beef cows for exit speed score, chute score, isolation and aggression towards humans and mother–young behaviour. The two tests of exit (flight) speed score and chute score were not related to the tendency to attack people. None of these three traits was related to maternal care of her calf (Turner *et al*., 2013). Allowing a calf to nurse is not related to the trait of attacking people who get near the calf. Brown *et al*. (2015) found that flight score had little relationship with maternal behaviour traits. These studies show that fearfulness as measured by exit (flight speed) is a separate trait from maternal traits.

Purebred Brahman cattle are more flighty but they may be higher in the nurture trait. Purebred Brahman that have been treated well will seek out people for stroking. In Australia, tame coacher cattle are used for acclimatizing newly arrived cattle. On one property, the Brahman coacher came up to seek (Fig. 4.3).



Fig. 4.3. Purebred Brahman (*Bos indicus*) that have been treated gently by people will often approach for stroking. English/continental cattle are usually less motivated to do this. (Photo: Courtesy of Temple Grandin)

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A Look at Common Livestock Temperament Measurements in the Framework of Panksepp Emotional Systems

Tests of fearfulness

Sudden exposure of an animal to novelty, exit speed tests and startle tests would measure reactivity, which is related to fear. Cattle that exit quickly from the squeeze chute (Exit Speed Velocity Score) have higher physiological measures of stress and poorer weight gain (Curley *et al*., 2006; King *et al*., 2005). It can be measured either electronically or with walk-trot-canter scoring (Burrows and Dillon, 1997; Vetters *et al*., 2013). Parham (2018) developed an exit scoring system where observers pick one of the following words to describe the animal's behaviour when it leaves the squeeze chute. The words are calmly, promptly, briskly, wildly or frantically. This method had high inter-observer reliability and it correlated well with physiological tests. This study was conducted with native English speakers who had a nuanced understanding of the meaning of the five words.

Chute (crush) score tests, which assess how agitated an animal becomes during restraint, would also assess fearfulness. Struggling and agitation in the squeeze chute or single animal scale can be scored with either a visual scoring system, strain gauges, accelerometers or fluctuations in weight readings from load cells (Voisinet *et al*., 1997; Grandin, 1993; Bruno *et al*., 2016). There are a number of different visual scoring systems. Below is a simple scoring system for use in headgates, or single animal scales. It works best when the restrained animal is not held really tightly. It is less accurate when the animal is held very tightly in a hydraulic squeeze chute.

1. Stands still.
2. Intermittent movement.
3. Continuous struggling.
4. Highly agitated, attempting to escape.

Chute scores may have inconsistent results in *Bos indicus* cattle. These cattle sometimes freeze and lie down instead of actually struggling (Fraser, 1960; Grandin, 1980). Research with pigs has shown that some animals run away during handling and others will freeze (Krause *et al*., 2017). The autonomic nervous system reacts differently depending on the pigs behavioural reaction. Chute scores may be more affected by experience than exit speed. To separate learning from genetic effects, the most accurate scores would be assessed at a younger age (Wegenhoft *et al*., 2005). More recent studies show that chute scores and exit velocity may be measuring slightly different traits. Bruno *et al*. (2016) and Parham (2018) state that these scores should be treated as independent measures. The author hypothesizes that exit speed may be a purer measure of fear. Chute score may be measuring some anger mixed in with fear. The differences in chute score and exit speed scores started showing up in the newer studies. When my former student Bridget Voisinet did her original temperament study in the mid-90s, US cattle were much wilder. The cattle in the author's study (Grandin, 1993) were also very wild. Twenty years of temperament selection has reduced fearfulness, which may have allowed other emotional traits to become more evident. This may explain some of the divergence between chute scores and exit scores. Flight speed had higher heritability compared to chute score (Sant'Anna *et al*., 2015).

Crush/chute score may measure anger in cattle selected for extreme calmness

The author hypothesizes that exit speed score and crush/chute score both measured fear before temperament selection for calmness was started. Years of intensive temperament selection may have changed the trait that chute/crush score measured. Both the author's own observations and reports from ranchers indicate that Angus cattle selected for both calmness and low hair whorls exited the squeeze chute at a walk. Some of these cattle actively resisted being restrained and kicked at people. Ranchers called this 'pissed' behaviour.

At our experiment station, we had cattle that were obtained from a local feedlot for a nutrition trial. Every month they were held in the squeeze chute and weighed. There was one steer with odd behaviour. While standing in line in the single-file race, he used the back stop gate as a back scratcher to remove his winter coat. He had no flight zone and refused to go into the squeeze chute. The use of flight zone movement patterns failed to work. Unfortunately, an electric prod had to be used to get him to move. While held in the squeeze chute he snorted and jerked his head violently when his head was touched. Other cattle in the same group tolerated having their heads touched. He definitely had a higher chute/crush score than exit speed score.

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I know I should not be anthropomorphic and give cattle human emotions, but this steer was angry and he was saying swear words to you all. The question is: 'Are we starting to over-select for low-fear cattle?'.

Pen scoring

Pen scoring is used to determine the size of the flight zone and ease of handling. This test may measure a combination of traits such as fearfulness, PANIC separation, distress and aggression. There are many variations of this test and it may be less accurate assessing a particular emotional trait. The reaction of a person invading the animal's flight zone is assessed. In another type of pen scoring, an individual animal is assessed in a small pen (Littlejohn *et al*., 2016).

PANIC – separation distress tests

Some animals react more to isolation than others. Some of the behavioural variables measured in an isolation test are vocalizations, running, jumping and other agitated behaviour (Brown *et al*., 2015). Vocalization can be used to measure two different types of experiences. The effect of isolation and response to a painful stimulus are separate traits. Sheep will vocalize strongly when separated from other sheep (Hazard *et al*., 2016). Pen scoring of a single calf in a pen may measure response to isolation and separation distress.

Vocalization response to handling

Sheep will not vocalize when they are hurt. Cattle and pigs will bellow, moo or squeal in direct response to a painful event. Grandin (1998, 2001) found that 99% of cattle vocalizations that occurred during handling or restraint were associated with an obvious aversive event such as excessive pressure from a restraint device, electric prods, sharp edges or pinching. Electric prod use will increase vocalization (Hemsworth *et al*., 2011). Vocalization during handling of pigs is associated with physiological measures of stress (Warriss *et al*., 1994; Edwards *et al*., 2010a,b). It is also associated with electric prod use or jamming in a chute (Edwards *et al*., 2010a,b).

SEEK tests

Tracking of cattle-grazing behaviour with GPS units clearly measured the seek trait. The 'go-getter' cattle in Goodman *et al*. (2016) would be cattle with a high SEEK trait. Research with water buffalo also showed that distance travelled on pasture was a separate trait to behavioural reactivity during milking (Carvahal *et al*., 2017). Tests that assess exploration such as an open-field test may be compounded with other emotional traits such as separation distress (PANIC) or fear. In a typical open-field test, a single animal is placed in an arena and allowed to explore. It may also be tested for willingness to approach either a person or a novel object that is in the arena. Fearful animals such as rodents will hug the perimeter and an animal that is experiencing separation distress may vocalize.

Aggression and nurturing tests

It is likely that maternal traits consist of two emotional systems. They would be defending the baby from predators and nurturing it. The aggression trait of defence is a separate trait from nurturing care for the calf. Ranchers have reported that a cow may vigorously defend her calf and then fail to lick and nurture it.

Conclusions

Use of the Panksepp Seven Emotional Traits may help sort out some of the confusing results of temperament tests done on farm animals. Composite temperament scores, where the results of different measures of temperament are combined, may confound genomic analysis of temperament. Research where single temperament tests are analysed with genomics may be more valuable. Valente *et al*. (2016) found that six genes were related to flight speed (exit speed). Other papers with genomic analysis of combined temperament tests will probably provide confusing results. This would be due to different emotional systems being confused. This is due more to temperament than fear. In many studies, agitated behaviour in cattle is sometimes described as aggressive. It is likely that the traits of fear and aggression are being mixed up. When temperament testing was first started 20 years ago, fearfulness was probably the primary behaviour that cattle breeders selected against. When fearfulness was reduced, other traits that are separate from fear may have become more evident. Some cattle that have been selected for low fear may become reluctant to move through handling facilities and have become more difficult to drive. These animals should be rewarded

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with a tasty feed reward after they are restrained. Rauw *et al*. (2017) warns that animal welfare improves by breeding calmer animals but genetic modification to produce 'senseless, emotionless machines' may be morally problematic.

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Videos of Handling and Livestock

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Pony Pullar, *Handling Elk and Wapiti in New Zealand, February 12, 2014* – animals being easily moved by a skilled stockperson. The author has observed that handling elk in the excellent way shown in this video would have been difficult 30 years ago. Over the years, elk temperament has become calmer. https://www.youtube.com/watch?v=CHffnuf91TY

Cows Chasing a RC Around the Field – there are several different versions of this video, which shows Black Angus cattle chasing a toy remote-controlled car. New things are both scary and attractive. At first, cattle run from the car and then they start to follow it. https://www.youtube.com/watch?v=92Z8-JBb-90

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5 Behavioural Principles of Handling Beef Cattle and the Design of Corrals, Lairages, Races and Loading Ramps

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Summary

Beef cattle and other grazing animals have behaviour patterns during handling that are influenced by vision. A prey species animal has wide-angle vision that will detect rapid motion and possible danger. The eight basic behavioural patterns during handling in grazing animals are: (i) flight zone; (ii) turn and look at people who are outside their flight zone; (iii) point of balance that controls direction of movement; (iv) natural following the leader behaviour; (v) return to where they came from; (vi) soft bunching; (vii) milling when a predator attacks; and (viii) isolation alone can be highly stressful.

Good stock people understand the principle of pressure and release. When cattle move in the desired direction, the handler reduces pressure on the flight zone. Tame cattle can be led instead of being driven. This chapter also contains drawings of popular layouts for races, yards, lairages and corrals for handling cattle. There is also a list of common design mistakes that can cause balking and refusal to move through a handling system. Cattle will move more easily through a race if visual distractions are removed. Common distractions are: shadows, sunbeams, reflections from shiny vehicles, and seeing people up ahead. Covering the outer perimeter fence of a facility will help block distractions.

Introduction

Dylan Biggs, one of the founders of modern low-stress livestock handling, said, 'Every step of every animal should be voluntary' (Biggs, 2013). Bud Williams and Dylan Biggs started teaching low-stress handling methods in the USA in the late 1970s and 1980s. The first edition of this volume recognized Williams's innovative work (Grandin, 1993). More and more ranchers and feedlot managers have adopted calmer improved handling methods. Today many stockmanship classes are available. It is likely that these methods may be rediscoveries of the ways of the stockmen of bygone years. In the late 1800s, cowboys handled and trailed cattle quietly on the great cattle drives from Texas to Montana. In *A Cowboy's Diary*, Andy Adams wrote: 'Boys, the secret of trailing cattle is to never let your herd know that they are under restraint. Let everything that is done be done voluntarily by the cattle' (Adams, 1903). Unfortunately, the quiet methods of the early 1900s were forgotten and some of the more modern cowboys were rough (Wyman, 1946; Hough, 1958; Burri, 1968). There is an excellent review of the history of herding in Smith (1998).

Progressive producers of cattle know that reducing stress will improve both productivity and safety. Effective low-stress methods of handling cattle will take time to learn and people have to have a positive attitude (Smith, 2018).

Animals can remember both good and bad previous experiences. If they are treated well, they will be easier to handle in the future (see Chapters 1 and 4). Cattle poked with electric prods will be harder to move through a handling facility in the future

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(Goonewardene *et al*., 1999). A sudden novel event can frighten cattle. In the 1800s and 1900s, stampedes were often caused by a horse with a saddle under its belly, or a flapping raincoat (Harger, 1928; Linford, 1977). Stampedes were more likely to occur at night (Ward, 1958).

Perception of Grazing Livestock

Vision

To assist in the avoidance of predation, cattle and other grazing ungulates have wide-angle (360°) panoramic vision (Prince, 1977), and vision has dominance over hearing (Uetake and Kudo, 1994). Bovines can discriminate colours (Thines and Soffie, 1977; Darbrowska *et al*., 1981; Gilbert and Arave, 1986; Arave, 1996). Cattle, sheep and goats are all dichromats (only two of the three primary colours can be discerned), with cones that are more sensitive to yellowish green (wavelength 552–555 nm) and blue-purple light (444–455 nm) (Jacobs *et al*., 1998). The horse is most sensitive to light at wavelengths of 539 nm and 428 nm (Carroll *et al*., 2001). Dichromatic vision may provide better vision at night and aid in detecting motion (Miller and Murphy, 1995). The visual acuity of bulls may be worse than that of younger cattle or sheep (Rehkamper and Gorlach, 1998).

Grazing livestock can see depth (Lemmon and Patterson, 1964), but they may have to stop and put their heads down to perceive it. This may explain why they balk at shadows on the ground. Observations by Smith (1998) indicate that cattle do not perceive objects that are overhead unless they move. Research with horses and sheep indicates that they have a horizontal band of sensitive retina, instead of a central fovea as in the human (Saslow, 1999; Shinozaki *et al*., 2010). This enables them to scan their surroundings while grazing. Grazing cattle have a visual system that is very sensitive to motion and contrasts of light and dark. They are able to scan the horizon constantly while grazing and they may have difficulty in quickly focusing on nearby objects, owing to weak eye muscles (Coulter and Schmidt, 1993). This may explain why grazing animals spook at nearby objects that suddenly move.

Wild ungulates, domestic cattle and horses respect a solid fence and will seldom ram or try to run through a solid barrier. Sheets of opaque plastic can be used to corral wild ungulates (Fowler, 1995), and portable corrals constructed from canvas have been used to capture wild horses (Wyman, 1946; Amaral, 1977). Excited cattle will often run into a cable or chain-link fence because they cannot see it. A 30 cm wide, solid, belly rail installed at eye height, or ribbons attached to the fence, will enable the animal to see the fence and prevent fence ramming (Ward, 1958).

Remove Visual Distractions from Handling Facilities

Visual distractions that cause animals to back up or refuse to move must either be removed from a handling facility or blocked by solid walls. Vehicles parked alongside a fence often cause problems. Some of the most common distractions are dangling chains, reflections on shiny metal or a wet floor, drain gratings, shadows, moving people, vehicles and flapping objects (Lynch and Alexander, 1973; Grandin, 1980a, 1987, 1989, 1990a,b, 2015; Grandin and Deesing, 2008). To locate visual distractions, people need to get into the race and look at it from the point of view of the bovine eye. Cattle will often stop and balk at shadows and high contrast. Highway departments found they could stop cattle from crossing the paved road by painting stripes on it (*Western Livestock Journal*, 1973). The animals may also stop if the flooring surface changes. Some examples are moving from dirt to concrete or from concrete flooring to a metal floor. If the visual distraction cannot be removed, the lead animal must be allowed to stop and look at it. If livestock stop at a drain grate, or a change in flooring, the lead animal will often stop and lower its head to look at it. The handler should wait for the lead animal to raise its head back up before attempting to move the group forward. If they are rushed towards, they may either balk and refuse to move or turn back.

Livestock Attracted to Light

Research conducted by Joe Stookey at the University of Saskatchewan showed that when cattle were given a choice, they preferred to move into a chute where they could see light. Fig. 5.1 shows a Y-shaped chute that was used to test this principle. Adding a lamp to illuminate a dark race entrance would significantly improve both cattle and pig movement (Van Putten and Elshof, 1978; Grandin, 1982, 2001). Ranchers have found that illuminating the inside of a truck or trailer will attract animals into it when they are loaded at night. It is often difficult

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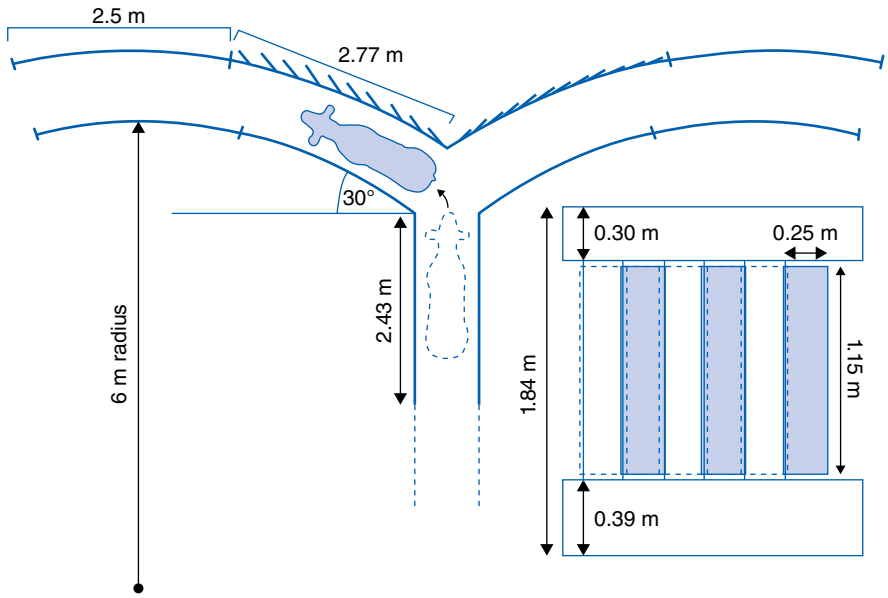


Fig. 5.1. Diagram of a Y-maze used to test preference for either a lighted or a darker single-file race. Opening or closing the louvres either illuminated or darkened either the right-hand or the left-hand side. Twenty-four out of 27 cattle exited via the arms with the open louvres, which enabled the cattle to see light ($p<0.001$). (From Stookey and Watts, 2014)

to get animals that are outside in bright sunlight to enter a dark building. They will enter more easily if they can see daylight through it. Another alternative is equipping it with translucent white plastic skylights to let in lots of diffuse shadow-free natural daylight. Even though cattle and other livestock are attracted towards a more brightly illuminated area (Grandin 1980a,b), they will not move towards a blinding rising or setting sun. To solve this problem, either change the time of day the cattle are handled or avoid facing races and chutes towards the sun.

Hearing

Grazing ungulates are sensitive to high-frequency sounds. The human ear is more sensitive at 1000–3000 Hz, but cattle are most sensitive to 8000 Hz (Ames, 1974; Heffner and Heffner, 1983). Cattle, horses and alpalcas can easily hear sounds of up to 10,000 Hz frequency (Algers, 1984). Heffner and Heffner (1992, 1983) and Heffner *et al.* (2014) found that cattle, alpacas, goats and other grazing animals have a poor ability to localize high-frequency sound. This may be related to their wide-angle vision (Heffner *et al.*, 2014). Ears that move assist cattle and other mammals to determine the location of a sound (Heffner and Heffner, 2018). This is due to a trait in prey species animals with wide-angle vision (Heffner *et al.*, 2014). Cattle and horses will 'watch' people and other animals with their ears (Grandin and Deesing, 2008); they will point each ear independently at two different people or animals. Noise is stressful to grazing animals (Pajor *et al.*, 2003). The sounds of people yelling or whistling is more stressful to cattle than the sounds of gates banging (Waynert *et al.*, 1999).

Never Yell at Cattle

Cattle are able to differentiate between the threatening sound of a person yelling at them and machinery noise that is not directed at them. When people yell at livestock, it has emotional intent. The animals know that yelling is directed at them. Shouting close to the ear of a cow may be as aversive as an electric prod (Pajor *et al.*, 2003). Yelling at cattle raised cortisol, but normal talking had no effect (Hemsworth *et al.*, 2011). Cattle may be able to habituate to steady machinery sounds that are not directed at them. Commercial manual squeeze chutes are noisy and can reach levels of 99–115 dB (Lyvers, 2013), but heart rate habituated when loud

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recorded sounds of the squeeze chute were played over several trials. Movement of the cattle in the squeeze chute increased at a noise level of 100 dB (Lyvers, 2013). Loud sounds over 85 dB increased heart rate more than sounds at 65 dB (Johns *et al.*, 2017). Subjecting cattle to loud recorded noise during handling raised cortisol levels but had no effect on weight gain in relatively tame Angus cattle at a research station (Bauer *et al.*, 2012). In both of these situations, the cattle may have perceived that the noise was not directed at them. The cattle at the research station may also have been less stressed by the treatment because they had become accustomed to many students handling them. Lanier and Grandin (2002) found that cattle that became agitated in an auction ring were more likely to flinch or jump in response to sudden, intermittent movements or sounds. Intermittent movements or sounds appear to be more frightening than steady stimuli.

Talling *et al.* (1998) found that pigs were more reactive to intermittent sounds than to steady sounds. High-pitched sounds increased a pig's heart rate more than low-pitched sounds (Talling *et al.*, 1996). Sudden movements have the greatest activating effect on the amygdala (LeDoux, 1996), the part of the brain that controls fearfulness (LeDoux, 1996; Rogan and LeDoux, 1996).

Basic Cattle and Livestock Behaviours that Are Governed by Vision

There are eight natural instinctual behaviours that cattle and other grazing animals have during handling. In completely tame cattle that are trained to lead, these behaviours may either disappear or become less obvious. The eight behaviours are:

1. Flight Zone – The animals move away when the flight zone is entered (Fig. 5.2).
2. Turn and Face People – 'Cattle want to see you' according to Ron Gill, Texas A&M University (effectivestockmanship.com – n.d.). There is a zone just outside the flight zone where cattle and other grazing livestock are aware of the handler's presence and they will turn and face the stockperson. There are many different names for this zone such as recognition zone (Smith, 1998), pressure zone, zone of awareness or zone of influence. Livestock handling specialist Curt Pate explains that groups of cattle can be easily turned or sorted by using a combination of 'driving pressure' when their flight zone is entered and 'drawing pressure' where the handler is just outside the flight zone (Detering, 2010). The cattle will want to watch and walk towards the handler. A person who is skilled at sorting groups of cattle will carefully alternate between driving pressure and drawing pressure to sort individual cattle from others in the group (curtpatestockmanship.com – n.d.).
3. Point of Balance – The animal will change direction of movement depending on how the handler is positioned in relation to the point of balance (Fig. 5.2). Livestock will usually move forward when the stockperson is behind the point of balance at the shoulder.
4. Natural Following Behaviour – Cattle and other livestock will follow the leader. Skillful handlers will use following behaviour by timing bunches of cattle when they are working in races (chutes). They wait until the race is empty so that they can utilize natural following behaviour to refill a partially empty race. Natural following behaviour is also used to move large groups of cattle in a low-stress manner.
5. Return to Where They Came from – Well-designed handling facilities and skillful sorting of cattle takes advantage of the natural behaviour of cattle, pigs or sheep to go back to where they came from. Handling systems, such as round-tub crowd pens or Bud boxes take advantage of this natural behaviour (Figs 1.3 and 1.4 in Chapter 1 and Figs 5.11, 5.12 and 5.14). To facilitate flow through a handling facility, do not store livestock in the crowd pen that leads up to the single-file race. Keep them moving to prevent them from turning around and attempting to go back to where they came from. When sorting cattle, move them into another pen and then sort them back into the pen they just left. This will take advantage of the natural behaviour of going back to where they came from.
6. Soft Bunching – Cattle and other grazing animals that live in areas where there are many predators will graze together in soft bunches. Laporte *et al.* (2010) found that when wolves were present, cattle grouped more closely together during grazing.
7. Milling – Cattle or other livestock will form a tight circle with the dominant animals pushing into the centre. This is a behaviour that occurs when predators attack. Good stockpeople *never* want to see this behaviour. If milling occurs, the handlers should wait 20–30 minutes for the cattle to calm down before attempting to handle or move them.

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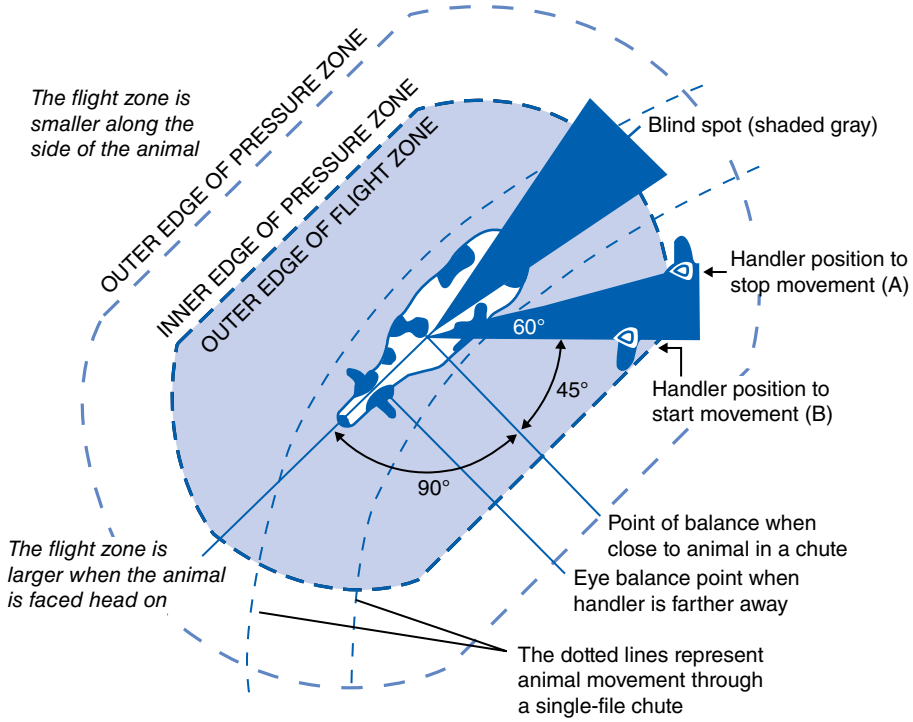


Fig. 5.2. There are two zones around cattle. They are the flight zone and the pressure zone ('cattle turn and face you' zone). When the handler moves outside the pressure zone, the cattle will ignore them. When the flight zone is entered, the animal will move away. This diagram shows the correct position for moving a single bovine through a race (chute). To move a single animal forward, the handler must be behind the point of balance and stay out of the blind spot directly behind the animal. When the handler is close to the animal, the point of balance is at the shoulder. When the handler is further away, the point of balance may move forward to just behind the eye. When the handler is on the outer edge of the pressure zone, the animal becomes aware of the handler's presence and turns around and looks. When the outermost edge of the flight zone is penetrated, the animal moves away. (www.grandin.com/principles/flight.zone.html). (Diagram: Temple Grandin)

8. Cattle and Sheep Do Not Like Being Alone – Many people get injured by a lone animal that wants to get back to its herdmates. Put some other animals in with it. Do not get into a small pen with an agitated lone bovine, bison, deer or other large grazing ungulate.

Flight Zone

The concept of flight distance was originally applied to wild ungulates. Hediger (1968) states:

> By intensive treatment, i.e. by means of intimate and skilled handling of the wild animals, their flight distance can be made to disappear altogether, so that eventually such animals allow themselves to be touched. This artificial removal of flight distance between animals and man is the result of the process of taming.

The size of a bovine's flight zone is determined by both genetics and previous handling experiences. Previous experiences with calm, patient stockpeople will reduce the size of the flight zone. Cattle with more flighty genetics may have a larger flight zone (see Chapter 4).

This same principle applies to domestic cattle and wild ungulates. Extensively raised wild cows on an Arizona ranch may have a 30 m flight distance, whereas feedlot cattle may have a flight distance of 1.5–7.61 m (Grandin, 1980a). Cattle with frequent contact with people will have a smaller flight distance than cattle that seldom see people, and cattle

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subjected to gentle handling will usually have a smaller flight zone than cattle subjected to abusive handling.

Fearfulness will enlarge the flight zone. Totally tame dairy cattle may have no flight zone and people can touch them. The edge of the flight zone can be determined by slowly walking up to a group of cattle. When the flight zone is entered, the cattle will turn and start to move away and, if the person stands still, the cattle will turn and face the handler but keep their distance. When a person re-enters the edge of the flight zone, the animals will turn around and move away. When the flight zone of a group of bulls was invaded by a moving mechanical trolley, the bulls moved away and maintained a constant distance between themselves and the moving trolley (Kilgour, 1971). The flight distance was determined by the size of a piece of cardboard attached to the trolley.

Cattle remain further away from a larger object (Smith, 1998). When a person approaches full-face, the flight zone will be larger than when approaching with a small, sideways profile. The author has also observed that large objects are more threatening to flighty antelope. Tame, hand-reared pronghorn antelope panicked and hit the fence of their enclosure when a large, novel object such as a wheelbarrow was brought into their pen. They had to be carefully habituated to each new large object. Small novel objects, such as coffee cups, that had been brought into their pens had no effect.

If the handler works on the edge of the flight zone, cattle can be moved more efficiently (Grandin, 1980a, 1987). The animals will move away when the flight zone is penetrated and stop when the handler retreats. Smith (1998) and Kosako *et al.* (2008) report that the edge of the flight zone is not distinct and that approaching an animal quickly will enlarge the zone.

If an animal rears up in a race, handlers should back up to remove themselves from the animal's flight zone. Handlers should not attempt to push a rearing animal down, because deep penetration of the flight zone causes increased fear and further attempts to escape. If cattle attempt to turn back in an alley, the handler should back up and remove him/herself from deep inside the flight zone. The angle of approach and the size of the animal's enclosure will also affect the size of the flight zone.

Experiments with sheep have indicated that animals confined in a narrow alley had a smaller flight zone than animals confined in a wider alley (Hutson, 1982). Cattle will have a larger flight zone when they are approached head-on. A basic principle is that the flight zone is smallest along the sides of the animal and greatest in front of and behind it (Cote, 2003). Extremely tame cattle are often hard to drive because they no longer have a flight zone. These animals should be led. More information and flight zones can be found in Smith (1998) and Grandin and Deesing (2008).

Point of Balance

To make an animal move forward in a single-file race, the handler should stand behind the point of balance at the shoulder, and to make the animal back up, the handler should stand in front of the point of balance (Kilgour and Dalton, 1984). When cattle are calm, the point of balance will move forward and be closer to the eye. It will never be in front of the eye. When cattle are being handled in groups, the point of balance may keep changing. Curt Pate, a low-stress handling specialist, recommends carefully working cattle to move the point of balance forward. The caption of Fig. 5.2 provides additional information about the point of balance. A common mistake made by many handlers when attempting to move an animal forward in a single-file race is to stand in front of its eyes and poke its rear with a stick. This gives the animal confusing directional signals. To turn an animal located in an open area, start on the edge of the flight zone at the point of balance and approach the animal's rear at an angle (Cote, 2003).

Another principle is that grazing animals, either singly or in groups, will move forward when a handler quickly passes the point of balance at the shoulder in the opposite direction to the desired movement (Grandin, 1998; Fig, 5.3). The principle is to move *inside* the flight zone in the opposite direction to the desired movement and *outside* the flight zone in the same direction as the desired movement. Using these movements to induce cattle to enter a squeeze chute makes it possible to greatly reduce or eliminate the use of an electric prod (see Fig. 5.3). Wait until the tailgate on the squeeze chute is open so the animal has a place to go *before* doing the movement pattern.

When an animal is approached head-on, it will turn right if the handler moves left, and vice versa (Kilgour and Dalton, 1984; Holmes, 1991). Calm cattle in crowd pens and other confined areas can be easily turned by moving plastic strips on a stick

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next to the animal's head. For example, when a cow's vision is blocked on the left side by the plastic strips, she will turn right. Handlers should avoid deep penetrations of the flight zone, because this may cause cattle to panic. Fig. 5.4 shows a curved single-file race where the solid wall of the building blocks outside distractions. A handler walking on the ground can easily perform the movement pattern shown in Fig. 5.3 through the partially open side.

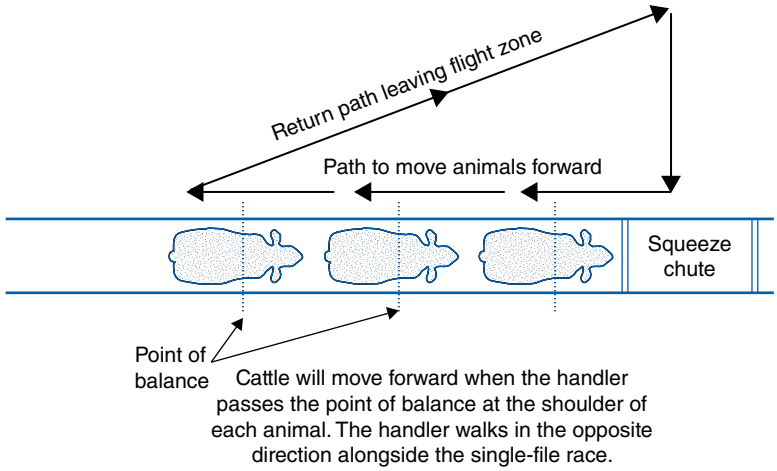


Fig. 5.3. Movement pattern to move cattle forward in a chute by walking inside the flight zone in the opposite direction to the desired movement. The handler should quickly walk by the point of balance at the shoulder. (Grandin, 2000)



Fig. 5.4. Curved single-file chute with a partially open inner radius. The building's wall creates a completely solid outer fence to block distractions. The curved race takes advantage of the natural tendency of cattle to go back to where they came from. The space close to the open-sided race must remain free of people except when the flight zone is entered to move a steer forward. (Photo: Courtesy of Temple Grandin)

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Move in Triangles for Moving Groups

Ron Gill at Texas A&M University, Guy Glossom at Mesquite, Texas, and many other people who teach good stockmanship explain that when groups are moved, herders should walk in triangles alongside a group of cattle (Fig. 5.5). The handler moves inside the flight zone in the opposite direction to the desired movement to speed up forward movement and outside the flight zone in the same direction to slow the group of cattle down. Bud Williams, a specialist in low-stress cattle-handling, developed these principles. Grandin (1993) worked with Bud Williams and made some of the first diagrams to show his principles. Dylan Biggs in Canada recommends a small version of the same movement pattern when cattle are being moved through a gate (Fig. 5.6) (Stookey and Watts, 2014). Curt Pate, a cattle stockmanship specialist, says: 'Concentrate on directing the animal's nose. When sorting, induce the animal to move when it is paying attention to the stockperson with its nose pointed in the right direction.'

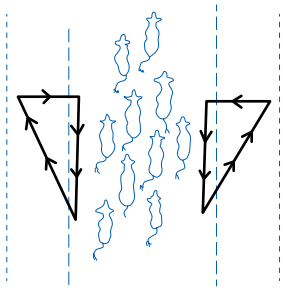


Fig. 5.5. The diagram shows the movement pattern when two people are moving a group of cattle. To keep the group moving, the triangle pattern is repeated multiple times. The dotted line with long dashes represents the outer edge of the collective flight zone. The dotted line with small dashes represents the outer edges of the animal's zone of awareness (pressure zone). When the pressure zone is entered, the animals become aware of the handler's presence. The handler is inside the outer edge of the collective flight zone when he walks in the opposite direction to the desired movement to speed the herd up and move them forward. The handler is outside the collective flight zone but still inside the pressure zone where he walks in the same direction to the desired movement. This double-triangle-pattern diagram is adapted from the work of Guy Glossom, Mesquite, Texas. He warns that it is essential to keep the angles on the triangle sharp. Never allow the triangles to turn into circles. (Diagram: Temple Grandin – www.grandin.com//principles/flight.zone.html)

Let Livestock Flow around the Stockperson

When a person positions themselves at the correct location at a gate, the cattle or sheep will flow around them (Fig. 5.7). The cattle will move around the handler just slightly outside the flight zone but still inside the pressure zone. Cattle have a natural behaviour to flow around on the edge of a bubble formed on the edge of the flight zone (Grandin, 2004). It is like a 'force field' in a science fiction movie that is formed around the stockperson. The collective flight zone of a large flock of sheep is shown in a photo in Grandin (1987).

Gathering Cattle and Other Livestock on Pasture

Wild and semi-wild cattle can be easily gathered on pasture by initiating a natural loose bunching pattern. Figure 5.8 shows a windscreen wiper pattern in which the handler walks on the edge of the group's collective flight zone. The handler moves at a slow walk and must be careful not to circle around the animals. Bud Williams was the originator of this principle and early published versions are in Smith (1998) and Grandin (2000). Many livestock specialists recommend walking in straight lines. Circling around livestock mimics the behaviour of a predator and must be avoided. The stockperson must also resist the urge to chase stragglers. When the bunching instinct is triggered, the herd will come together and line up. The stragglers will join the other cattle.

Care must be taken to be quiet and keep the animals moving at a walk. The principle is to induce bunching before any attempt is made to move the herd. The animals will move towards the pivot point of the windscreen wiper. If too much pressure is applied to the collective flight zone before bunching, the herd will scatter. More information can be found in Grandin (2000), Smith (1998), Grandin and Deesing (2008), Grandin (2017), Ruechel (2006) and Beaver and Hoagland (2016) and *Stockmanship Journal* (2012–2016). This method will not work on completely tame animals with little or no flight zone. Leading is often the best low-stress method to move really tame cattle.

Cattle-bunching is less intense than sheep-bunching. Sheep have extreme bunching behaviour. A flock of sheep will often immediately bunch when they see a dog. Inducing soft bunching activates a mild anxiety, but induction of high-stress milling and

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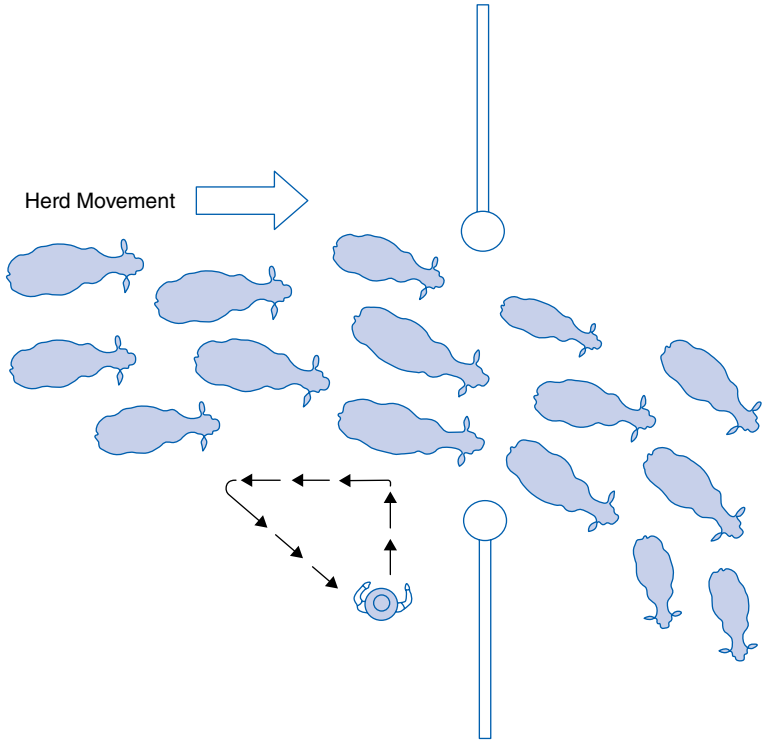


Fig. 5.6. Movement pattern to quietly move cattle out of a gate. (Adapted from Dylan Biggs – Stookey and Watts, 2014)

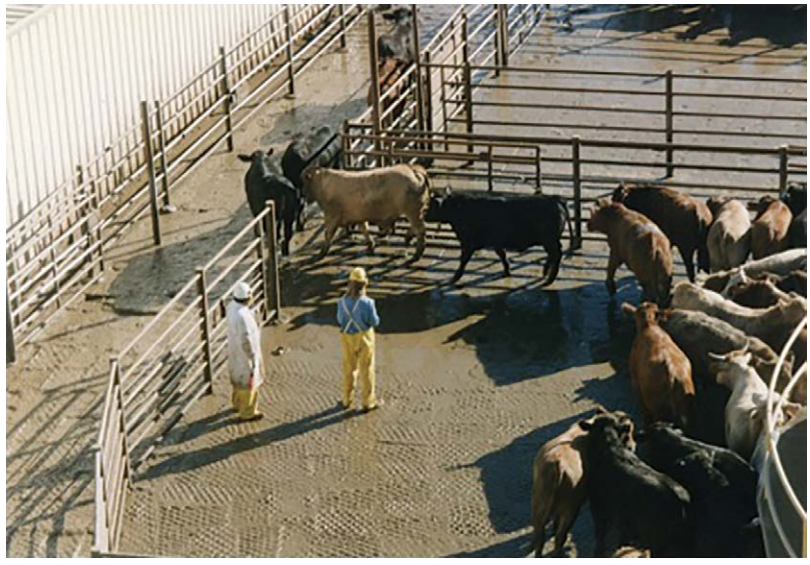


Fig. 5.7. When a handler stands at the correct position at a gate, the cattle will flow along the stockperson on the edge of the flight zone. (Photo: Courtesy of Temple Grandin)

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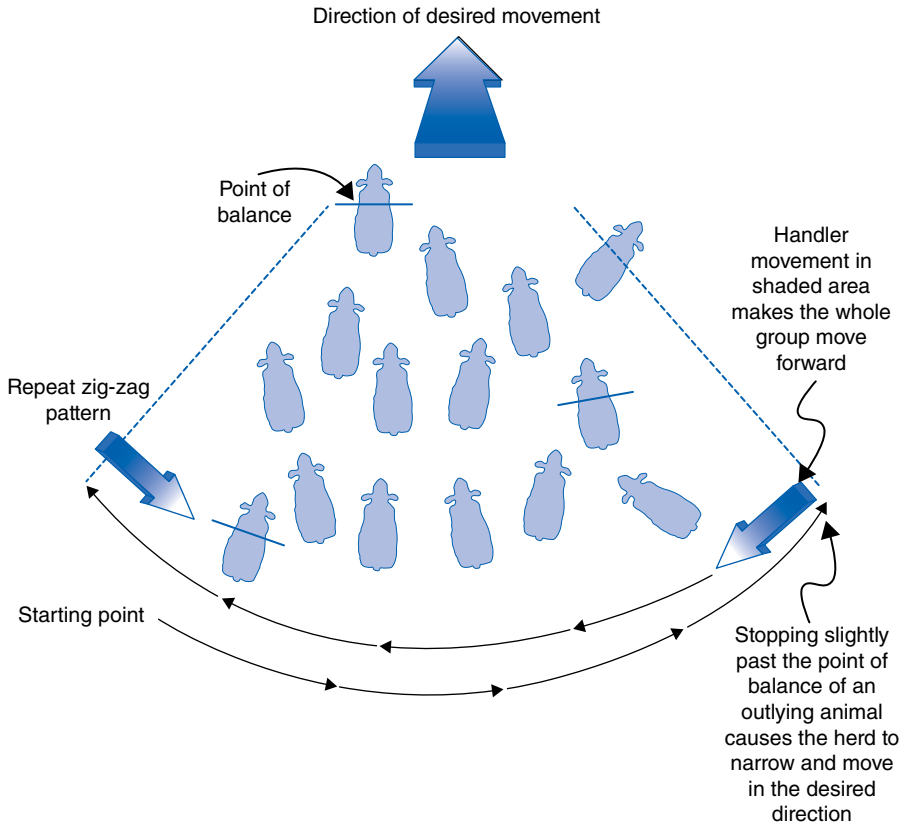


Fig. 5.8. Stockperson movement pattern for gathering cattle that are not completely tame. The handler walks back and forth on the edge of the flight zone but well inside the pressure zone (zone of recognition). Imagine that the leaders are on the pivot point of a windscreen wiper. Do not circle around the cattle. Do not enter the flight zone until the herd moves together. If the flight zone is entered too quickly, the herd may scatter. The width of the zig-zag narrows when the herd starts to move forward. (From Grandin, 2000)

circling should be avoided. The least stressful handling procedure would be entirely voluntary.

Smith (1998) states that there is no black-and-white dividing line between herding, leading and training. It is likely that cows gathered with the windscreen-wiper method (Fig. 5.8) may have slight anxiety at first, but then become completely trained and have diminishing anxiety. Figure 5.9 shows a movement pattern developed by Bud Williams to bring a split herd back together (Grandin, 1993).

Training Cattle to Trust People during Herding on the Range

Bud Williams further developed his herding methods so that they are no longer dependent on triggering hard-wired, instinctive behaviour patterns. Cote (2003) has written a book that explains these methods. The principle is to train groups of cattle on a pasture to calmly respond to pressure on their collective flight zone. It is a process of training them to move quietly rather than simple habituation. This may be similar to settling cattle before a cutting horse contest. You want them to be 'feeling a little bit scared' (Rice, n.d.). When cattle and calves learn to trust the handler, they will move straight and away from the handler. They will stop attempting to circle around to look at the person (Cote, 2003). Cattle-handling specialist Ron Gill at Texas A&M University explains how a handler can teach cattle to stop when pressure on the flight zone is removed. The handler will need to spend time with the herd and gradually reduce the flight

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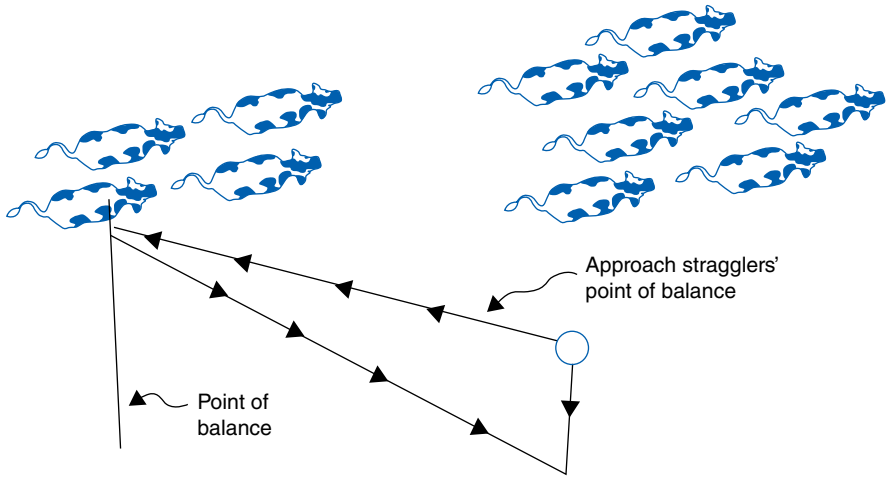


Fig. 5.9. Handler movement pattern for bringing a split herd back together. The handler moves inside the flight zone in the opposite direction to the desired movement and outside the flight zone in the same direction. This diagram was developed after the author worked with Bud Williams. (From Grandin, 1993)

zone. Stock people have learned good technique when an animal can be moved by penetrating its flight zone and then having it stop when the handler retreats from the flight zone.

Instinct is now overridden by trust and learning, but the handler must never work in the blind spot because cattle will turn if they cannot see the handler. All handler movements are done at a walk. The three main principles are:

- never apply pressure to the flight zone when an animal is moving where you want it to go;
- release pressure when cattle move where you want them to go;
- reapply pressure only when the cattle stop moving where you want them to go.

Reward Cattle by Relieving Pressure on the Flight Zone

Stock people must avoid the temptation to put extra pressure on the flight zone when cattle or other livestock are close to their destination. At this time, the handler should back up and relieve the pressure. Dylan Biggs warns that when cattle are getting close to a gate, this is not the time to apply more pressure (Biggs, 2013). He has successfully loaded bulls into an empty stock trailer that was in the middle of the pasture. This required patience. If the bull faced the trailer, he retreated from the flight zone. If the bull looked away from the trailer, he slightly penetrated the flight zone. Gradually he rewarded the bull for any behaviour directed towards the trailer. All of the stockperson's movements were at a slow walk. Cattle and other livestock need time to make decisions. Give them time to process the incoming information. Curt Pate stated, 'You want them to think instead of just reacting' (Curt Pate, personal communication, 2018).

Leaders and Leading Cattle

The natural following of cattle can be used to facilitate cattle movements. On the old cattle drives in the USA, the value of calm leaders was recognized. The same leaders would lead a herd of 1000 cattle every day (Harger, 1928). A good leader was usually a sociable cow and she was not the most dominant animal. Smith (1998) contains excellent information on the effect of social behaviour on handling.

In frontier days, excitable, nervous animals that became leaders were usually destroyed and calm leaders were kept (Harger, 1928). If the cattle herd refused to cross a bridge or brook, a calf would be roped and dragged across to encourage the other cattle to follow (Ward, 1958). In Australia, a herd of tame 'coacher' cattle is used to assist in gathering

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wild feral cattle (Roche, 1988), and similar methods have also been used with wild horses (Amaral, 1977).

Fordyce (1987) also recommends mixing a few quiet old steers in with *Bos indicus* calves to facilitate training in handing procedures. Dumont *et al.* (2005) found that to determine which animal is the true leader, one should observe spontaneous long-distance movements to a new feeding site. The leader cannot be determined by watching cattle slowly graze through a field.

Cowboys and stock people working in large feedlots in Australia are using leading to move cattle in feedlots. Kev Sullivan from Queensland, Australia, encourages handlers to lead cattle every time they have the opportunity (Smith, 2018). A skilled handler uses 'drawing pressure', which has been described by Curt Pate. According to Tom Noffsinger, a skilled handler has a positive attitude and develops a 'presence' that attracts the cattle (Smith, 2018).

Bos indicus cattle have a much stronger following instinct than *Bos taurus* cattle. Observations by the author indicate that tame, purebred Brahmans are difficult to drive but will often follow a person or a trained lead animal. Progressive stock people in Brazil are leading Nelore cattle with a person on foot. No driving aids are used. The person finds a leader who is looking in the right direction who will slowly follow them. When they get near the destination gate, the handler relieves pressure on the flight zone. To stop the person from arm-waving, hands are held behind the back. In Australia, they have been trained to follow lead dogs.

Tina Williams, the daughter of Bud Williams, warns that cattle that have never learned how to be driven can become highly stressed when they are taken to a new location where driving is the standard handling method.

Calling Cattle

Cattle reared under extensive conditions can easily be trained to come when called. The animals learn to associate a vehicle horn with feed (Hasker and Hirst, 1987). Jason C. Holt of the USDA NRCS (US Department of Agriculture Natural Resources Conservation Service) and David Kitner at Duval County Ranch in Texas (personal communication, 2012) trained cattle to come when called from huge 6000-acre pastures. The cattle were trailed to a series of successively larger paddocks. In the northern USA, when snow is on the ground, cattle will come running when they see a feed truck. However, the animals can become a nuisance if they always chase a truck for feed. They should be trained to associate the vehicle horn with feed, and then the truck can be driven in a pasture without the animals running after it. Young calves are less likely to become stressed and separated from their mothers if the mothers have learned not to constantly chase vehicles.

Many ranchers have adopted intensive grazing systems in which cattle are switched to a new pasture every few days (Savory, 1978; Smith *et al.*, 1986). The cows quickly learn to make the switch. Calves are sometimes stressed when the cows rapidly run into the new pasture and leave them behind. To prevent calf stress, handlers should either stand near the gate of the new pasture and make the cows walk by them at a walk or lead them slowly into the pasture. To prevent cattle from mobbing around a gate, the gate should remain shut until the cows have settled down. They have to learn that they must walk calmly when pastures are switched. The goal is to have them walk past a person at a gate in an orderly single file. Ranchers who carry out intensive rotational grazing in which cattle are moved every few days usually lead cattle instead of driving them. Cattle can also be easily trained to come into corrals by feeding them in the corrals.

Intensive Grazing without Fences

There is increasing interest in practising intensive grazing methods without the expense of fences on vast extensive ranges in the western USA. Herding methods are being used to both keep cattle groups in a specific area and to move them to new grazing sites. When cows and calves are moved, it is important to move them slowly so that the calves do not become separated from the cows. On long moves, the animals should have time to graze. Relaxed, calm cattle will stay in a new location. Frightened, stressed cattle will return to the old location. Bailey (2004), a grazing specialist in Montana, suggests a combination of herding and other methods to encourage cattle to stay in a new location. When cows with calves are moved long distances, the move should be timed so that they arrive at their destination in the late afternoon when it is time for the calves to bed down. This will encourage the cows to stay in the new location. Tasty supplements placed in the pasture also encourage cows to stay. Research on extensive rangelands in Montana indicated that low-stress herding methods reduced the

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percentage of the herd grazing in riparian areas (Bailey *et al*., 2008). Keeping cattle out of these areas will prevent damage to fragile lands along streams.

One of the big problems is that some cattle are 'bunch quitters' and do not want to stay with the herd (Nation, 1998). These are most likely to be high-headed, nervous cows. Selling the bunch-quitting cow is often the best option. Herding works best with uniform groups of cattle that have all been raised on the same ranch. Bunch quitters are more likely to be a problem in cows obtained from several different ranches. The principle of herding without fences is to relieve pressure on the collective flight zone when cows stay where you want them and to apply pressure when they go to where you do not want them to be. To encourage cattle to stay in a new location, wait for them to relax and graze in random orientations (Tina Williams, personal communication, 2014). This is the same principle that is used when settling cattle for sorting in an open field. Settled cattle will graze in a bunch while facing in different directions (Whitehurst, 2017).

Learning also has a huge effect on grazing. Livestock prefer the feeds that they ate with their mother when they were little (Provenza, 2003). Bringing adult cows to an area that has unfamiliar feeds can cause big problems. When replacement animals are purchased, they should come from areas that have similar pasture (Nation, 2003). Calves can be taught to eat a new feed in the future by feeding this to both the cow and the calf. Cattle that are being brought in from a different part of the country can be taught as calves to eat feeds that they will encounter when they grow up.

Herders have to spend many hours with their herds and have lots of patience. More information on pasture herding can be found in Biggs and Biggs (1996, 1997), Herman (1998), Nation (1998), Smith (1998), Williams (1998) and Lanier and Smith (2006).

Self-mustering Systems

In extremely extensive operations, it may be difficult to gather and muster all the cattle. For years, ranchers have successfully used trap gates which allow cattle to enter a corral to eat or drink but they cannot leave. These systems are described in Stookey and Watts (2014), Anderson and Smith (1980), Webber (1987), Ward (1958), Connelly *et al*. (2000) and Adcock *et al*. (1986)

Herding by Pastoral People

The herding methods that have been described in this chapter are a relearning of old pastoral herding methods that have been used for thousands of years. In all of these methods, a great deal of time is spent with the animals. Norwegian reindeer herders are in close contact with their animals and the animals associate the smells and noises of camp with serenity (Paine, 1994). The Fulani African tribesmen have no horses, ropes, halters or corrals (Lott and Hart, 1977, 1982). Their cattle are completely tame and have no flight zone. Instead of chasing the cattle, the herdsman becomes a member of the herd and the cattle follow him (Lott and Hart, 1979).

Handling Dominant Animals

The nomadic Fulani tribesmen use the animals' natural following, dominance, submission and grooming to control the overall herd. If a bull makes a broadside threat, the herdsman yells and raises a stick. The herdsman charges at the bull and hits it with a stick if it attempts a charge. Similar methods have also been used successfully in other species. Raising a stick over the handler's head has been used to exert dominance over bull elk (Bud Williams, personal communication; Smith, 1998). The stick is never used to hit the bull elk.

The author has used similar methods to control aggressive pigs. Pigs exert dominance by biting and pushing against another pig's neck (Houpt and Wolski, 1982). The aggressive pig was stopped by shoving a board against the neck to simulate the bite of another pig. Using the animal's natural method of communication was more effective than slapping it on the rear. Exerting dominance is not beating an animal into submission. The handler used the animal's own patterns to become the 'boss' animal. The aversion that cattle have for manure can be used to keep them away from crops, by smearing the borders of a field with faeces (Lott and Hart, 1982). Manure is also smeared onto the cow's udder to limit milk intake by the calf.

Stroking and Leading Cattle

The Fulani stroke their cattle in the same areas where a mother cow licks her calf (Lott and Hart, 1979), so adult cattle will approach and stretch out their necks to be stroked under the chin (Lott and Hart, 1982).

Similar methods are used at the J.D. Hudgins Ranch in Hungerford, Texas, and at the J. Carter

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Thomas Ranch in Cuero, Texas. Purebred Brahmans are led to the corrals and will eat out of the rancher's hand. Cows and bulls in the pasture will come up to Mr Thomas for stroking and brushing (Julian, 1978).

Small herds of Zebu cattle raised in the Philippines have no flight zone and are easily led by small children. The author's observations indicate that taming crossbreeds of Brahman and *Bos taurus* is more difficult. This may be partially due to a lower level of inquisitiveness, and a desire for stroking and following. The cattle-herding methods of the Fulani are also practised by other African tribes such as the Dinka (Deng, 1972; Schwabe and Gordon, 1988), and the Nuer (Evans-Pritchard, 1940). The less nomadic tribes do use corrals and tethers, but the cattle are still completely tame with no flight zone. Surplus bulls are castrated and kept as steers by all tribes.

The cattle-handling practices of African tribes date back to before the great dynasties of Egypt (Schwabe, 1985; Schwabe and Gordon, 1988). It is also noteworthy that the religion of the Nuer and Dinka tribes centres around cattle (Seligman and Seligman, 1932; Evans-Pritchard, 1940). One factor that makes African tribal handling methods successful is that relatively small herds are handled and each tribe has many herdsmen. Therefore each herdsman has time to develop an intimate relationship with each animal.

Herding and Observing Cattle with Drones

Some ranchers have used a drone to move cattle. A review of several online videos indicated that moving cattle with drones ranged from excellent, calm working on the edge of the flight zone to terrible running and chasing of cattle. These videos can be easily found by using the keywords 'Videos', 'cattle drone' and 'herding'. Tillman-Brown (2018) explains that some drones may malfunction near cell phone towers. Some of the problems may be due to other non-cell (mobile) phone equipment that is mounted on the same tower.

Bull Behaviour

Dairy bulls have had a bad reputation for attacking humans, possibly due to the differences in the way beef bulls and dairy bulls are raised. Bulls are responsible for about half of the fatal accidents with cattle (Drudi, 2000). Dairy bull calves are often removed from the cow shortly after birth and raised in individual pens, whereas beef bull calves are reared by the cow.

Price and Wallach (1990) found that 75% of Hereford bulls reared in individual pens from one to three days of age threatened or attacked the handlers, while only 11% threatened handlers when they were hand-reared in groups. These authors also report that they have handled over 1000 dam-reared bulls and have experienced only one attack. Bull calves that are hand-reared in individual pens may fail to develop normal social relations with other animals, and they possibly view humans as a sexual rival (Reinken, 1988).

Both dairy and beef breed bulls will be safer if bull calves are raised on a cow and kept in groups with other cattle. This provides socialization with their own species and they will be less likely to direct attacks towards people. Similar aggression problems have also been reported in hand-reared male llamas (Tillman, 1981). Fortunately, hand-rearing does not cause aggression problems in females or castrated animals. In contrast, it will make these animals easier to handle. More information on bulls can be found in Smith (1998). Ron Gill (2012, personal communication) warns to never turn your back on a bull. Also, when bulls are being driven, do not deeply invade their flight zone, especially in small pens or pastures. Bulls are more likely to become aggressive towards handlers when they are overcrowded than are cows or steers.

Vision and Design of Cattle Restraint Devices

One of the reasons why cattle become agitated in a squeeze chute is due to the operator being deep inside their flight zone. They can see him/her through the open-bar sides. Cattle will remain calmer in a restraining device that has solid sides and a solid barrier around the headgate to block the animal's vision (Grandin, 1992; Muller *et al.*, 2007). Cattle also struggled less in a restraint device if their vision was blocked until they had been completely restrained (Grandin, 1992), and they are less likely to attempt to lunge through the head opening if there is a solid barrier 1.2 m in front of the head opening. This prevents them from seeing a pathway of escape.

Restraint device designs that have been successfully used in slaughter plants could be adapted for handling on the ranch and feedlot (Marshall *et al.*, 1963; Grandin, 1992). Most cattle stood quietly

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when the Marshall *et al*. (1963) restraint device was slowly tightened against their bodies (Grandin, 1992). Solid sides prevent the animals from seeing the operator or other people inside their flight zone. Observations also indicate that cattle unaccustomed to head restraint will remain calmer if body restraint is used in conjunction with head restraint. Head restraint without body restraint can cause stress (Ewbank *et al*., 1992).

Breeders of American bison prevent injuries and agitation by covering the open-barred sides of squeeze chutes and installing a solid gate (crash barrier) about 1.0–1.5 m in front of the headgate. Covering the sides of a squeeze chute so that the animal does not see the operator standing beside it will keep animals with a large flight zone calmer. When bison are handled, the top must also be covered to prevent rearing. Squeeze chutes are now commercially available with rubber louvres on the sides to block the animal's vision. The louvres are mounted at a 45° angle and the drop bars on the width of the chute can still be opened. A cow's-eye view of a squeeze chute equipped with louvres may be found in Grandin (1998). Covering the open-barred sides of a squeeze chute with cardboard will also result in calmer cattle because they will not see the squeeze chute operator who is deep in their flight zone.

Cattle will remain calmer if they 'feel restraint'. Sufficient pressure must be applied to hold the animal snugly, but excessive pressure will cause struggling due to pain. There is an optimal amount of pressure. If an animal struggles due to excessive pressure, the pressure should be slowly and smoothly reduced. Many people mistakenly believe that the only way to stop animal movement is by greatly increasing the pressure. Sudden, jerky movements of the apparatus will cause agitation, whereas smooth, steady movements help to keep the animal calm (Grandin, 1992). Handlers must be careful to avoid rewarding struggling. Cattle should not be released from a squeeze chute until they have stopped struggling (Stookey and Watts, 2014). Fumbling a restraining procedure will also cause excitement (Ewbank, 1968). It is important to restrain the animal properly on the first attempt. (See Chapters 5 and 22 for more information on restraint.)

Dark-box restraint

For artificial insemination (AI) and pregnancy testing, mechanical holding devices can be eliminated by using a dark-box race (Parsons and Helphinstine, 1969; Swan, 1975). This consists of a narrow stall with solid sides, a solid front and a solid top. Very wild cattle will stand still in the darkened enclosure. A cloth can be hung over the cow's rump to darken the chamber completely. Comparisons between a dark box and a regular squeeze chute with open-bar sides indicated that cows in the dark box were less stressed I(Hale *et al*., 1987). Further experiments indicated that cortisol levels were lower in the dark box, but heart rate data were highly variable due to the novelty of the box (Lay *et al*., 1992).

Blindfolding of both poultry and cattle reduces heart and respiration rates (Douglas *et al*. 1984; Jones *et al*., 1998; Stookey and Watts, 2014; Don Kinsman, personal communication). Mitchell *et al*. (2004) reported that blindfolding Hereford × Angus × Charolais heifers with several layers of opaque dark towel resulted in less struggling in the squeeze chute compared with control non-blindfolded animals. Observations by Jennifer Lanier in the author's laboratory showed that blindfolds on American bison had to be opaque to provide the greatest calming effect. Installation of a solid top on a squeeze chute also kept bison calmer.

If large numbers of cattle are inseminated, two or three dark boxes can be constructed in herringbone configuration (McFarlane, 1976; Canada Plan Service, 1984) (Fig. 5.10). The outer walls are solid, with open-barred partitions between the cows. Side-by-side bodily contact helps to keep cattle calmer (Ewbank, 1968). To prevent cattle from being frightened by a novel dark box, the animals should be handled in the box before insemination.

The effectiveness of dark-box restraint is probably due to a combination of factors, such as blocking the view of an escape route and preventing the animal from seeing people that are outside its flight zone. Darkness, however, has a strong calming effect. Wild ungulates remain much calmer in a totally dark box. Small light leaks sometimes cause animals to become agitated. A well-designed dark box for domestic cattle has small slits in the front to admit light. Cattle will enter easily because they are attracted to the light. For wild ungulates, it may be desirable to block the slits after the animal is in the box.

Use of solid or open sides on races

Many stockmanship specialists advocate the use of open sides on single-file races so that cattle can see

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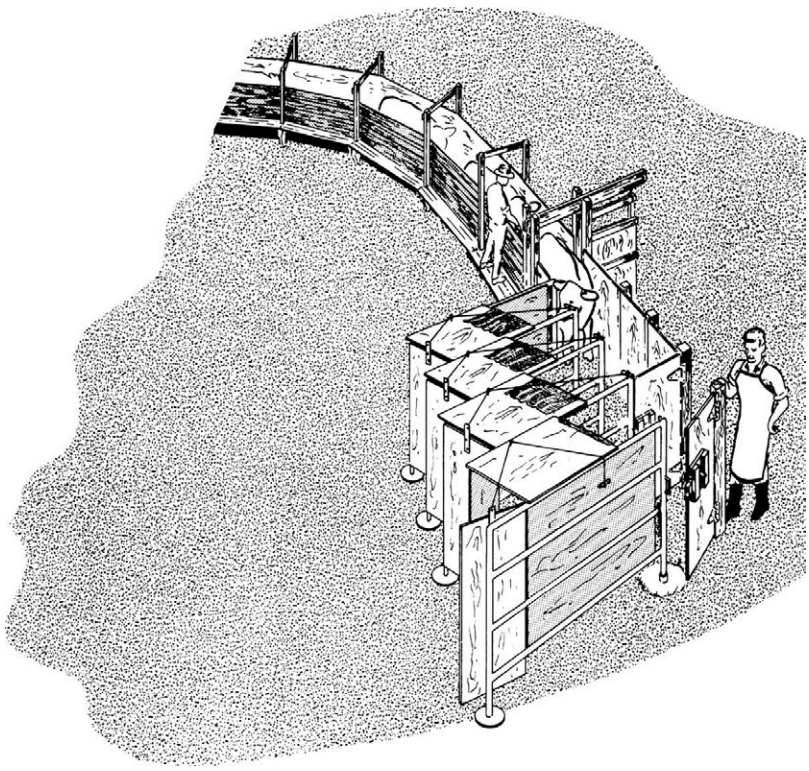


Fig. 5.10. Dark-box restraint races in a herringbone configuration. The solid sides restrict vision and keep cattle calmer during artificial insemination. (From Canada Plan Service, 1984)

the position of the stockperson and move away in a controlled manner. For years the author has recommended the use of solid sides on all the races. Who is correct? Both, according to the situation. Before temperament selection started in the USA, extensively raised cattle would remain calmer in chutes and races with solid sides. Today, in many parts of the USA, *Bos taurus* cattle are much calmer due to 20 years of genetic selection for a calmer temperament (see Chapter 4). A skilled stockperson can easily use a race with open sides on pastures that are free of visual distractions. In slaughter plants and other places with lots of activity around the single-file race, adding a solid side reduced electric prod use and improved cattle movement (Ercolano, 2018).

Depending on the size of the animal's flight zone, handlers must maintain a people-free zone around a race with open sides. This zone is only entered when an animal has to be moved. If people stand in the 'force field' alongside the race, the cattle will become agitated. If an animal rears up in the race, the handler must back up and retreat from the flight zone.

Cover the outer perimeter to block vision

Many new systems on ranches and feedlots have been built with a partially open fence along the inner side where the people work, and a completely solid high fence on the outer perimeter to block the view of vehicles and other distractions outside the facility. The use of the open fence eliminates the need for catwalks and prevents the problem of a person suddenly appearing when the cattle do not expect to see them. Figures 5.11 in this chapter and 1.3 and 1.4 in Chapter 1 are simple designs with an open inner fence and solid outer perimeter fence (Grandin, 2017).

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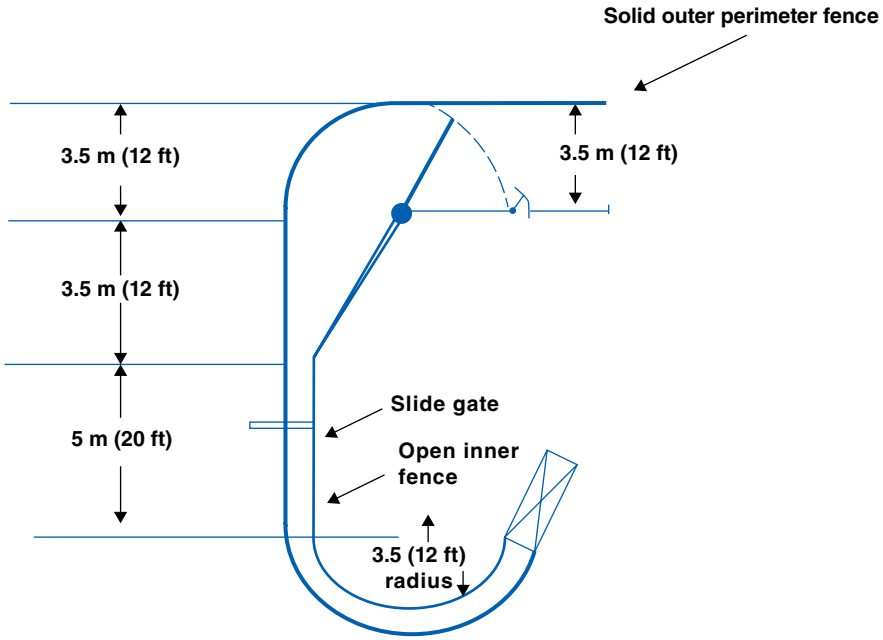


Fig. 5.11. Single-quarter round crowd pen and curved single-file race that can be easily constructed from portable panels. The handler works at the pivot point of the crowd pen and the cattle circle around. The design takes advantage of the natural tendency of cattle to circle around the handler. All catwalks are eliminated. The outer perimeter fences are solid and the inner fence is open on the top. (Courtesy of Temple Grandin)

Design of Corrals, Yards and Lairages

Modern curved races and round crowd pens evolved independently in Australia (Daly 1970), New Zealand (Kilgour, 1971; Diack 1974) and the USA (Oklahoma State University, 1973; Rider *et al*., 1974; Thompson, 1987). In the mid-1960s and early 1970s, many large feedlots were built with curved single-file races, round crowd pens and diagonal pens (Paine *et al*., 1976). Grandin (1980a, 1983a,b) combined the best features of many different designs and developed layout principles to make the systems work more efficiently. Vowles and Hollier (1982) and Vowles *et al*. (1984) reported that cattle moved more efficiently through curved single-file races.

Figure 5.12 shows a large system for a ranch with numerous pens for sorting cattle after they have been weighed and evaluated. Numerous sorting pens are strongly recommended when cattle have to be marketed to programmes that have strict specifications. Variations of this design are also shown in a computerized cattle-sorting system (Pratt 2007, 2009). Fig. 5.13 clearly illustrates why blocking a bovine's vision of outside distractions is important. Cattle moving through this single-file race could see trucks being loaded. In a feedlot that had two identical working areas, this explained why this one worked poorly and the other one worked well.

The more efficient facility with the solid outer wall is shown in Fig. 5.14. Large beef abattoirs should have stockyard/lairage designs that have one-way traffic flow through the yards. Angled pens eliminate sharp corners (Grandin, 1997, 2008). The pens should be on a 60–80° degree angle (Fig. 5.14). Do not use a 45°angle. A high-capacity truck loading ramp is shown in Fig. 5.15. This design will work well when many trucks have to be loaded. Fig. 5.16 shows an old Australian yard design that is still popular.

Strategic Location of Solid Barrier to Block View of a Person Up Ahead

Cattle and other livestock will often balk and refuse to approach people they can see up ahead.

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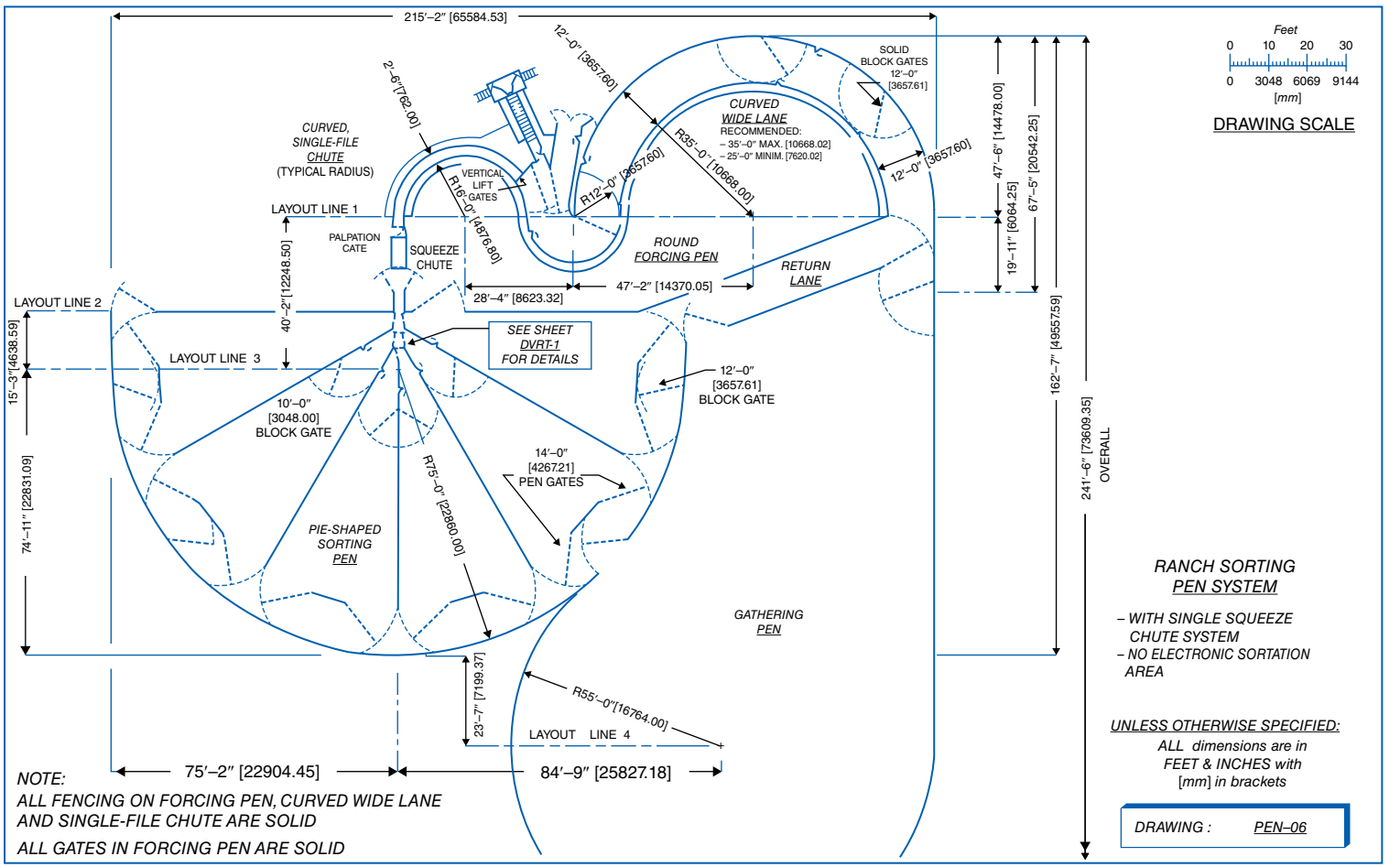


Fig. 5.12. Large corral design suitable for drafting cattle with individual IDs into the pie-shaped pen. Managers of large ranches often need numerous sorting pens that cattle can be directed into after they have been individually weighed and classified. (Grandin, 2000)

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Fig. 5.13. Single-file race with a partially open side. This system would have worked better if the outer perimeter was completely solid. The cattle moving through the race are able to see trucks being loaded. This distraction can cause cattle to balk. (Photo: Courtesy of Temple Grandin)

Solid barriers for stock people to hide behind will often facilitate cattle movement. They are especially important in abattoirs where cattle have to go up ramps.

Portable Cattle Corrals on Rented Land

Since the fourth edition, more and more people need portable cattle-handling corrals that can be used on rented or leased pasture. They need to have facilities that can be easily moved to a new location. In many countries, cattle have been selected for a calmer temperament. This has made it easier for less skilled people to use simpler facilities constructed from portable panels. Figure 5.11 in this chapter and 1.3 and 1.4 in Chapter 1 are designs that can be easily constructed from portable components. There are two types of portable yards and corrals. The first type is designed to be easily moved from pasture to pasture on a trailer. The second type is a semi-permanent installation that would only be moved when the rancher stops leasing the land. These systems are described in Grandin (2017).

Avoid Layout Mistakes when Designing Cattle-handling Facilities

Layout mistakes can reduce the efficiency of cattle movement through a handling facility. Some of the most common mistakes are:

- **Dead-ending the race** – bending the junction between the single-file race (chute) entrance and the crowd pen too sharply. When an animal

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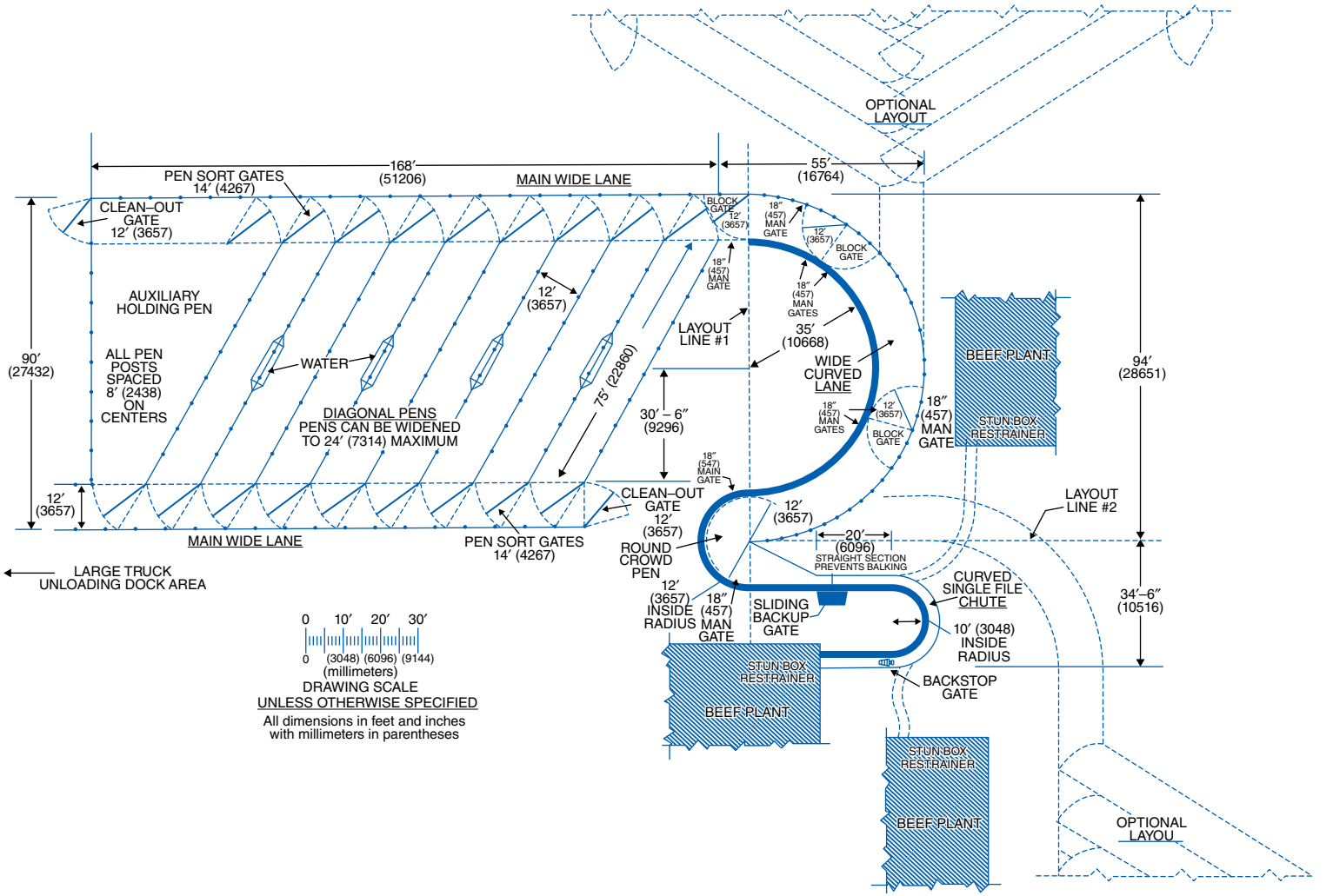


Fig. 5.14. Large lairage stockyard layout for a beef abattoir. The angled pens in the stockyard facilitate one-way cattle traffic flow through the yard (Grandin and Deesing, 2008) (Drawing by Mark Deesing, courtesy of Grandin Livestock Handling Systems, Inc.)

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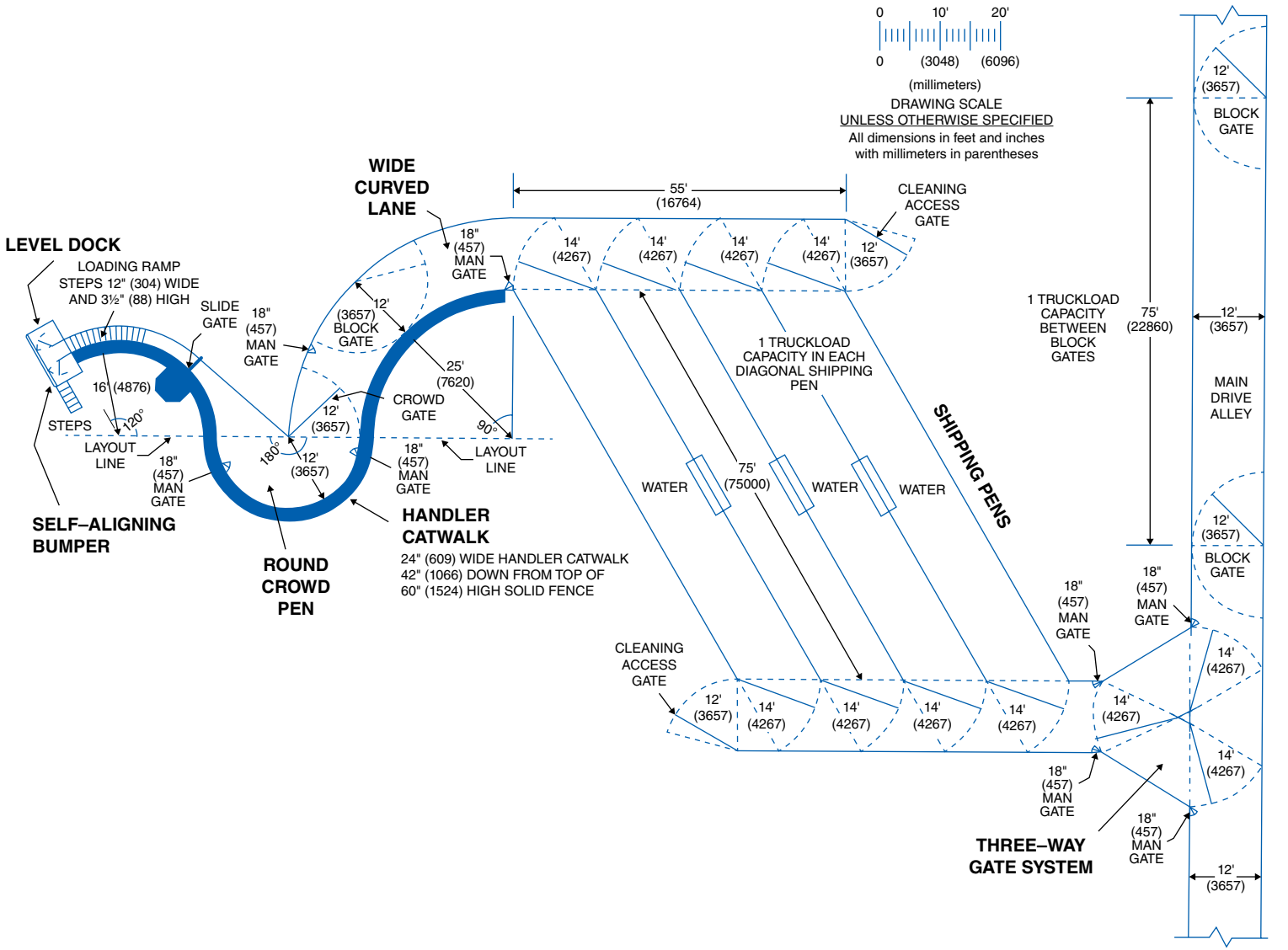


Fig. 5.15. Loading ramp with a round crowd pen and diagonal pens for use in a large feedlot or stockyard (Grandin and Deesing, 2008). The round half-circle crowd pen takes advantage of the natural behaviour of cattle to go back to where they came from. The angled pens provide easy one-way traffic flow. (Drawing by Mark Deesing, courtesy of Grandin Livestock Handling Systems, Inc.)

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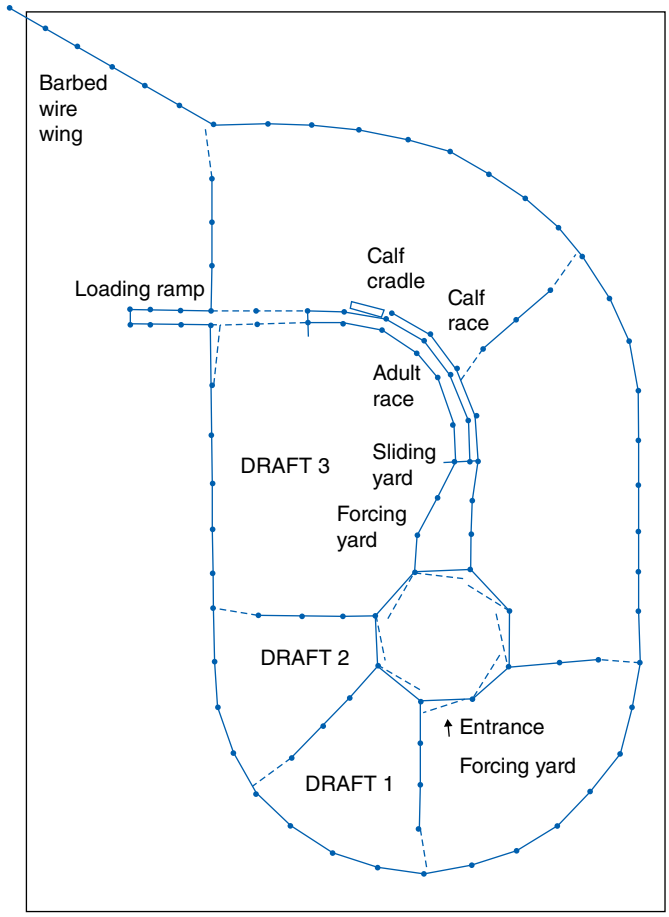


Fig. 5.16. Australian Weean cattle yard (Thompson, 1987). This is an old design that is still very popular. This diagram originally appeared in the 1993 version of this book. Cattle are sorted (drafted) in the round pound yard that is located in the middle of the yard. This layout can be easily constructed from portable steel panels. In 2018, several different Australian equipment companies had the Weean yard on their websites.

stands at the single-file race (chute) entrance, it must be able to see two body lengths up the race; they have to see a place to go before going around a bend.

- **Round crowd pen (tub) is either too big or too small** – on a circular crowd pen the recommended radius for the crowd (forcing) gate is 3 m (10 ft) minimum and 3.5 m (12 ft) maximum (Grandin, 1997).
- **Bud box is too narrow (see Fig, 1.3, Chapter 1)** – the width should be 3.5 m (12 ft) minimum and preferably 4.2 m (14 ft.). The cattle have to be able to go around the person. A Bud box is always a rectangle. It should be 6 m (20 ft) to 7.6 (25 ft) long.
- **Crowd pen angle leading to a single-file race is wrong** – when a funnel-type crowd pen is built, one side should be straight and the other side should be on a 30° angle. The stockperson should work on the angled side.
- **Never put a crowd pen on a ramp** – if a system requires a ramp, it should be in the single-file race portion of the system. Never hold or store groups of cattle on wide ramps because they may pile up on the rear gate.
- **Flooring is too slippery** – cattle become agitated on a slick floor. Animals standing in a race or scale doing numerous little slips will become agitated. Provide good non-slip flooring (OIE 2017; Grandin and Deesing, 2008; Grandin, 2017).

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Ramp surface

- On concrete ramps, stairsteps are recommended. The steps should have a 10 cm (3.5 in) rise and 30 cm (12 in) to 45 cm (18 in) tread length (Grandin, 1987). Cattle and other large livestock can easily walk on stairsteps even when they became worn. On steel or wood ramps, space the cleats (battens) so that an animal's hoof will fit comfortably between them. The space should be 20 cm (8 in) for cattle (Mayes, 1978; Grandin, 2008).

Cattle-restraining Crushes

Before the invention of squeeze chutes (crushes), range cattle were caught and restrained with a lariat (Ward, 1958), which is a rope that is thrown to catch and restrain cattle. The invention of mechanized restraint devices both improved animal welfare and reduced labour requirements. These devices also required less skill to operate than a lariat. Good lariat use requires tremendous skill to maintain an acceptable level of animal welfare. The lariat is a good example of a method that is low-cost but highly skill-dependent (see Chapter 1). One of the first mechanical devices for restraining cattle was patented by Reck and Reck (1903). It had squeeze sides that pressed against the animal and a stanchion to hold its head. In the 1920s, Thompson (1931) developed a head-catching gate designed for wild, horned cattle, which was installed on the end of a single-file race. Squeeze chutes are more expensive than roping animals, but they greatly improve employee safety. Good equipment for restraining cattle can also help to reduce injuries. An Australian study showed that 57% of the injuries to veterinarians occur either during pregnancy checking or the examination of cattle (Lucas *et al*., 2012).

A squeeze chute restrains an animal with two devices – a stanchion (head bail) is closed around the animal's neck and side panels that press against its body to control movement. This device is available with either manual or hydraulic controls. The best squeeze chutes have two side panels that close in evenly on both sides of the animal's body. A double-sided squeeze enables the animal to stand in a balanced position. An animal may struggle and resist being restrained if pressure is applied to only one side of the body. Struggling occurs because the animal is thrown off balance. Non-slip flooring is essential in squeeze chutes because animals often panic if they start to slip. Today, most adult range cattle are restrained in a squeeze chute. Lariats are still used on some large ranches for the restraint of calves for branding and vaccination. One of the first mechanical devices for holding calves was invented by Thompson and Gill (1949) and there are some good designs by Kratky (1976) and Priefert (1990).

Headgate Design

There are six different types of headgates (head bails or stanchions) for restraining cattle. These can be used either alone at the end of a single-file race or in conjunction with a complete squeeze chute. The six types are: self-catch (Pearson, 1965), positive (Thompson, 1931; Heldenbrand, 1955), scissors stanchion, pivoting horizontal, sliding doors, and rotating headgates (see Cummings, 1993, 1999; Mollhagen, 1994, 2010; Daniels and Schmitz, 2003; and Daniels *et al*., 2012).

The advantage of pivoting, rotating headgates or horizontal sliding doors is that they open up to the full width of the squeeze and the animals can exit more easily. These designs may also help to reduce shoulder injuries. A picture of the rotating headgate may be found in Grandin (1998). The Cummings (1993, 1999) headgate requires very little force to restrain the animal compared with scissors-stanchion headgates. Many of the references given here are to US patents, and the diagrams can be found by searching Google Patents or the US Patent and Trademark Office (USPTO) database.

Types of Headgates

All types of headgates are available with either straight vertical neck bars or curved neck bars. Stanchions with straight neck bars are recommended for general-purpose uses because they are less likely to choke an animal. Pressure on the carotid arteries exerted by a neck stanchion will quickly kill cattle (White, 1961; Fowler, 1995). Stanchions with straight vertical neck bars are the safest because cattle can lie down and there is no pressure on the carotid arteries.

Curved-bar stanchions provide a good compromise between control of head movement and safety for the animal. Positive headgates (Thompson, 1931), which clamp tightly around the neck, provide better head control but have an increased risk of choking the cattle (Grandin, 1975, 1980b). Both

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positive-type headgates and a curved-bar stanchion must be used with squeeze sides or some other apparatus to prevent the animal from lying down and choking in the headgate.

Types of Squeeze Sides

There are two commonly used designs to prevent animals from lying down in squeeze chutes. They are: (i) pivoting of the two squeeze sides on the floor so that they form a V- shape to support the animal; or (ii) brisket bars, which are used with squeeze sides that remain perpendicular to the floor when the squeeze is tightened (Daniels and Schmitz, 2003; Daniels *et al*., 2012). Perpendicular squeeze sides open up wide at the floor so that it is easier for large, fat cattle to enter and exit. The disadvantage is that cattle can easily lie down unless a brisket bar (sternum support bar) is installed on the floor. Brisket bars must never be used when the squeeze sides are hinged at the floor to form a V because the space between the sides is too narrow. Sides that form a V-shape are mechanically simpler to construct than sides that remain perpendicular. They work well unless cattle are very large and fat. Non-slip flooring is essential in all types of restraint devices. Cattle become agitated when they slip on the floor.

Hydraulic squeeze chutes

Hydraulically activated squeeze chutes have become increasingly popular. To reduce noise, the pump and motor should be removed and located away from the chute. Some squeeze chutes have plastic inserts to reduce noise and prevent metal-to-metal noise when the gates open and close. A properly adjusted hydraulic chute is safer for both people and cattle. Operator safety is improved because long, protruding lever arms are eliminated. However, the pressure relief valve must be properly set to prevent severe injury from excessive pressure. Injuries may include broken ribs and internal ruptures. Additional information on the proper adjustments can be found in Grandin (1980b, 1983b, 1990b). If an animal vocalizes (moos or bellows) immediately after it is squeezed in a hydraulic powered restrainer, the pressure setting must be reduced (Grandin, 2001; Bourquet *et al*., 2011). The valve must be set so that the squeeze sides automatically stop squeezing before excessive pressure is applied. This will prevent a careless operator from applying excessive pressure. Other indicators of excessive pressure are laboured breathing and straining.

If the chute has an additional hydraulic device attached to the headgate (Mollhagen, 2010) to hold the animal's head still, it must have its own separate pressure relief valve. Head-holding devices must be set at a pressure that is much lower than the pressure required to operate the squeeze.

Carelessness and rough handling are the major cause of injuries to cattle in squeeze chutes (Grandin, 1980a). Bruises directly attributable to the squeeze chute occur in 2–4% of cattle. In one study, bruises occurred in five out of seven feedlots, and 1.6–7.8% of the cattle had increased bruising compared with animals that had not been handled in the squeeze chute (Brown *et al*., 1981). Observations have also indicated that cattle can be injured when the headgate is suddenly closed around the neck of a running animal. Cattle should be handled quietly so that they walk into a squeeze chute and walk out. Hitting the headgate too hard can cause heamatomas and bruises. The shoulder meat may still be damaged when cattle are slaughtered.

Dipping Vats

In many places, dipping vats have been replaced with pour-ons, sprays and other types of pharmaceuticals. There are still some places where dip vats are used. Grandin, (1978, 1980a,c) developed an improved dip-vat entrance. Drawings can be found on www.grandin.com. Other useful publications are Hewes (1975); Texas Agricultural Extension Service (1979); Fairbanks *et al*. (1980); Sweeten (1980); Sweeten *et al*. (1982); Kearnan *et al*. (1982) and Midwest Plan Service (1987). The dip-vat system designed by the author can be seen in the HBO movie *Temple Grandin*. An exact working replica was built from the original drawings.

Conclusions

Low-stress handling of cattle and other livestock requires both skilled stock people and good equipment. Handlers need to understand the eight natural cattle behaviours that can be used for effective handling. Corrals and races should be designed to use natural behaviours such as cattle wanting to go back to where they came from. Restraint device operation requires extra care to prevent injuries and stress.

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Videos of Handling and Livestock

Due to licensing restrictions on YouTube, a number of these videos are not currently available outside the US. To access them from other countries, please search for the video title followed by the word 'video' using your preferred search engine.

National BQA, *Cattle Handling Tips: Facilities* – it shows three different types of handling facilities. They are: (i) small farm facility; (ii) round crowd tub; and (iii) Bud Box. Temple Grandin and Curt Pate demonstrate the round crowd tub. https://www.youtube.com/watch?v=qLW1vh39m9k

Temple Grandin, *Cattle Handling in Chutes and Races* – shows how to move cattle forward in a single-file race (chute) by walking in the opposite direction of desired movement. To motivate the animal to move forward, the handler needs to walk briskly past it, to prevent it from backing up. https://www.youtube.com/watch?v=RV10-Cyfx18

Temple Grandin, *Yard Demo at Beef Works* – shows quiet movement of cattle through a curved single-file race that has an open inner fence and a solid outer fence. It demonstrates how to work

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the flight zone. https://www.youtube.com/watch?V=cFa8k2rW2Ro

FarmQuip – Argentina has many new videos of cattle being handled in yards with both curved races and round crowd tubs, and portable systems with a straight single-file race. Three notable videos were uploaded in 2017. https://www.youtube.com/watch?v=e-8BE3MF78c

Instalacion en San Jorge Santa Fe Completo – shows aerial view of a large curved corral. https://www.youtube.com/watch?v=cFA8kznW2Ro

Corral Desmontable Farmquip – shows a portable corral with a simple straight race. https://www.youtube.com/watch?v=qRlgAktr6to

Farmquip Uruguay, *Installation ganadera* – shows a smaller curved system. https://www.youtube.com/watch?v=f8_LFJF24L4

Temple Grandin, *Proper Operation of Cattle Squeeze Chutes* – shows methods to improve the operation of squeeze chute (crushes). https://www.youtube.com/watch?v=5cUk9RH61Q

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6 Dairy Cattle Handling, Transport and Well-being

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Summary

Dairy cattle are handled intensively, especially when compared to other livestock production systems. The task of milking involves daily human interaction in varied measures dependent upon parlour design. The relationship between the stockperson and the cow is important. Calm handling should be practised by all stock people. Cows with smaller flight zones that do not fear people give more milk. Stock people working with bulls must be trained to recognize a broadside threat. Bulls that display a broadside threat towards people are dangerous and culling them is the safest option. Only cattle and calves that are fit for transport should be loaded onto a trailer. Other welfare-related tasks involving hoof trimming and stray voltage are important to consider.

Keywords: milking centre, behaviour, stockmanship, animal welfare

Introduction

The knowledge and understanding that stress impacts cattle have been known for many years (Whittlestone *et al*., 1970; Stephens, 1980; Grandin, 1997). In fact, W.D. Hoard, founder of *Hoard's Dairyman*, wrote, nearly 100 years ago, that loud, rough handling decreased the flow of milk. Fulwider *et al*. (2008) and Donegan (2011) report that cows that approach people have lower (better) somatic cell count and more milk production. In addition, Jack Albright stated that tame dairy cows that are willing to approach people will give more milk. Handling should be performed in a calm, safe manner, which will facilitate efficient animal movement, worker safety and a low-stress environment. The practice should be carried over to a low-stress manner to transport cattle as well. All animals should be evaluated before being shipped. An animal should never be transported if it is deemed unfit for transport.

This chapter is dedicated to Jack Albright. A great expert in the field of cattle behaviour who has recently died; we must never forget the plethora of knowledge that he has shared with the industry. Albright (1986a,b) reminds people that 'Humans and farm animals contribute to the mutual well-being of one another'.

Milking Centre Parlour Design

Until the advent of centralized milking centres, most cows were milked in their stalls. A disadvantage of this method is that it is labour-intensive and hard on the knees of those milking the cows. The idea of milking cows on an elevated herringbone platform originated in Australia (O'Callaghan, 1916; Albright and Fryman, 1964). Early US designs enabled a single person to milk two cows while seated on a swivel chair or to use elevated side-opening milking centres (Albright and Fryman, 1964). Due to labour shortages and high wages, New Zealand dairy farmers were motivated to develop rotary centres (Gooding, 1971). At the time, these turnstile systems were a great innovation, but they had high maintenance costs. During the 1970s, simple herringbone layouts with automated gates and milking

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machine detachers became popular, possibly due to shorter walking distances (Smith *et al*., 1998). Larger rotary milking centres are available for larger herds in the USA (see Fig. 6.1). Since 2000, Fair Oaks and other large dairies are milking their cows on 72-cow rotary milking centre platforms. Extensive time and motion studies have been conducted on different milking centre designs (Armstrong and Quick, 1986; Armstrong, 1992; Smith *et al*., 1998). More recent efficiency studies in rotary parlours, herringbone and parallels have been conducted by Carreira *et al*. (2013), Edwards *et al*. (2012) and Andersson (2014). Rotaries with 70–80 cows have greater operator efficiency than 60-cow rotaries (Edwards *et al*., 2013). The addition of automation, such as powered gates, has enabled simple designs – such as herringbones, trigons and polygons – to achieve greater labour efficiency than the early smaller rotaries. Good reviews of these simple designs of different milking centre layouts can be found in Reinemann and Rasmussen (2016), Reinemann (2013), Armstrong (1992) and Midwest Plan Service (2000).

The most common design used to be the herringbone, where two rows of cows were milked from a central pit. The parallel milking centre is a popular design in the USA. The milking machines are attached from the rear between the cow's legs instead of from the traditional side position. During milking, the cows stand at 90° to the pit. All the cows are released at once after milking by lifting either an entire row of stanchions or a long bar which runs in front of the animals. This design is more efficient than older-style herringbones, which did not have the rapid-exit feature. Herringbone milking centres with the rapid exit design combine some of the best features of both herringbones and parallel milking centres.

Training heifers and cows to enter

New heifers are easier to train to a herringbone and the cows can easily be milked from the side (Armstrong *et al*., 1989, 1990), especially with rapid-exit stalls (see Fig. 6.2). Cows should move

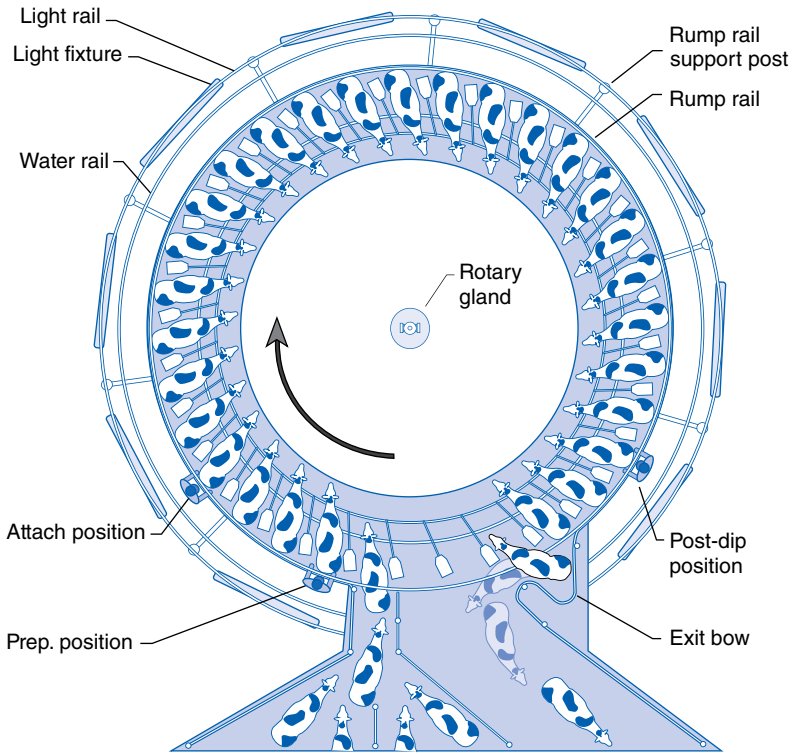


Fig. 6.1. Rotary parlour. Large dairies prefer rotaries with 70–100 milking units. A large rotary is more efficient than other small rotaries designed for 20–30 cows. (Courtesy of DeLaval, Inc.)

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Fig. 6.2. Herringbone rapid-exit brisket bar. The straight, rapid-exit brisket bar in a herringbone allows cows and heifers of various sizes to be milked together with ease and maximum comfort. Longer cows slide along the bar. Heifers may adapt more easily to being milked in a herringbone. Cows of varying age, size and infirmity may have difficulty making the sharp turn into a parallel milking centre. (Photo courtesy of DeLaval, Inc.)

easily and quickly into the milking centre. They have been observed to self-load with ease in large herringbone milking centres staffed by one milker (Fulwider, unpublished data). While one side was prepared and milkers attached, the cows on the other side loaded by themselves. In large milking centres where more than one milker is required, the tasks should be evenly distributed. Ceballos and Weary (2002) found that small quantities of feed reduced the need to push cows or use other interventions that might negatively affect the animals. The use of a powered crowd gate to make the holding pen smaller induces cows to enter the milking centre. Crowd gates should not be used to forcibly push cows or apply electric shocks. Automatic alley scrapers and crowd gates can cause injuries resulting in death or the need to cull cows prematurely. According to Fahey *et al.* (2002), the length of time in the holding pen from a short (40-minute) period to 120 minutes does not significantly affect production or stress indicators in the short term. A more recent study shows that longer waiting times may have detrimental effects on welfare (Dijkstra *et al.*, 2012). In fact, the regular milking order in which cows are milked daily may have a greater effect than once thought. Beggs *et al.* (2018) reported that in larger dairies that bring up large groups to be milked, the cows milked towards the end will ultimately wait longer. This can decrease the laying and eating times for those cows compared to cows milked earlier.

Proper training of cows and of milking centre operators will also improve the efficiency of movement through the facility. Cows should be encouraged to enter voluntarily without prodding. The milker should avoid leaving the pit to chase the animals because this conditions them to wait for the milker to chase them into the milking centre. Cows also have individual preferences for music, weather, certain people and which side of the milking centre they will enter (Albright *et al.*, 1999). There is a need to engineer quieter equipment. Arnold *et al.* (2008) found that when heifers were given a choice, they avoided a maze arm that had a tape-recorded milking parlour noise. Other methods of encouraging cattle movement, especially when entering the parlour, have been explored. Research has shown that the use of conditioning cows to acoustic sounds for a feed reward may be beneficial for encouraging movement (Russell *et al.*, 2017). Russell *et al.* (2017) also reported that this type of sound-calling encouraged faster movement when groups of cows were called, compared to calling individual cows. A study with Brown

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Swiss heifers, found that implementing a training protocol pre-lactation helped habituate heifers to the milking routine. It also led to less stepping and kicking during the udder preparation phase (Kutzer *et al*., 2015). The use of tactile stimulation in heifers before calving reduced reactivity to the milker and increased milk production (Néri *et al*., 2016). Pre-partum udder massages for 30 sessions in primiparous heifers were shown to reduce fear as shown by a lower incidence of urination and defecation and a lower temperament score related to gentle behaviour (Das and Das, 2004). Since cows are creatures of habit, consistency is imperative from one milking to the next.

Worker ergonomics and safety

In dairy operations, worker safety is really important. There is increasing concern about repetitive motion injuries in milkers (Douphrate *et al*., 2012). The task of milking cows every day is a physically demanding, repetitive task that can cause strain or injury with long periods of work over time. In fact, milking tasks have been shown to increase the risk of experiencing musculoskeletal symptoms and musculoskeletal disorders (Douphrate *et al*., 2016; Mixco *et al*., 2016). The increase in herd sizes, especially in the USA has led to increased muscle activity during milking compared to smaller herd sizes (Masci *et al*., 2016). Muscle activity is the amount that muscles are used in performing specific tasks.

The working height, which is defined as a ratio of the worker's height to the udder base height, is critical when considering the workload of the dairy worker. A lower working height results in a decreased muscular load (Cockburn *et al*., 2017). A parlour designed at the height of the udder, at or above the shoulder height of the worker, may reduce back and neck strain (Oyama *et al*., 2017). A milking health formula uses milker (worker) height, average herd udder height and parlour type to calculate the ideal depth of the pit in order to help reduce the musculoskeletal workload for workers (Cockburn *et al*., 2015). Additionally, special attention should be paid to the amount of space between the animal and the worker (Jakob and Liebers, 2017). When the distance is too great, extra stress may occur because the worker has to overreach to place the milker on the udder. Ideally, the cow's teats should be at the worker's shoulder height and the milking cluster should be lightweight (Jakob *et al*., 2012). Parallel parlours have been shown to be more physically demanding than a herringbone design (Oyama *et al*., 2017). Milking from the side, which occurs in a herringbone design, allows for decreased muscular exertion compared to milking from behind, which occurs in a parallel parlour design. Furthermore, a rotary parlour design requires lower muscle activity and a higher percentage of muscular rest compared to both the herringbone and parallel parlour designs (Douphrate *et al*., 2017). Workers in a rotary parlour experienced lower muscle activity and increased muscular rest, which results in an easier milking task.

A small study conducted on several Colorado dairy farms determined that a majority of workers are in favour of occupational health and safety management systems (OHSMS) to potentially help prevent injury on dairy farms (Autenrieth and Román-Muñiz, 2017). The primary workforce on US dairies are immigrants, usually Latino. There may be a need to create guides for occupational safety and health training with consideration for different cultures (Menger *et al*., 2016). Other countries and cultural backgrounds view animal production in different perspectives, and they may speak different languages. Clear communication is important to ensure that concepts are completely understood and performed in the correct manner. Worker safety and calm animal handling is especially important.

Behaviour and Management of Dairy Cattle

Albright (1978), Seabrook (1980) and Hemsworth *et al*. (2000) have all shown that animal behaviour differs among dairy herds. Gentle stroking on the same parts of the body where a mother cow licks her calf or cows groom each other is beneficial (Schmied *et al*., 2008a,b; Sharin, 2018). One factor that varies, both within and between groups of cows, is flight distance or how close one can approach an individual animal without it moving away. In some dairy herds this distance may be almost zero, whereas in others it may be as great as 6 m. One study indicated that the cows' flight distance was larger on dairies where there were more negative interactions such as yelling or hitting (Hemsworth *et al*., 2000). It has been recognized that the dairy cow's productivity can be adversely affected by discomfort or maltreatment. Aversive handling can result in a generalized fear of humans, making handling more difficult and increasing the chances of injury to both

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animal and handler (Seabrook, 1991; Table 6.1). This fear can be overcome by positive handling.

Discrimination was generalized to other locations, and cattle appear to be more fearful of humans in an unfamiliar location (de Passillé *et al*., 1996). In order to determine if an aversion corridor could be used to evaluate various handling practices, 60 cows were randomly assigned to five different treatments: electric prod, shouting, hitting, tail twisting and control. Cows walked down a corridor and treatments were applied at the end of the corridor. The results suggest that cows found the electric prod most aversive, followed by shouting, hitting, tail twisting and control (Pajor *et al*., 1999). In a follow-up experiment, 54 cows were randomly assigned to four treatments (hit/shout, brushing, control and food). The time and force required for cows to walk down the corridor were measured. Cows on the hit/shout treatment took more time and required more force to walk through the corridor than cows on other treatments ($P < 0.001$). In addition, brushed cows took longer to move through than cows given food ($P < 0.05$) (Pajor *et al*., 1999). Aversion-learning methods show promise as an effective method of determining which handling procedures cows find more aversive or friendly.

Alert handlers have the perception and ability to read 'body language' in animals. For example, healthy calves and cows will exhibit a good stretch after they get up, then relax to a normal posture. Increased standing of cattle is now often taken as a sign of discomfort or discontent in studies of cow and calf confinement (Albright, 1987). Cattle under duress show signs of distress by bellowing, butting or kicking. Behavioural indications of adjustments to the environment are always useful signs of whether the environment needs to be improved. In some cases, the way animals behave is the only clue that stress is present (Stephens, 1980; Albright, 1983). Step behaviour and heart characteristics were examined in multiparous dairy cows that showed that the task of milking itself was not stressful for the animals (Kézér *et al*., 2015), though, increased stepping behaviour and decreased parasympathetic tone index of the high-frequency component occurred during the waiting period after milking compared to the period of udder preparation before milking, which shows that this may be a sensitive time for animals (Kézér *et al*., 2015). Looking-up (head up) behaviour in the holding pen has been linked to low motivation to be milked due to fear of humans (Ishiwata *et al*., 2005). This behaviour was most common in cows during third lactation and under. It is positively correlated with flight-zone distance and milking centre entrance order, and negatively correlated with productivity. Clues to a cow's mood and condition can be obtained by observing the animal's tail. When the tail is hanging straight down, the cow is relaxed, grazing or walking, but when the tail is tucked between the cow's legs, it means the animal is cold, sick or frightened. During mating, threat or investigation, the tail hangs away from the body. When galloping, the tail is held straight out, and a kink can be observed in the tail when the animal is in a bucking, playful mood (Kiley-Worthington, 1976; Albright, 1986a; Albright and Grandin, 1993; Albright and Arave, 1997). According to Kiley-Worthington (1976), when studying the cause and function of tail movement it is necessary to consider the whole posture of the animal as well as the contexts that give rise to it. In cattle (and horses), the immediate association one makes with lateral tail movements is with cutaneous irritation. In these species there are morphological changes of the tail that point to its use as a fly switch.

There is new data on cows and grooming. Cows with access to motorized brushes have a glossier hair coat than others. The second author has observed that animals will actively seek out the motorized brush and apply it to many parts of the head and body (see Fig. 6.3). Recent research shows that dairy cows are highly motivated to use the brush (McConnachie *et al*., 2018). If a cow is either sick or lame, she is less likely to use a brush that is located

Table 6.1. General response of dairy animals under different handling treatments. (From Seabrook, 1991 and Seabrook 1972, 1977, 1980)

Action of Cow	Pleasant Handling	Aversive Handling
Mean entry time to milking centre (s/cow)	9.9	16.1
Flight distance (nervousness)(m)	0.5	2.5
Dunging in milking centre (times/h)	3.0	18.2
Free approaches to humans (times/min)	10.2	3.0

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far away from the feedbunk (Mandel *et al*., 2017, 2018). Producers reported that cows without access to an automatic brush during the drying period would spend a few days at the brush upon return to the milking barn. Cows were also reported to spend time at the brush immediately after calving. The second author noted that some dairies that did not wish to invest in multiple brushes often placed a single one in a common walkway.

Social Behaviour during Milking and Handling

Dairy cattle are social animals that function within a herd structure and follow a leader to and from pasture or the milking centre. Cows exhibit wide differences in temperament, and their behaviour is determined by inheritance, instinct, physiology, hormones, prior experience and training. Cows are normally quiet (non-vocal) and thrive on gentle treatment by handlers. Handling procedures are more stressful for isolated animals; therefore attempts should be made to keep several cows together during medical treatment, artificial insemination or when moving cows from one group to another (Whittlestone *et al*., 1970; Arave *et al*., 1974). Cattle should have visual contact with each other and with their caretakers. Mixing multiparous and uniparous cows should be avoided, as this disrupts normal social behaviours and causes reduced milk yield.

Cows consistently entering one side of the milking centre were more fearful in novel situations than less consistent herdmates. The consistent cows were also more successful in accessing food resources (Prelle *et al*., 2004). Paranhos de Costa and Broom (2001) have reported that there was no evidence of discomfort or poor welfare even when highly consistent cows were milked on their non-preferred side. Grasso *et al*. (2007) observed that 72% of the cows had no side preference. Many dairymen allow their cows to develop their own individual personalities as long as no special care or treatment is



Fig. 6.3. Cows seek out the motorized brush to broom themselves. It is well worn and less than a year old. This brush is located in the walkway and accessible to 400 cows as they enter and exit the milking centre. Producers who have provided motorized brushes for their cows report that cows spend the bulk of their free time for days at the brush if they have been previously kept in a pen without one (e.g. during the day period). Cows that have access to a brush in the calving pen may seek comfort by the brush immediately after calving. Producers who provide a brush for cows in each pen claim that use of the device results in cleaner, glossier cows. Some producers have chosen to mount a brush in the walkway to be accessed as cows approach and return from the milking centre. (Photo Courtesy of Temple Grandin)

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required. Mass handling of cows dictates that individual cows fit into the system rather than the system conform to the habits of the cow. The slow milker, the kicker, the boss cow, the timid cow, the explorer and the finicky eater are usually removed from larger herds, regardless of pedigree. Although concern is expressed from time to time about temperament and behavioural problems, most attempts at reinforcing correct behaviour and disciplining improper behaviour have been successful. One dairy study showed that behaviour as a reason for disposal occurred in less than 1% of cases (Albright and Beecher, 1981; Albright, 1986c). Although creatures of habit, gentle dairy animals may be prompted into rebellion by the use of unnecessarily severe methods of handling (e.g. shouting and shock prods) and restraint. Attempts to force an animal to do something it does not want to do often end in failure and can cause the animal to become confused, disoriented, frightened or upset. Handling livestock requires that they be 'outsmarted' rather than outfought and that they be 'outwaited' rather than hurried (Battaglia, 1998). Most tests of will between the handler and the cow are won by the cow.

Cattle Behaviour Pertaining to Specific Groups of Animals

Bulls

According to Sheldon *et al.* (2009), bulls have probably been responsible for more livestock-related injuries and fatalities to human beings than any other domesticated animal apart from the horse. Bulls continue to contribute to an unacceptable number of injuries and deaths. Following an increase in the number of bull-attack cases in 2006, identified during routine surveillance of agricultural work-related injuries, a search of agricultural injury data was initiated to gain a better perspective. Approximately three years' worth of data, gathered from daily reviews of online sources plus a review of more than 12,000 prior injury reports, were combined, coded and summarized. A total of 287 cases, primarily from the USA were documented and analysed (Sheldon *et al.*, 2009). Contributing factors identified, where available, were age of victim, type of bull, handling facilities, handler experience and time of year. The risk of injury tends to be associated with:

- handlers with more hours of exposure to bulls than working with cows;
- the risk of bull-related fatalities based on the hours of exposure appears to be higher than other known hazards such as operating tractors;
- victims for the most part had considerable experience working with bulls;
- bulls raised and kept on the same farm appeared to be more aggressive;
- during most incidents the victim has been inside the bull holding area.

The safety of humans and animals is the chief concern underlying management practices. By virtue of their size and disposition, dairy bulls may be considered one of the most dangerous domestic animals. Management procedures should be designed to protect human safety and provide for bull welfare.

Threat postures

There are certain major behavioural activities related to bulls. These are threat displays, challenges, territorial activities, female-seeking and directing (nudging) and female-tending. These behavioural activities tend to flow from one to another (Fraser, 1980). Threat displays in bulls and ungulates (e.g. antelope, bison) are a broadside view (see Fig. 6.4) when a person or a conspecific invades its flight zone.

The threat display of the bull puts him in a physiological state of fight-or-flight. The threat display often begins with a broadside view with back arched to show the greatest profile, followed by the head down – sometimes shaking the head rapidly from side to side, protrusion of the eyeballs and piloerection of the hair along the dorsal line. The direct threat is head-on, with head lowered, shoulders hunched and neck curved to the side toward the potential object of the aggression. Pawing the ground with the forefeet and sending the earth flying behind or over the back – as well as rubbing or horning the earth – are often components of the threat display. If in response to the threat display the recipient animal advances with head down in a fight mode, a short fight with butting of horns or heads ensues. If the recipient of the threat has been previously subdued by that animal, he will probably withdraw with no further interaction (Albright and Arave, 1997). While a bull is showing a threat display, if an opponent such as another bull (or person) withdraws to about 6 m, the encounter should

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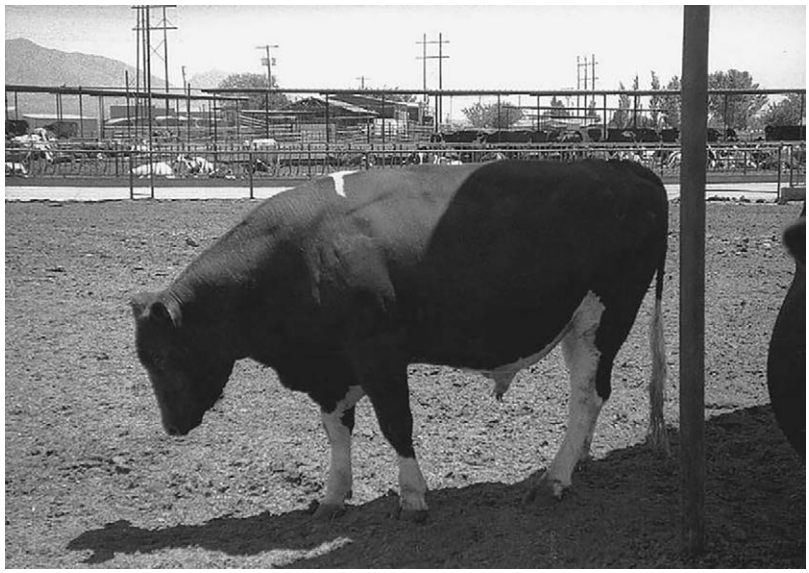


Fig. 6.4. Broadside threat display is a warning that a human has invaded his territory. A direct threat is head-on with head lowered, shoulders hunched and neck curved to the side. Bulls that display broadside threats towards people are dangerous and should be either culled or sent to a secure bull stud. (Photo courtesy of Jack Albright)

subside and the bull will turn away. If not, the bull will circle, drop into the cinch (flank) body position or start with a head-to-head or head-to-body pushing. At the first sign of any of the above behaviours, humans should avoid the bull and back away quickly – hopefully via a predetermined route. Do not turn your back and run; the rapid movement of running may cause the bull to attack. Many people lack the background, attitude and awareness of dealing with dangerous bulls and parturient cows; therefore, additional training and bull/cow behaviour information are needed. It is wise to respect and be wary of all bulls – especially dairy bulls – as they are not to be trusted. Every bull is potentially dangerous. Bull attacks are the number-one cause of livestock handler fatalities. He may seem to be a tame animal, but at any time he may turn and severely injure or perhaps kill a person, young or old, inexperienced or experienced. This is especially true when a cow is in oestrus and needs to be removed from 'his' group or the group is moved to the holding pen for milking (Albright, 2000). Never handle the bull alone. For self-protection, when moving cattle, attempt to appear larger and carry a cane, stick, handle, metal pipe or plastic pole with flap. To reduce the tendency of bulls to attack people, bull calves must be raised in a social group to prevent them from imprinting on people. Bull calves should either be raised together in a pen starting at six weeks of age, or on nurse cows. The most dangerous bull is the bull calf that was reared alone, away from other cattle (Price and Wallach, 1990). Bull accident reports indicate that a young bull is most likely to start attacking people when he becomes mature at 18–24 months of age (Temple Grandin, personal communication, 2006). It is important to recognize the broadside threat. Bulls that display either a broadside or direct threat towards milkers should be immediately culled before they kill or injure someone. For further information about bull behaviour and handler safety refer to Albright and Arave (1997).

Other dairy animals

In addition to bulls, humans must be careful around certain steers, heifers and recently calved cows protecting their calves. Some animals are different and do not follow the threat display behaviour previously mentioned. Be careful of following behaviour, walking the fence, bellowing, a cow in oestrus and the bull which protects the cow, thereby attacking the handler. A bull's first attack should be his last and he should be sent to the abattoir (Wilson, 1998). The system of management under which dairy cattle are raised and kept has a

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profound effect on their temperament, and this is not always taken into consideration. For example, bull calves should never be teased, played with as a calf, treated roughly or rubbed vigorously on the forehead or the area of the horns. Pressing or rubbing on the forehead should be avoided because this encourages butting. The Fulani herdsmen stroke under the chin (rather than on top of the head) as an appeasement, taming and grooming-type behaviour. This is essentially the way cows groom each other (Hart, 1985; Albright and Grandin, 1993; Albright and Arave, 1997).

Handling and Transport Tips

1. When loading dairy animals for shipping, allow plenty of handling space. Cattle need ample room to turn; the leaders will then move into the chute with other animals following. This is an example of leading–following, as in cattle or sheep, goats and ducks.
2. Stair steps are recommended for concrete loading ramps. Each step should be 10 cm high with a 30 cm tread width.
3. Loading ramps for young stock and animals that are not completely tame should have solid sides. Non-slip flooring should be used for all types of handling facilities, especially during loading and unloading.
4. Never attempt to transport cows that become emaciated or too weak to stand. If rehabilitation does not occur within a reasonable time, the animal should be humanely killed on the farm (Livestock Conservation Institute, 1992; American Association of Bovine Practitioners, 2013). More details may be found in Agriculture Canada (1990) and OIE (World Organization for Animal Health) (2018).
5. When transporting young dairy animals or lactating cows, always handle them gently. Since cows are curious, allow them to quietly investigate their new environment and ease into it without outside distractions.
6. Try to ship dairy animals under favourable weather conditions. Avoid extremely hot or extremely cold temperatures that create undue stress and may cause sickness. Dairy producers have much to gain when cows and young stock are properly handled and cared for (Albright and Grandin, 1993). Palmer (2005) has compiled valuable information on animal-handling needs including methods, locations and possible systems.
7. Ensure that the trailer provides ample space for the size and number of animals being transported. Lambooji *et al.* (2012) suggest that allowing 20 cm above the withers in a trailer compartment may decrease the period of head-butting in cattle.

Handling and transport of newborn calves

Calves require special handling and care from the time they are born. The most important point to remember is to feed the newborn calf colostrum soon after birth and within the first 6 hours. A Holstein calf should be given 8–10% of its body-weight in fresh colostrum by bottle, bucket or tube feeder; twice within 24 hours following birth. Colostrum is nutrient-rich and provides the calf with vital immunoglobulin. Neave *et al.* (2018) found that calves that exhibited more exploratory and active behaviours started to eat calf starter at a younger age, which further led to greater starter dry-matter intake and higher average daily gain. Good nutrition, along with proper handling, starts a calf on its way towards a healthy life. Housing also has an impact on calves. Individually, crate-housed calves showed a greater increase in plasma and saliva cortisol levels as compared to group-housed calves after handling and transport.

Human interaction during the early stages of life can have a large impact on calves. Veal calves that are provided with routine human contact (i.e. stroking) tend to be less fearful of humans (Lensink *et al.*, 2000a,b). A small dairy study performed in Norway with Norwegian Red calves showed that stock people that use patient handling involving petting and calm voices tend to experience greater levels of positive moods (Ellingsen *et al.*, 2014). There is a link between both calf and human behaviour in relation to both animal and human welfare. Calves can discriminate between different people, especially involving positive versus aversive handlers. Fear can result from aversive handling but can be overcome with positive handling (de Passillé *et al.*, 1996).

If young calves are to be marketed, the following three procedures should be used:

1. Provide individual care and colostrum for two to three days after birth.
2. Calves should always have a dry hair coat, dry navel cord and walk easily before being transported either to auctions or travelling long distances. A one-day-old calf can stand, but it is unsteady and

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wobbly and is not ready for market (Albright and Grandin, 1993). In the UK and Canada, the sale of calves less than a week old is forbidden. Calves should not be brought to a livestock market until they are strong enough to walk without assistance. To reach adequate strength and vigour, calves need to be a minimum of five days old (Grandin, 1990). Jongman and Butler (2012) report that nine- to eleven-day-old Holstein dairy calves are easier to move than three- to five-day olds, pertaining to time to move and the requirement of assistance. If the calves are going to be transported to a nearby specialized calf rearing facility, they can be transported sooner, but the necessary precautions should be taken to do so, such as not transporting in temperature extremes and allowing room to lie down if necessary while in transit.

3. Handle calves in transit carefully, protecting them from the sun and heat stress in the summer, and from the cold and wind chill in winter.

Transport is particularly stressful for young calves, which experience mortality rates greater than 20% and bruised stifles to an incidence of 50% or more (Hemsworth *et al*., 1995). Adverse effects of transport of young calves can be controlled by several known modulators (yeast cell-wall products) and ascorbic acid, thereby decreasing morbidity and mortality (Eicher *et al*., 2004; Eicher, 2006, personal communication). Eicher (2001) further indicates that attention must be paid to length of studies regarding young calves, as they may succumb to disease one month following transport.

The Implications for Animal Welfare

In the herd where there is a good relationship between humans and cows, production is higher, flight zones are smaller and the cows move into the milking centre more quickly. The cows also release less adrenalin to block milk let-down. They are less nervous, more settled and steady in an environment created by a confident handler. From an animal welfare point of view, the pertinent point is that these are not necessarily the best-equipped herds, technically, e.g. in milking centre design. Cow behaviour that indicated fear of humans was moderately ($P < 0.05$) to highly ($P < 0.01$) correlated with production and composition. By regression analysis, fear of humans accounted for 19% of variation in milk yield between farms (Breuer *et al*., 2000). In other words, cows may be under stress in a well-designed system if they cannot develop a good relationship with people. Similarly, they may be in a poor system, but may be content and under little stress if they have confidence in and a good relationship with the person who tends them. Efficient dairy management and animal welfare would both be served by selecting cow handlers who have the correct traits, and then further by training them to develop a relationship with their animals, thus ensuring that the animals are able to live in an environment where stress is reduced to a minimum. Design of a system from a welfare perspective is only part of the solution. There are now in place national programmes that provide animal welfare assessments or audits of dairies. An assessor will use many tools such as guidelines, tape measure, stopwatch, a body condition scorecard, locomotion score card and a hygiene score card (Roenfeldt, 2005).

Hoof trimming

Hoof trimming is performed on dairy cattle to maintain healthy hoof and claw health. This practice aims to optimize the appropriate weight allocation and function of the hooves. Regular trimming can help to prevent uneven wear, claw lesions and lameness. Current practice usually involves two main types of restraint systems for hoof trimming. A walk-in- or stand-up-style restraint involves the animal being able to walk into the restraint and remain standing. The feet are trimmed by a pulley system to suspend each foot in the air. Another type of restraint is a tilt table, in which the animal is inverted and restrained on its side so that all four feet are easily accessible to the hoof trimmer. Both systems have positive and negatives aspects pertaining to animal handling and behaviour. Significantly less time was required to perform claw trimming and fewer escape movements were observed when a cow was restrained with a tilt table as compared to a mobile walk-in crush system (Pesenhofer *et al*., 2006). On the contrary, another study found that cattle were less stressed based on distress responses when restrained in a stand-up-style chute versus the tilt table (Spasov *et al*., 2010). Distress during restraint may be more related to design faults of the particular restraint device than to the position of the cow. The restraint device used must facilitate 'optimal pressure'; the animal should feel enough restraint to remain calm and still, but not such excessive restraint that the pressure causes pain and/or injury to the animal (Grandin, 1992). Pinch points must also

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be avoided. Training cattle to be restrained in hoof-trimming systems can help to reduce the stress.

Handling types and handler attitude can play a large role in the impact that a hoof-trimming event has on cattle. A study performed in Sweden found that injury risk increased when moving cattle to hoof trimming as compared to milking (Lindahl *et al*., 2015, 2016). This suggests that minimizing the cow's fear and stress with calm handling techniques to hoof trimming is critical to both animal and worker safety.

Other Dairy Welfare Topics

Stray voltage from milking equipment

Stray electrical voltages from malfunctioning electrical equipment can cause discomfort to dairy cows and lower milk production (Rodenburg, 1998). Numerous research studies have quantified the physiological and behavioural responses of dairy cattle to electrical currents (Lefcourt, 1991; Aneshansley *et al*., 1992; Hannah, 2002; Erdreich *et al*., 2009; Reinemann *et al*., 2005). The electrical currents required for perception, behavioural change or physiological effects to occur are widely variable. Dairy cows can feel very low voltages of only 1 volt when they occur between a water bowl and the rear hooves (Gorewit *et al*., 1989). A short-term, four-week exposure time to 3 mA or less did not affect production (Erdreich *et al*., 2009). Reinemann *et al*. (2005) stated that the current level required to produce a behavioural response was less than that required to cause a short-term reduction in feed and water intake and milk production. Some cows in the study responded by submerging the entire muzzle in the water bowl, effectively providing a larger contact surface area while reducing the maximum local current density in the muzzle. Reinemann *et al*. (2004) also noted that if cows have adequate time to consume water between current pulses, water was consumed at the same rate as in the absence of any current stimulus. The sources of relatively small amounts of electrical currents passing through animals are often very difficult to locate. Stray voltage or electrical currents may arise because of poor electrical connections, corrosion of switches, frayed insulation, faulty equipment or heavily loaded power lines. Information on how to detect and correct stray voltage problems has been available for some time (Appleman, 1991). Periodic evaluation of facilities for stray voltage is suggested. Solutions include voltage reduction, control of sources of voltage leakage, gradient control by use of equipotential planes and transition zones, and isolation of a portion of the grounding or grounded neutral system from the animals. Proper installation of electrical equipment and complete grounding of stalls and milking centre equipment should help prevent stray voltage problems. Although stray voltages and electrical currents cannot be totally eliminated, they can be reduced (Albright *et al*., 1991; Lefcourt, 1991; Gorewit *et al*., 1992). Graves (2006) concludes that stray voltage must not be used as an excuse for poor management practices that cause low milk production or high somatic cell counts.

Conclusions

Dairy farms are settings for daily cattle handling and transport events. All stock people must be trained and knowledgeable pertaining to appropriate handling techniques and tools. Low-stress handling should be practised. Transport and all loading/unloading that is involved should be performed by trained drivers and handlers too. Observation of dairy cattle has been going on for centuries and helps to increase knowledge and improves husbandry techniques. A logical approach to the study of cow behaviour is now advocated, linking it to dairy herd management in commercial operations. Knowledge of low-stress handling, transport fitness and normal behaviour patterns provides an understanding about cattle and results in improved management and handling that will achieve and maintain higher milk yields, animal comfort and well-being.

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Due to licensing restrictions on YouTube, a number of these videos are not currently available outside the US. To access them from other countries, please search for the video title followed by the word 'video' using your preferred search engine.

National Dairy Farm Program, *Dairy Stockmanship* – excellent new video that demonstrates behavioural principles of handling dairy cows. https://www.youtube.com/channel/UC3N-BiUEYldTTftFhTQdEqg

Dairy Master, *Stainless Steel Rotary Milking Parlor in Little Falls, New York, USA* – 50-stall parlor with grain feeders, posted July 1, 2016. https://www.youtube.com/watch?v-FYQcJhUOuNs

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Dairymaster, *50 point Rotary Parlous (Netherlands)* – posted July 23, 2015. https://www.youtube.com/watch?v=H46tJH_Hy1

Farm Journal Milk, *GEA Dairy Pro Q Robot Rotary* – shows a rotary milking parlor with robots from GEA Group, based in Germany. Posted September 26, 2014. https://www.youtube.com/watch?v=Z1ooALds_Fc

Pearson Milking Technology (Ireland), *Pearson Milking Technology Rapid Exit* – great video that shows how cows enter and leave parallel milking parlor. Posted November 7, 2017. https://www.youtube.com/watch?v=VWLW_xo-52c

Dairy NZ, Niel Chesterson, *Milk Smart Improving Cow Flow* – discusses the importance of gentle handling and how cows may fear people who make excessive noise. He also discusses the correct speed for power crowd gates. https://www.youtube.com/watch?v=XUnzfh9JpPM

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7 Robotic Milking of Dairy Cows: Behaviour and Welfare

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Summary

This chapter describes cow behaviour, health and welfare in dairy herds using robotic (automated) milking systems (AMS). We discuss three key aspects of milking that differ in AMS herds compared to conventional systems, and their implications for cow behaviour and welfare. We review the automation of the milking process itself, followed by the fact that milking is done individually, instead of in groups. Finally, we discuss how to motivate cows to visit the robot voluntarily or to direct them using different traffic systems. With each of these aspects and their associated challenges, we provide management recommendations to improve cow behaviour and welfare in robotic milking herds.

Introduction

Milking with single-box automated (robotic) milking systems has revolutionized the way we manage milk dairy cows. Cows walk to and from the milking box where they are milked and fed a supplemental feed (Fig. 7.1). Each unit can milk 50–60 cows (Hulsen and Rodenburg, 2008; Jacobs and Siegford, 2012a), and as with any technology, AMS will be the most efficient if the robot is not overstocked with too many cows. The robotic arm completes all the necessary milking tasks, from preparation to post-milking teat disinfection. Most often, a cow must be supervised during her first milking of each lactation, to teach the robotic arm where her udder is, and after that it remembers the location and uses lasers to position itself correctly. If cows visit the AMS too soon after their last milking, the AMS will refuse them, ensuring that cows are not milked too often. On the other hand, if cows do not visit the AMS enough, farmers are electronically alerted and must go and fetch those cows. Usually, farmers move cows in need of milking into a small holding pen near the robot with one-way gates to ensure that cows go through the robot to be milked. After milking, cows can then return to the main group, which can be separated into multiple pens, or into a smaller pen behind the robot, such as a special needs or fresh cow pen.

There are two basic systems of traffic flow in robotic milking barns. First, free cow traffic allows cows to freely move between feeding areas, rest areas, drinkers and milking areas (Fig. 7.2). As we discuss later, this design is better for cow freedom, health and behaviour, but may require producers to fetch more cows. The second option is guided or directed traffic, which controls the movement of cows between areas of the barn and reduces the need to fetch cows. Milk-first systems guide cows from the lying area through the robot to access feed (Fig. 7.3). Feed-first systems direct cows from the feed bunk and through the robot on the way to the rest area (Fig. 7.4). Selection gates can be installed just before the milking area in both free and guided systems to avoid congestion in holding areas and reduce wasted robot time spent sorting cows who are ineligible to milk. In intermediate designs, cows may have free access to and from feed until eligible to milk again. Selection gates may also route cows to concentrate feeders after milking. One-way gates

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Fig. 7.1. An automated milking system (AMS) from inside the 'robot room'. The robotic arm is responsible for all milking tasks, including teat preparation, milking and post-milking disinfection. During milking, the cow consumes a supplemental feed provided in the AMS, which is dispensed into a bowl at the front of the milking stall.

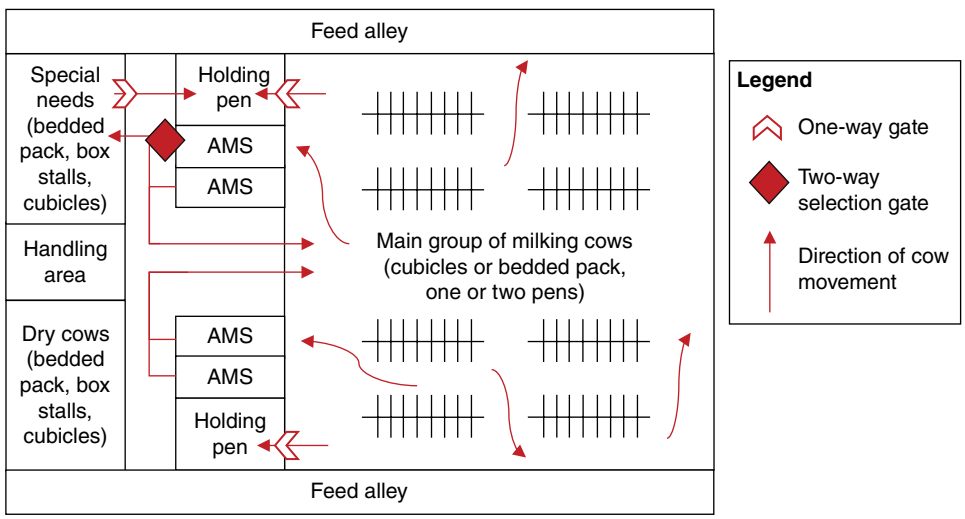


Fig. 7.2. Diagram of free cow traffic design with four milking units.

can be used to guide cows in one general direction throughout the barn, with or without controlling access to certain areas.

As of 2014, over 25,000 farms, globally, were using AMS (Barkema *et al.*, 2015) and this number continues to grow. In Europe, AMS is most popular in the Netherlands and Nordic countries, where 10–20% of farms are using AMS (Barkema *et al.*, 2015). In Canada, 10% of herds use AMS (Canadian Dairy Information Centre, 2017). Benefits of AMS

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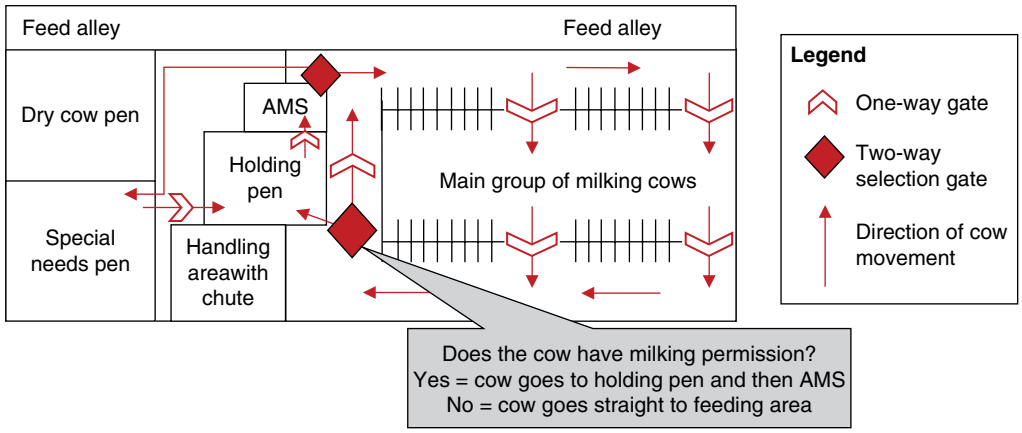


Fig. 7.3. Diagram of milk-first traffic design with one milking unit.

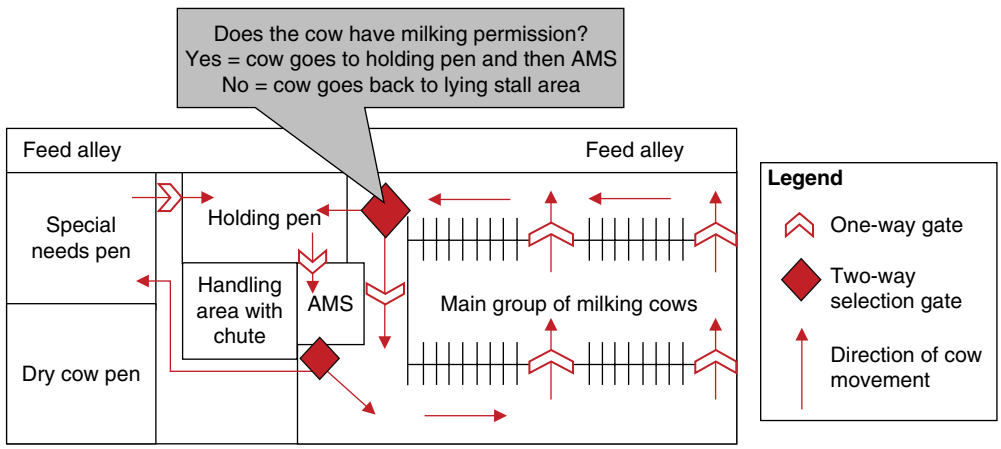


Fig. 7.4. Diagram of feed-first traffic design with one milking unit.

adoption for dairy producers include reduced stress and labour requirements and greater time flexibility (Tse *et al*., 2018), such as having opportunities to eat meals with the family and attend events without scheduling around milking times. The reduction in labour and modification of how time is spent in the barn is helping smaller family farms, and those wishing to grow remain functional without hiring outside labour. When deliberating between investing in a milking parlour or an AMS unit, producers must consider the decreased labour requirements of the AMS versus the increased fixed costs and depreciation differences (Bijl *et al*., 2007). Typically, AMS has the greatest potential economic benefit for the 50- to 120-cow dairy (Rotz *et al*., 2003).

In terms of benefits for cow behaviour and welfare, AMS gives cows more choice and freedom to control how they spend their time and perform desired behaviours (Jacobs and Siegford, 2012a). Within the three-pillars framework for animal welfare (Fraser *et al*., 1997), AMS has a large impact on *basic health and functioning*, and they can also influence *affective states* and *natural behaviours*. In a recent survey, 66% of producers reported that, after transitioning to AMS, they changed their health management strategy, and 80% of producers found illness detection to be easier than before because of the AMS and the associated health monitoring software (Tse *et al*., 2017). Therefore producers must learn to interpret AMS data

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correctly, and AMS reports must provide timely, valid and actionable information. Management skills must become more technology-based as dairy producers spend more time viewing data when making management decisions.

Managing cow welfare with AMS requires adaptation of conventional management techniques and consideration of new strategies. Three key aspects of the milking process differ in AMS herds compared to conventional systems and will be discussed in this chapter: (i) milking is automated; (ii) cows are milked and offered supplemental feed on an individual basis; and (iii) milking times are unscheduled and variable. Each aspect has positive and negative ramifications for cow behaviour and welfare, and proper management is crucial in maintaining a productive and healthy herd.

Key Aspect 1: Automation of Milking Procedures

In theory, automating the milking process provides more consistency in the implementation of milking protocols and a more predictable experience for cows in comparison with human workers using conventional milking equipment (Svennersten-Sjaunja and Pettersson, 2008). Research comparing cows' physiological and behavioural stress responses in conventional parlour milking and AMS have reported no conclusive differences (Hopster *et al*., 2002; Wenzel *et al*., 2003; Jacobs and Siegford, 2012a). Therefore, there has been no evidence to suggest that AMS impairs welfare or causes greater stress for cows.

Milking in AMS is quarter-based, such that each quarter is milked for less time and teat cups release at the quarter level when milk flow drops below a certain threshold. This, and the fact that AMS flushes teat cups between cows, reduces the risk of over-milking, the spread of bacteria between quarters through the milking claw, and the risk of intramammary infection. The extent to which liner slippage occurs in AMS is unknown, but less over-milking should reduce slippage (Hogeveen *et al*., 2001; Hovinen and Pyörälä, 2011). Quarter-based milking also better mimics the natural sucking that would be performed by a calf. However, AMS is unable to determine udder shape and cleanliness as well as a manual operator, which could decrease the effectiveness of pre- and post-milking teat disinfection (Edmondson, 2012). Another disadvantage is that AMS does not dry teats after washing, nor can it forestrip teats as well as a manual operator.

Often, the transition to robotics comes with other changes such as transferring to an entirely new barn or transitioning from tie-stall facilities to a free-stall barn. To control for this, Hovinen *et al*. (2009) compared herds switching from tie-stall to free-stall barns and herds switching from tie-stall or free-stall systems to AMS. Although udder health declined in the short term for all farms, the transition in milking system had a greater impact on udder health than the change in barn type, likely due to reduced separation of mastitic milk in robotic barns. Free fatty acids (FFA) in milk were also higher in AMS in all studies reviewed by De Koning (2010), most likely due to many factors (shorter milk intervals, smaller milk tubes, high air intake and leakage during milking, stirring bulk tank milk at low levels, low milk yields and low-energy diets).

The automation of milking also relieves producers from routine milking chores, freeing up time to focus on health management, either in the barn, office or elsewhere, using data from milking and health monitoring software (discussed later). However, this can also mean that producers spend less time interacting with individual cows, which could impair their ability to visually detect oestrus, lameness, mastitis and other health problems. Producers may rely more heavily on AMS data and reports, but these technologies should only be used to supplement visual observation of cows and not to completely replace spending time in the barn.

Key Aspect 2: Milking Cows Individually

Given that cows are individually milked and provided supplemental feed in the AMS, producers can now manage each cow individually to maximize her metabolic and udder health. This includes: (i) milking early lactation cows more often to maximize peak milk yield and providing nutritional supplements to improve metabolic health; and (ii) stepping down milking frequency before dry-off to reduce physiological stress, mammary pressure and the risk of IMI (Bertulat *et al*., 2013; Zobel *et al*., 2013; Gott *et al*., 2016). For example, producers and their advisers often use different feed tables (i.e. feeding schedules with different settings for supplement allowance) to increase supplement provision based on a cow's parity, stage in lactation

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and milk yield. These settings are complemented by milking permission or milk access settings, which typically give early-lactation cows permission to milk a greater number of times per day, and they later taper this frequency after peak lactation and towards dry-off.

Providing a customized supplemental feeding regimen to each cow can help combat negative energy balance (NEB) in early lactation, which can help manage body condition and resultant health disorders. For example, loss of body condition during early lactation has been associated with greater risk of subclinical ketosis (SCK) and hoof horn lesions. Cows who lose more body condition during the transition period (two weeks before to four weeks after calving) are more likely to have SCK (Kaufman *et al*., 2016) and develop lameness (Lim *et al*., 2015), as we know that claw horn disease is related to body condition and the thickness of the digital cushion in the hoof (Bicalho *et al*., 2009). Therefore, it is crucial to manage energy balance and body condition to maintain metabolic and hoof health. Supplemental feeding at the cow level gives AMS herds the advantage of customizing feed regimens, especially in early lactation, but more research is required to effectively manage energy balance with AMS supplementation.

Feed supplementation and maximal milking frequency for early and peak lactation cows may also have negative consequences for cow health. In a recent study, AMS herds were associated with having a higher within-herd prevalence of SCK, as measured through milk ketone levels (Tatone *et al*., 2017); this could be due to inadequate supplemental feeding of concentrates in the AMS or the increased frequency of milking during early lactation, but older studies did not report greater NEB for AMS herds (as reviewed by Jacobs and Siegford, 2012a). The extent to which NEB affects AMS herds requires more research, but it is crucial to balance feed consumption at the feed bunk with supplement intake in the AMS (Hare *et al*., 2018). More work is also needed to establish optimal feeding strategies to manage and improve metabolic health in AMS.

The ability to reduce milking frequency for late-lactation cows can reduce the physiological stress of dry-off; this is important for high-producing cows (>20 kg/day) but may not be necessary for lower-producing cows (<15 kg/day) (Bertulat *et al*., 2013). Reducing milking frequency should reduce milk yield before and milk leakage after dry-off, resulting in a reduced risk of IMI during the dry period and next lactation. Gradual milking cessation by skipping every second milking over five to seven days has successfully lowered milk yield (Zobel *et al*., 2013; Gott *et al*., 2016) and milk leakage (Zobel *et al*., 2013). Gott *et al*. (2016) found no difference in milk leakage or IMI after dry-off between gradual and abrupt dry-off, but did see that the results differed between first lactation and older cows. Therefore, there may be differences in optimal dry-off strategies for cows based on parity, providing another benefit to managing udder health at the cow level in AMS. Most AMS software includes customizable dry-off management and step-down features; however, research is lacking in this area and it is unknown if producers utilize and benefit from this option. Field observations indicate there is large variation in use among farms.

In AMS herds, the lack of cohesive milking times for large groups of cows may reduce their behavioural synchrony, which can improve feed access through reduced competition. In a direct comparison of AMS and parlour-milked cows, the percentage of cows at the feed bunk was generally lower in AMS, particularly after the parlour group's milking time, but also much more consistent throughout the day (Wagner-Storch and Palmer, 2003). Because greater feed space helps reduce displacements of lower-ranking cows (Huzzey *et al*., 2006) and has been associated with improved milk yield and udder health (Sova *et al*., 2013; Deming *et al*., 2013), asynchronous milking in AMS may reduce competition and improve feed access, udder yield and production.

With all the options for individualized management, producers are still limited in how much they can do at a cow level. For example, producers must still feed the same partial mixed ration (PMR) to each pen of cows, and small herds typically have only one main pen, making it difficult to meet the needs of cows of all ages and stages of lactation. Targeted supplement allowance is not always realized (Bach *et al*., 2007; Hare *et al*., 2018), probably because milking frequency does not always achieve that which is targeted by milking permission settings (Melin *et al*., 2005). These are areas for future research to examine and provide recommendations to the industry.

Key Aspect 3: Voluntary, Unscheduled and Variable Milking Times

The voluntary nature of milking in AMS provides more behavioural freedom for cows, which may

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enhance cow health, but also creates challenges for managing milking intervals and udder health. In AMS, cows can make more choices regarding their daily routine and time budget (Jacobs and Siegford, 2012a) and, particularly with free cow traffic, cows can move throughout the barn freely (Rodenburg, 2017). This behavioural freedom can enhance cows' ability to express natural behaviours, thereby satisfying their internal motivations, as well as potentially enhancing their health. Feeding and lying behaviour greatly influence cow health, and each cow may have different behavioural wants and needs throughout the day. For example, having choice in feed selection has been suggested to promote good welfare in cattle (Manteca *et al*., 2008). It is plausible that behavioural freedom improves cow health in AMS because cows can make decisions according to their individual needs.

Despite this freedom, the social rank of a cow can potentially limit their ability to make certain choices. Lower-ranking cows may be limited as the social status of a cow will impact when she is comfortable and successful at accessing the AMS unit. Lower-ranking cows (assessed through displacements) spend more time waiting to milk and end up milking at less preferred times of the day; as a result, more dominant cows have higher milking frequencies (i.e. shorter milk intervals) than subordinate cows (Ketelaar-de Lauwere *et al*., 1996; Jago *et al*., 2003). Particularly in partially directed and forced traffic systems, low-ranking cows (assessed through displacements) have been demonstrated to wait longer in front of the AMS (Lexer *et al*., 2009) and have reduced daily chewing times compared to dominant individuals (Melin *et al*., 2007). To better accommodate lower-ranking cows, free cow traffic barn design, with a split entry holding pen near the AMS (Rodenburg, 2017), can be utilized, allowing cows a better chance to milk when needed, reducing their wait times and increasing chewing times.

Relying on voluntary behaviour of cows to visit the milking unit also creates vast variation in milking intervals (i.e. the time interval between two milking events). Because AMS can refuse cows who return too quickly since their last milking, longer milk intervals are of concern and they also increase labour needed to fetch cows for milking. Cows that had to be fetched for milking demonstrated a greater avoidance distance when a familiar person approached (Rousing *et al*., 2006). It is not clear whether fetching resulted in increased avoidance distance or whether these cows were more fearful or timid to begin with.

Long milk intervals cause milk accumulation and changes in udder tissue, such that connections between cells become leaky, which changes milk composition and impairs secretion (Hogeveen *et al*., 2001). As a result, overall milk production and yield per quarter may be reduced, while flow rate may be greater in cows with leaky quarters and/or elongated milk intervals (Persson-Waller *et al*., 2003; Bach and Busto, 2005; Tänavots *et al*., 2015). Reduced milking frequency and milk leakage have been associated with higher somatic cell count (SCC; Stelwagen and Lacy-Hulbert, 1996; Hogeveen *et al*., 2001; Hovinen and Pyörälä, 2011). Overall, cows in AMS herds exhibited more milk leakage overall and while lying down, but these results are from very small studies (Persson-Waller *et al*., 2003; Tänavots *et al*., 2015).

The ideal situation is for cows to voluntarily visit the AMS for milking, and to do so at an appropriate frequency each day. This is not always as easily achieved as one would expect due to many factors, but all can be managed to improve cow motivation and ability to visit the AMS. In the next section, we present management considerations that are crucial to achieving success in AMS. It must also be noted that there are different targets for daily milking frequency based on management system. For example, cows in grazing systems typically have lower milking frequencies (1.4–1.9 milkings/day as opposed to 2.8–3.3 milkings/day), as do those who were offered only small concentrate portions in the AMS (Jago *et al*., 2007; Davis *et al*., 2008). Even among intensive free-stall AMS barns, producers have different management strategies to enhance productivity; some farmers aim for three milkings/day or more, while others target 2–2.5 milkings per day to increase milk yield per milking.

Management Consideration 1: Training Cows to Visit the AMS

Cows must be taught how to use the AMS and be continually encouraged to visit the AMS using a variety of strategies. Training is an important aspect of transitioning to AMS and involves exposing cows to the sounds and mechanical movements of the AMS before their first milking (Jago and Kerrisk, 2011). Training prior to calving has had a positive effect on milking interval, frequency of

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feeding and milk production after calving, particularly for heifers (Widegren, 2014). Despite these benefits, Tse *et al.* (2018) reported that less than half of surveyed AMS producers (42%) trained cows or heifers to use the AMS before the first milking with the robot when transitioning. Producers often provided feed in the AMS during training of cows and heifers, but they were less likely to have the robot arm spray teats with disinfectant (to create awareness of the arm) as part of their training (Tse *et al.*, 2018). When transitioning an entire herd to an AMS, it has been reported that the training process takes three to four weeks until 80–90% of cows use the system voluntarily (Rodenburg and Wheeler, 2002; Jacobs and Siegford, 2012b). Jago and Kerrisk (2011) reported that first-lactation cows adapt more quickly to the AMS than multiparous cows. After a successful transition, 56–100% of cows are still fetched at least once during the first 14 days of lactation, either when they are being trained or are recalling how to use the AMS (Rousing *et al.*, 2006; Jacobs and Siegford, 2012a).

Very little is still known about whether or not producers invest time in cow training and what methods they use. Companies that distribute AMS recommend various training programmes to help with the transition to and continuing use of AMS, but these programmes are not standardized and vary greatly. Training programme recommendations range from bringing cows to the AMS unit from one to four times daily for three to 14 days before starting the herd on the AMS (Tse *et al.*, 2018). On average, Tse *et al.* (2018) found that producers took one week to train cows or heifers. Other researchers that trained cows (Jacobs and Siegford, 2012b) or did not train cows (Spolders *et al.*, 2004) reported a similar average of seven to eight days for cows to adapt to AMS. The average time for an entire herd to adapt was 30 days (Tse *et al.* 2018; Rodenburg, 2002).

There may be animals, especially heifers, who are extremely difficult to handle in the AMS. If this is the case, it is crucial that you handle the animal calmly and slowly. Try to make the experience as positive as possible, by having a calm cow or a familiar stockperson close by. Some animals may attempt to force their way out of the milking box. Never chain the exit gate of the AMS closed to restrain an animal inside, as this can cause extreme stress or injury to the animal or people involved and can damage the milking equipment.

Management Consideration 2: Motivating Cows to Visit the AMS

Although udder pressure is often assumed to be the main motivation for cows to visit milking stations, Prescott *et al.* (1998) found that cows were more motivated to consume feed than to be milked. By giving a group of six high-producing cows the choice between being milked versus receiving 0.33 kg of their total mixed ration (TMR), all cows chose to feed over milking at every test. Therefore, even in high-producing cows assumed to have the greatest udder fill, experimental evidence indicates that feed is the main stimulus for AMS milking activity (Prescott *et al.*, 1998; Bach *et al.*, 2007; Scott *et al.*, 2014).

The amount of supplemental feed offered to cows is usually based on their milk production, parity and stage of lactation and can be manipulated to optimize milking frequency. However, there is also the risk of overfeeding concentrate and over-satiating cows, because additional concentrate in the AMS does not necessarily increase the voluntary milk visits of cows provided the same TMR (Halachmi *et al.*, 2005; Bach *et al.*, 2007). Increasing concentrate provision can also reduce overall DMI, because cows may eat less of their PMR in the feed bunk (Bach *et al.*, 2007; Hare *et al.*, 2018). This may put cows at a greater risk for rumen health problems, such as acidosis, as decreasing intake at the bunk would subsequently decrease intake of physically effective NDF (Owens *et al.*, 1998). Therefore, it is critical that PMR intake be balanced with supplemental concentrate allowance in the AMS.

Various types of supplement may also be offered, with differing consistencies, compositions and flavours; only certain alterations appear to influence milk frequency and production. According to Rodenburg *et al.* (2004), the physical stability of pellets is the most important factor to consider, because differences in pellet composition were not as influential as the stability of the pellet in terms of AMS visits and milkings. Supplement delivery equipment should cause very little pellet breakdown, because visits and milking frequency have been reported to decline when cows were offered a weaker, crumbly pellet (Rodenburg *et al.*, 2004). Composition, starch and fibre content may also affect daily intakes of concentrate, total AMS visits and number of fetch cows, but may not necessarily alter milk yield or composition (Halachmi *et al.*, 2006; Madsen *et al.*, 2010).

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Management Consideration 3: Directing Cows to Visit the AMS

Instead of focusing on motivating cows to visit the AMS, producers may opt to install different designs of cow traffic. A summary of the pros and cons of free and guided traffic systems is provided in Table 7.1. Interestingly, Melin *et al*. (2007) reported that many low-ranking cows in directed traffic learned to go backwards through the selection gates to enter feeding areas, suggesting that cows were not satisfied with their access to feed. With the option to take a free route versus a selection system with concentrate, cows often chose the free route, especially during busy times at the AMS (Ketelaar-de Lauwere *et al*., 1998). To summarize, there are no differences in milk yield or cow stress between traffic designs, but free traffic is much more conducive to good rumen health and feeding behaviour (Bach *et al*., 2009), as well as lower waiting times, especially for low-ranking cows.

Management Consideration 4: Managing Healthy and Comfortable Cows

Regardless of milking system, crucial factors for good welfare and production are stocking density, hoof health, hygiene and cow comfort. At a farm level, milk yield per AMS and milk yield per cow both declined with increasing lameness prevalence in AMS herds (King *et al*., 2016). Not only do lame cows in AMS produce less milk, but they have also been demonstrated to milk less often per day and are more likely to be fetched for milking (King *et al*., 2017).

Stocking density is highly related to production and lameness. Greater stall-stocking density has been linked to greater lameness prevalence in AMS herds (King *et al*., 2016; Westin *et al*., 2016). In milking parlours, milk yield was positively associated with the number of stalls per cow (Bach *et al*., 2008). In an AMS herd, feed-bunk space was associated with milk production (Deming *et al*., 2013). Even though there may be less behavioural synchrony in robot barns (Wagner-Storch and Palmer, 2003), due to cows' retention of their natural diurnal lying behaviour (Munksgaard *et al*., 2011), it is still necessary to maintain lower stocking density in lying areas so that all cows can lie down simultaneously overnight (e.g. 1:1 ration of cows to stall). The number of cows per robot negatively affects milking frequency, showing the importance of all aspects of stocking density (Deming *et al*., 2013; King *et al*., 2016; Tremblay *et al*., 2016); however, at higher milking frequencies (three times/day versus two times/day), Tremblay *et al*. (2016) found an inverse relationship such that more cows per robot was associated with greater milk production.

Bedding should be kept clean and dry and maintained at an adequate depth to encourage cows to rest, because excessive standing time, particularly perching in lying stalls, has been associated with a greater number of lesions and lameness cases (Leonard *et al*., 1996; Galindo and Broom, 2000). The surface and size of lying stalls are also known to affect cow behaviour, production and health. In AMS herds, herd-level risk factors for lameness were obstructed lunge space, narrow stalls and narrow feed alleys, whereas sand-based stalls tended to lower the probability of lameness (Westin *et al*., 2016). It is also beneficial to separate sick and lame cows and provide them with comfortable bedding (ex. bedding pack) and easy access to the milking area (Rodenburg and House, 2007; Rodenburg *et al*., 2010). Holding areas and multiple access points to enter

Table 7.1. Summary of differences between free and guided traffic in AMS herds.

	Free traffic	Guided traffic
Cow stress	No difference	
Milking frequency	Lower	Higher
Need to push/fetch cows	Higher	Lower
Milk production	No difference	
Feeding behaviour	Cows ate slower, in more longer meals (better for rumen health)	Cows ate faster in fewer, longer meals (bad for rumen health)
Rumination behaviour	Highest rumination times and dry-matter intake (fewer social rank effects)	Lowest chewing and rumination times (especially for low-ranking cows)
Waiting time in front of AMS	Lessened for low-ranking cows	Longer for low-ranking cows

Sources: Ketelaar-de Lauwere *et al*. (2000); Hermans *et al*. (2003); Hagen *et al*. (2005); Gygax *et al*. (2006, 2007); Melin *et al*. (2007); Lexer *et al*. (2009); Bach *et al*. (2009); Munksgaard *et al*. (2011)

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each robot are great ways to improve access for sick and low-ranking animals.

Producers with AMS often install automatic alley scrapers to avoid driving through manure alleys multiple times per day. King *et al*. (2016) reported that scraping alleys more frequently was related to lower lameness prevalence and fewer fetched cows, but it is currently unknown what the optimal alley scraping frequency is for AMS herds. Running footbaths in AMS herds is another challenge. Unless cows are manually directed, not all cows in a herd will pass through specific areas of the barn at similar frequencies. Recommendations for footbath placement can be found in Rodenburg (2014) and adequate dimensions (i.e. at least 3 m in length) can be found in Cook *et al*. (2012).

Conclusion

Designing and managing a productive AMS herd requires farmers to adapt old strategies and to incorporate new technologies. Here are the main take-home messages to succeed with AMS:

- Technology is not automatic management. Use all the data from AMS to make informed decisions about your cows, but do not completely rely on this information to replace time spent in the barn.
- Make good use of individualized management opportunities. Milk early-lactation cows more often and supplement them with appropriate feed to optimize their production and health. Before dry-off, use the automatic step-down setting for milking frequency to reduce milk leakage and udder pressure.
- Train heifers and cows before they use the AMS. When you transition to AMS and before each animal calves, give them experience with the robotic arm and the sounds it makes, while feeding them in the AMS.
- Keep cows healthy and motivated to visit the AMS voluntarily for milking. Otherwise you may have to spend time fetching cows. Another option is to install selection gates to force cows through the AMS, but this is not ideal for feeding behaviour or intake, particularly for lower-ranking cows.

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Lely Astronaut A5, *The Art of Milking*. https://www.youtube.com/watch?v=hojnPpvl6-I

NSW DPI Agriculture, *Pasture-Based Automatic Milking Systems* – shows cows coming in from pasture and being milked by a robot. Filmed in Australia and posted August 1, 2016. https://www.youtube.com/watch?v=FWj3T17mTO

Lely Astronaut, *Perfect Grazing* (English) – pasture-based dairy with robotic milking. Posted October 6, 2015. https://www.youtube.com/watch?v=S5pG-08oJM

Journal Paysan Breton, *Fullwood Packo Merlin M2 Milking Robot* – the dairy is located in France. Posted July 13, 2017. https://www.youtube.com/watch?v=mMM_xox3uk

Milkomax, *Tie-Stall AMS Milking Robot by Milkomax, Quebec, Canada* – the robot unit rolls down the alley and stops at each cow, and she backs into it. Posted December 1, 2016. https://www.youtube.com/watch?v=imMM_x0v3uhs

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8 Handling Cattle Raised in Close Association with People

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Summary

Cattle that are managed in close association with people are tame and may have no flight zone. They are either trained to lead with a lead rope or they are easily herded in small groups. These animals are accustomed to lots of human activity around them. Tame intact bulls that have been kept tied up during rearing will fight vigorously when mixed in group feedlot pens. In Africa and other developing areas, small herds of cattle are kept for draught and milk. There is a concern that the hardy indigenous breeds will be lost. Genomic analysis indicates that they have many valuable traits, such as disease resistance and heat tolerance. There is a need to improve handling practices. Many animals arrive at markets with injuries caused by handlers. Harness design for working oxen also needs to be improved. Injuries to the nose can be prevented by using a halter (head collar) to tie the cattle instead of a nose ring or nose cord. Draught animals would be more physically fit for work if they were exercised year-round. Even though these animals are tame, there is a need for handling facilities, such as truck-loading ramps and a single stall with a head stanchion for veterinary work. This chapter also describes methods for restraining cattle with ropes, blindfolding or pressure applied to various parts of the body. Stroking cattle is most effective for calming cattle when it is done on the ventral region of the neck.

Keywords: animal welfare, cattle markets, dairy cows, draught animals, oxen, restraint

Introduction

Cattle have been domesticated by humans for several thousands of years and they are currently used in very large numbers as sources of meat and/or milk and for draught purposes. As a result of this long and close contact, there is great practical knowledge within the agricultural community as to their management, care and handling. Some of the early pioneers in recognizing the importance of understanding livestock behaviour are Fraser and Broom (1990), Houpt (2010), Hafez (1969), Albright (1986) and Ewbank (1964).

Cattle raised in close association with people are raised on two types of farms. They are either smallholder farms in developing parts of the world or large indoor intensive operations. This chapter will concentrate on tame cattle that are either trained to lead (Fig. 8.1), kept haltered and tied during rearing, or moved in small groups with long periods of contact with people. Cattle that are trained to lead are common in China, France, Asia and Africa.

The indigenous breeds of cattle in Africa, China and Russia have unique genotypes for valuable traits such as disease resistance and heat tolerance (Gao *et al*., 2017; Kim *et al*., 2017; Mwai *et al*., 2015; Yurchenko *et al*., 2018; Zeng *et al*., 2018). It is important for sustainability to preserve the cattle breeds that are locally adapted and to respect and learn from the people who handle them (Kassie *et al*., 2009).

Type of Intensive Rearing, either Individually or in Small Groups

In China and Indonesia, intact bulls are kept tied up with a lead rope during rearing. Such animals are tame and easily led by people. There are severe problems with fighting when these individually reared bulls are mixed in groups in feedlot pens (Mark Deesing, 2013, personal communication). Animals that are reared without socialization with other animals at a young age will often engage in

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Fig. 8.1. In much of the world, tame cattle live in close association with people and they are trained to lead. Complex handling facilities are not required for cattle that are trained to lead and have no flight zone. (Photo: Miriam Parker)

intense fighting when they are mixed (Grandin, 2005). Grouping the bulls into temperament groups may help reduce fighting. The most aggressive bulls are grouped together to prevent them from attacking the gentler animals.

Another method is rearing small groups that have contact with people every day. They are either driven or led by handlers and no lead ropes are used. These cattle often become very accustomed to many human activities. For instance, *Bos indicus* cattle grazed along the roads learn to ignore bicycles and buses (Fig. 8.2).

The facilities required to handle cattle that have been raised in close association with people can be much simpler than those required to handle much wilder, extensively raised cattle that have had much less contact with people. In many countries, cattle that are trained to lead can be easily handled without races and crowd pens. In Sudan, the second author has observed skilled herders at a local market who corralled their cattle by using people as fences (Fig. 8.3).

The people positioned themselves around a group of cattle on the boundary of the flight zone. In England and New Zealand, groups of cattle come when called and can be led by a handler to new pasture. However, in abattoirs and large veterinary facilities, cattle that are not trained to lead with a lead rope should be handled in facilities that are designed for extensively raised cattle (see Chapters 1 and 5; Grandin, 1998; Grandin and Deesing, 2008).

Types of Smallholder in Europe and Africa

Intensive, traditional family farm systems of stock keeping are still common in many parts of the world. Small numbers of cattle are reared and kept in close contact with humans (FAO, 2002; Samkol *et al*., 2015; Ashley *et al*., 2018). They are either grazed under careful supervision in small fields or kept on tethers. Sometimes they are kept indoors in tie-up cow sheds or covered yards. Their calves are often hand-reared by humans or kept on their dams. They become habituated to the near presence of humans at an early age. As a general rule, cattle husbanded in these ways are tame, co-operative and easily handled (Kilgour, 1987; Creel and Albright, 1987). Stroking and brushing of calves makes them less reactive (Sato *et al*., 1984; Bouissou and Boissy, 1988). Cattle are able to differentiate between different human handlers (Rushen *et al*., 1998; Taylor and Davis, 1998).

In many parts of Africa, cattle are raised in small herds of five to 25 animals (Mapekula *et al*., 2009; Stein *et al*., 2009). Traditional African breeds are valued for their hardiness, disease resistance,

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Fig. 8.2. Cattle in the Philippines are grazed along roads and other places with high human activity. They have lived near cars, bicycles and other activity all their lives. These animals do not react to a bicycle or car because it is no longer novel. (Photo: Temple Grandin)

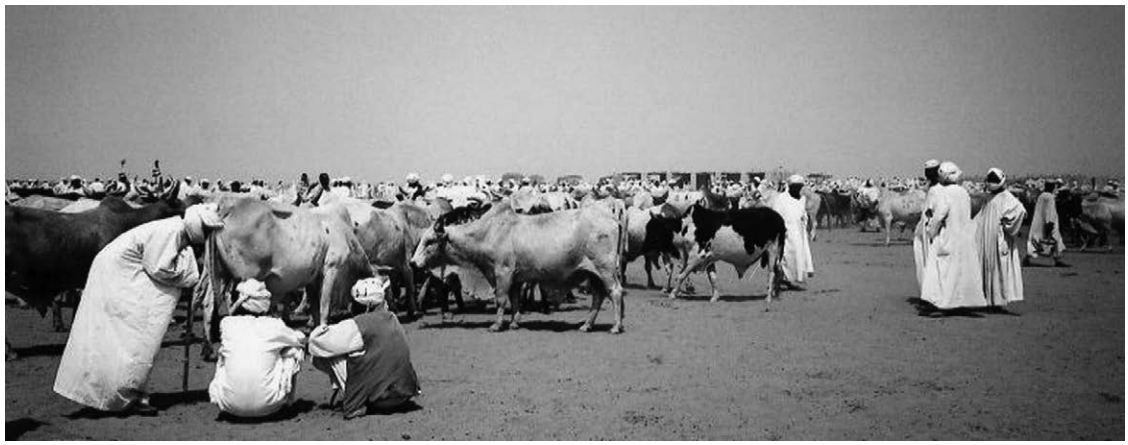


Fig. 8.3. In Sudan, cattle are corralled for sale by positioning groups of people around them on the perimeter of their flight zone. The animals are fenced in by the people. They have a small flight zone, but are not trained to lead. (Photo: Miriam Parker)

fertility and ability to work (Zander and Drucker, 2008). For many small farmers, cattle are a major source of income (Stein *et al*., 2009; Okello *et al*., 2015; Ashley *et al*., 2018). There is a big concern about the loss of valuable indigenous breeds (Kassie *et al*., 2009). In crossbreeding programmes, indigenous breeds are used in terminal crosses with other breeds (Scholtz and Theunissen, 2010). This type of crossbreeding programme requires a steady supply of the local breeds, which may help preserve indigenous breeds. The local genetics is valued for its hardiness. However, introduction of foreign cattle breeds to supply export markets may endanger the local breeds (Behnke, 2008; Zander and Drucker, 2008; Scholtz and Theunissen, 2010).

Effects of Breed and Experience

Many different breeds of cattle have been developed (Epstein and Mason, 1984; Tucker, 2009) and it is generally accepted that these can be grouped into two main types: the humped (Zebu)(*Bos indicus*) animals native to subtropical and tropical areas (see Payne, 1999 for an account of Zebu

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cattle types and their husbandry) and the non-humped (*Bos taurus)* cattle of European origin (Albright, 1981; Albright and Arave, 1997). There are some behavioural differences between these cattle types (Hafez and Bouissou, 1975; Grandin and Deesing, 2014). It is widely held, for example, that Zebu-type cattle are more difficult to restrain than their European equivalents. This view probably stems from experience with these animals under extensive pastoral conditions, as *Bos indicus* cattle husbanded/reared in close contact with humans on the family farm as milk or draught animals are usually easily handled. When they are completely tamed with no flight zone, the *Bos indicus* breeds appear to be more responsive to stroking compared to the *Bos taurus* breeds. Intensively reared *Bos indicus* cattle often actively seek out stroking, and this is most effective when body regions that are licked during social grooming are stroked. Stroking of the neck ventral regions has been shown to be the most effective for reducing heart rate (Schmied *et al*., 2008), and such actions may help form a bond with the handler. Furthermore, when stock people remained quiet, with no arm-waving, yelling or poking cows with sticks, Nelore (*Bos indicus*) cows used in embryo transfer had more viable embryos (Macedo *et al*., 2011). Stock people who used positive methods and avoided aversive methods, such as hitting calves, were able to weigh calves more efficiently (Destrez and Boivin, 2018). The importance of good stockmanship cannot be over-emphasized (see Chapter 1; Seabrook, 1987; English *et al*., 1992; Rushen and de Passillé , 2009; Ekesbo, 2011; Hemsworth and Coleman, 2011).

The husbandry systems under which cattle have been reared have a more significant effect on flight zone size and tameness than the effects of genetic differences between the different breeds (Murphey *et al*., 1980; Kabuga and Appiah, 1992). As a general rule, within European (*Bos taurus*) cattle, females of the dairy breeds are quieter to handle than females of the beef breeds. The opposite is true for the males. (See Chapters 4 and 8 for more information on handling bulls and the effects of previous experiences on cattle behaviour during handling.)

Oxen and Other Intensively Handled Bovines in Developing Countries

A significant percentage of the world's population uses draught animals, such as cattle or water buffalo, to cultivate their crops (Fig. 8.4) (Wilson, 2002). Compared to donkeys and horses, bovines can pull more weight (Pearson and Vall, 2004). Their speed is slower, but the greater power of these heavier animals is preferable for many tasks. Draught animals are used extensively in Nigeria, Ethiopia and Uganda (Abubaker and Ahmad, 2010; Desa and Shu'aibo, 2010; Chanie *et al*., 2012; Okello *et al*., 2015). In China, the use of draught animals has greatly declined as farmers shift to machinery (Zhou *et al*., 2018). In Nigeria, Sokoto Gudall and White Fulani breeds are popular (Abubaker and Ahmad, 2010). Tsige *et al*. (2010) found that the use of oxen is hampered by whip injuries, sores from the harness and lameness. Poor harness design is a problem. (See Heleski *et al*., 2015 for information on materials to improve harnesses.)

The health and welfare of oxen can be easily improved. Chanie *et al*. (2012) have some simple suggestions for improvement. An ox should be 3 years old before doing hard work and he needs exercise year-round to stay in physical condition for strenuous work. He is more likely to break down if he is idle for most of the year, and then does a period of hard work. Additional information on draught animals can be found in Bartholomew *et al*., (2005), Sims *et al*. (2003) and Conroy (2015). Unfortunately, there is still a high incidence of poor handling of draught animals. Fifty-one per cent of the cattle and 15% of the water buffalo arriving at livestock markets in Bangladesh had tail injuries (Alam *et al*., 2010a,b). These injuries occur when the tail is twisted to make the animal move. Tail twisting is illegal in the UK and other internal guidelines state that it should not be used (OIE, 2011). Apart from tail injuries, 13% of the water buffalo and cattle had skin injuries that were consistent with abuse from stock handlers (Alam *et al*., 2010b).

The second author has made many observations during extensive travels in Asia and Africa. She observed that educating people on basic principles of handling could bring about great improvements in animal welfare. For instance, she trained people to use a simple rope halter (head collar) (Fig. 8.5) instead of tying animals by a nose ring. Tying cattle in a transport vehicle by the nose may result in severe injuries. Below is a list of simple, easy-to-implement and low-tech recommendations to prevent injury when animals are tied up by a lead rope.

1. Do not tie with a nose ring. A halter or head collar should be used. Almost half of the water buffalo

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Fig. 8.4. Draught oxen being used to plough a field.

and cattle that had nose piercing had injured nostrils when they arrived at market in Bangladesh (Alam *et al*., 2010a).

2. Do not tie large and small animals together or weak and strong animals together. Animals should be grouped by size and weak animals should be in a separate group.

3. Tie horned and dehorned or polled cattle in separate groups.

4. Provide non-slip flooring in the transport vehicle.

5. Provide ramps for trucks unloading. Do not make animals jump off vehicles. Figures 8.6 and 8.7 show a well-constructed ramp.

Animals can be easily trained to voluntarily co-operate with minor procedures such as injections. For example, cattle can be trained to co-operate so that their stress is greatly reduced (Grandin, 2000). Cattle kept for special purposes, such as for show, AI (artificial insemination) studies and agricultural trials are usually easier to handle. Figure 8.8 shows a simple hoof-trimming stand that a tame cow is led into.

Handling in Tie-up Stalls or Self-locking Stanchions

This method is mainly used in dairies. The advantages for the stockperson in handling cattle while they are being held in their own tie-up stalls (stanchions) are:

1. The animal is already caught, i.e. it does not have to be chased and captured. The cattle are already accustomed to being restrained when they are fed.

2. The head of the animal is being held in either the chain tie or the neck yoke.

3. The animal is in its own living place and is between known companions in the adjacent stalls, i.e. it is usually relaxed and confident.

4. The husbandry system is generally such that the animal is used to frequent physical contact with humans while it is being fed/milked/having its bedding replaced, etc.

5. The animal is surrounded by bars and pipes to which the various ropes etc. used in restraint (see later) can be attached.

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Fig. 8.5. A rope halter should be used for tying a tame bovine. Tying by a nose ring or a cord through the nose may cause nose injuries. The ring or nose cord should only be used during handling or for steering a draught animal. (Photo: Miriam Parker)

6. Graves (1983) shows stanchions that are incorporated into hospital pens.

There are also a number of disadvantages:

1. There may not be much space around the animal. Cattle in adjacent stalls can be moved away, but this often distresses the one left isolated.
2. The floor is probably hard (concrete) and the cow may damage itself if it falls.
3. The animal may begin to associate its own stanchion with unpleasantness and become reluctant to enter it again. This is especially true of painful operations, e.g. foot dressing, that are repeatedly carried out in the home stall. It may be better to move the animal away from its home stanchion for potentially distressing procedures.
4. Sometimes it is difficult to administer injections in the neck. Injections in the hind quarter should be avoided because they damage the meat (George *et al*., 1995, 1996; Roeber *et al*., 2002).

Handling while Confined Closely Together as a Group in a Small Pen

In this method of handling, animals, which can be young stock, polled (dehorned) dairy cows or intensively housed beef cattle, are put into a restricted



Fig. 8.6. Cattle being unloaded onto a loading ramp built by local masons in India. Construction of unloading ramps will prevent injuries to both cattle and people. (Photo: Miriam Parker)

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Fig. 8.7. Cattle are easily led down this well-constructed unloading ramp. Since the cattle are tame, side rails or solid fences are not required. (Photo: Miriam Parker)

area (pen) such that they are in close contact with each other and have little space for movement. Once the cattle have settled down, the human handler(s) can enter the pen, push between the animals and catch and/or handle them at will. The animals usually remain quiet. This is possible because: (i) they have little scope for individual movement; and/or (ii) they remain relaxed while in close physical contact with their peers. An animal separated from its group soon becomes agitated and difficult to handle. In the USA, a system called a management rail is used. Adams (2012) contains an excellent diagram.

Handled Individually by Means of Ropes or Pressure on the Body

There are many different descriptions of using ropes to control and manipulate cattle (McNitt, 1983; Holmes, 1991; Haynes, 2001; Battaglia, 2006). There are also a number of veterinary texts (e.g. Leahy and Barrow, 1953; Stober, 1979; Kennedy, 1988; Sheldon *et al*., 2006; Fowler, 2008; Holtgrew-Bobling, 2012; Chastain, 2017) that provide additional details. There are numerous specialized handling and surgical restraint techniques that can be used (as appropriate) on calves, young stock and adult cattle. Ropes, in particular, are used across the world to aid in the restraint or handling of cattle. However, there is a multitude of regional and local variations and only a few have been formally documented or researched.

When cattle are being handled individually, the animal should, ideally, be within a 'safe' space, such as the centre of a pen or large loose box. For some methods or procedures, it may be necessary to have overhead attachment points for ropes or slings.

The Use of Pressure or Force on the Animal's Body

Once cattle are confined or restrained (e.g. within a crush, small pen, stall or by means of a halter or ropes), additional steps may be necessary to reduce movement further and/or safely access a part of the animal's body to carry out a procedure. A number of methods have become established over the years which act on the principle of applying a degree of force to the animal's body. In some instances, this has been shown to produce both calming and immobilizing effects.

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Pressure Applied to the Whole Body

It has long been recognized that the tightening of single or multiple rope loops, which have been placed around the bodies of cattle (e.g. udder hitches, chest twitches and Reuff's method of casting) cause the animal to stand still, and, if tightened further, to appear to be partly paralysed and go down. If the rope loops are kept tight, the animal stays down. Kumar (2006) and Smith-Thomas (2018) have good diagrams. The reason why this works is largely unknown. Toth *et al.* (2012) report that rope restraint casting when done correctly reduced heart rate, respiration and induced a sleep-like state in neonatal foals. Further information on the gentle use of pressure from ropes on foals is in Pickler *et al.*, 2014; Aleman *et al.*, 2017; and Nogradi and Magdesian, 2017.

This partial paralysis may be related to so-called tonic immobility (fear paralysis) that is seen in some animals when pressure is applied to their bodies and/or when they are exposed to fear-inducing situations. This phenomenon has been studied under experimental conditions in chickens, rodents and rabbits, and there is now some understanding (Carli, 1992) of the behavioural and physiological mechanisms involved. It is known in rodents that sudden and/or aversive stimuli can lead to tonic immobility and that it is sometimes accompanied by a drop in the animal's heart rate (Hofer, 1970; Steenbergen *et al.*, 1989). Tonic immobility is a sign of fear (Jones and Boissey, 2011; Tambeli *et al.*, 2012). It is exhibited by a prey animal when it is caught by a predator and cannot escape (Vieira *et al.*, 2011). The physiological mechanisms are now understood (Vieira *et al.*, 2011). It has been noted in cattle (Leigh, 1937) that the tightening of a rope around the body slows down the movement of the heart, as mentioned above for neonatal foals.

The quietness shown by animals, both in the squeeze crush (squeeze chute) and when being restrained in close physical contact with others of their kind – as in handling pens, raceways or loose boxes – may, at least partly be as a result of this 'pressure on the animal's body' phenomenon (Ewbank, 1961, 1968). Pressure over wide areas of the body can have a calming effect that is different to tonic immobility. Dogs that wore a tight-fitting garment (thundershirt) had a lower heart rate when they were left alone (King *et al.*, 2014). (See Buckley, 2018 for a review of four studies.)

Pressure Applied to the Legs

A rope noose tightened around the hind leg of a cow just above the hock joint, or the application of a specially designed pincer clip device to each side of the tendon that runs down to the point of the hock, can result in the leg seemingly becoming temporarily paralysed. The animal is not really calmed and it is often distressed, but the leg can be easily handled. Occasionally, the animal will go down. This may be due to a loss of balance on the three non-affected legs rather than a general calming/immobilization effect. Removal of the rope noose or the pincer clip soon restores the animal's ability to move and use the leg. Sometimes there is a degree of swelling at the application site and an associated, temporary slight lameness. This is a severe method which should only be used if squeeze chutes and other restraint methods are not available.

Pressure Applied to the Tail versus Blindfolding

Holding a cow or calf's tail in a near vertical position seems to partially restrict the movement of the hind legs and allows a relatively safe examination of the groin or udder region of the animal. This method is used to make difficult-to-handle animals stand still. It should never be used as a method to motivate animals to move forward, and it must be done carefully to avoid injury to the tail. Recent research shows that blindfolding water buffalo was more effective than tail pressure for reducing both behavioural and physiological indicators of stress (Mohamed *et al.*, 2018). There is more information on blindfolding in Mitchell *et al.* (2004) and Chapter 5. Soft, dark, fully opaque cloth should be used.

Pressure Applied to the Nose

The grasping of the nose of the animal by placing a finger and thumb on each side of the *septum nasi* or by the application of blunt-ended pincer-like tongs (bulldogs) to the same site usually results in the animal standing still and tolerating a certain amount of interference to the rest of its body. The impression is given that the animal's whole attention is concentrated on its nose. It has been suggested that it will only continue to stand still as long as the distress/pain of the interference is equal to or less than the distress/pain of its nose. Once the interference

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distress is greater than the nose distress, control over the animal's movement will be lost.

A major disadvantage of using a nose pincer is that cattle remember the pain and they will resist application of the pincer in the future. When a halter is used to hold the head for multiple blood samples collected over a number of days, an animal will often become increasingly more co-operative. When the nose pincer is used, cattle may become progressively more difficult to handle in the future. In most instances, a halter or head collar should be used to restrain the head.

Lip Twitches on Horses

The twitch that is used on the horse is a more subtle device. A loop of cord around the horse's upper lip can be relaxed and tightened at will and, in effect, the stimulus to the lip can be titrated against the stimulus of the interference being carried out on other parts of the animal. In the horse, it has been suggested that the twitch has somewhat similar action to acupuncture (Lagerweij *et al*., 1984), with an increase of circulatory endorphins causing possible changes in pain susceptibility and/or mood of the animal. A more recent study showed that a lip twitch may have a calming effect for five minutes (Flakoll *et al*., 2017). Heleski *et al*. (2015) also found that leaving the twitch on for only a few minutes did not increase aversion to having it reapplied in the future. It is recommended to use a twitch for under five minutes and it should not be used as a replacement for training animals. Twitching by bending the ear is highly stressful and should not be used (Flakoll *et al*., 2017). It is not known whether there are increases in endorphin levels in the blood of cattle subjected to pressure/force being applied to all or part of their bodies.

Bull Rings

Metal rings or ropes are often permanently placed through the soft anterior parts of the *septum nasi* in cattle (mainly adult males) to facilitate handling (e.g. the bull nose ring and Indian cow ring). Various staffs, chains, ropes etc. can be attached to the ring or rope when needed, and can probably help to control the animals by causing them a degree of discomfort/pain if they do not respond to the pushes and pulls exerted on the rings. A halter (head collar) should always be used in conjunction with a rope tied to the ring. This will prevent a frightened animal from pulling the ring out. For dairy bulls, a snap attached to a 1 m-long stick can be attached to the ring to enable the handler to keep the bull at a safe distance. This is often used in Holstein bull studs when bulls are handled for semen collection.

Restraint of the Head and Neck

Animals that have their necks held in yokes or tie-chains in their individual standings (stanchions) are still able to move their heads about, and are usually capable of some limited movement of their whole bodies. This is also true of animals detained within the various designs of cattle crushes. There is now a mechanical, rubber-lined scoop device available that can be attached to the front of a cattle crush and which allows the head to be held firmly in one position. Additional physical control of these animals is generally achieved by grasping their heads. This is usually done by a human handler, who should be standing to one side of the animal's head, taking hold of the horn or ear closest to him/her and at the same time seizing the *septum nasi* between finger and thumb of the other hand. When this is done, the animal will usually keep its head and body still. If the head is pulled sideways and back towards the animal's flank (i.e. rotated around the chain, tie/bar of the yoke) the cow will tend to swing away from the handler and, in many instances, steady itself by pushing the side of its body against the adjacent pen division, crush side or wall.

The arm-over-the-side-of-the-face head grip technique should only be used on young, relatively small polled or dehorned stock. The handler, standing to one side of the animal's head, reaches over the animal's head so that his/her arm covers the animals far eye and cups his/her hand around the anterior part of the animal's upper lip. The handler's other hand goes to the side of the face and either grasps the lower jaw, with a finger and thumb pressing on the gum line just behind the incisor teeth, or seizes the *septum nasi* between his/her finger and thumb. The animal is restrained by a mixture of force, calming through the use of the arm as a blind (on the smallest animals) and distraction by the action of the hands/fingers inside the animal's mouth. A modified version of the arm-over-the-side-of-the-face head grip can be used on animals safely held by the neck in a stall stanchion (neck yoke) or a cattle crush headgate (Fig. 8.8).

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Fig. 8.8. Arm-over-the-side-of-the-face head grip. One advantage of this grip is that is restricts the animal's vision and has a blindfolding effect. This method is preferable to methods where the nostrils are gripped. Gripping the nostrils is highly aversive.

Conclusions

During all of these procedures, cattle should be kept calm, as calm cattle are easier to handle. The animal will usually remain calmer if the various holds are applied with steady force and sudden jerky motion should be avoided. The rope-restraint methods described in this chapter are mainly used when restraining crushes (squeeze chutes) are not available. Simple improvements in harnesses and exercising of draught animals can improve their ability to work. All types of farm animals can be easily trained to co-operate voluntarily with handling and restraint (see Chapters 4 and 15).

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Miriam Parker, *An Introduction to Cattle Handling Systems with Miriam Parker* – shows how to quietly move cattle on a cattle farm in the UK. https://www.youtube.com/watch?v=sf3Z2QNZSMK

Joseph Stookey, University of Saskatchewan, *How to Properly Apply Tail Twist* – shows how to gently use tail twist to move a stubborn cow, applying the principles of pressure and release. https://www.youtube.com/watch?v=GRmwlAqjYiY

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9 Cattle Transport in North America

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Summary

It is interesting to note that since the first edition of this book, the most significant welfare concerns for cattle during transport have remained unchanged. These concerns include the transport of unfit (sick, emaciated, debilitated) cattle, overloading – particularly in lightweight and young animals – and excessive transport distances with long periods between food, water and rest. There is also concern about marketing through auctions, and more information is needed on transportation durations experienced by cattle (usually of poor condition or quality) that are sold and resold through the auction markets. Trips of over 30 hours should be avoided if possible because death losses increase sharply. Ambient temperatures below –15°C or above 30°C are detrimental and space allowances (using an allometric coefficient, the *k* value) lower than 0.015 and greater than 0.035 are associated with greater losses. Cattle that lose 10% of their bodyweight during transport have a greater likelihood of dying, becoming non-ambulatory or lame. A study of heath records from many feedlots indicated that mortality was 1.3% and sickness 4.9%. Truck drivers with more years of experience had fewer compromised animals. Feeder cattle destined to feedlots were twice as likely to die during transport compared with fattened cattle. To provide incentives to reduce losses, there needs to be economic accountability throughout the supply chain for dead, non-ambulatory cattle bruises and dark cutting meat. There also needs to be economic accountability for failure to precondition and vaccinate beef weaners before they leave the ranch of origin.

Introduction

Continued research in the area of cattle transport since the fourth edition of this book highlights the sustained interest and importance of transport to animal welfare and meat quality and necessitates updates to this chapter specific to the effects of road transport on cattle under North American (NA) conditions including assessments of trailer microclimate and its relationship to animal well-being. Cattle transport trucks are highly visible to the NA public and may be the only contact many people have with livestock production today. At the same time, North Americans are several generations removed from the farm and have no or limited knowledge about livestock production. Increased transport research is a direct result of the increased public, animal rights, government and industry group concern regarding the effects of transport on animal welfare, food safety, and meat and carcass quality (Keeling, 2005; Marahrens *et al*., 2011; Clark *et al*., 2016). As an example, the most frequent letter of concern to the Canadian Minister of Agriculture continues to concern livestock welfare during transport. The most common concerns remain excessive transport durations, limited access to feed and water, inappropriate loading densities, exposure to variable and or extreme climatic conditions and transport of compromised cattle. To illustrate the importance of this issue, there is now an entire book with chapters on consumers' perception of food and animal welfare (Matsumoto and Otsuki, 2018).

In order to fully understand the effects of transport on cattle it is necessary to acquire that understanding based on science conducted under the conditions in which they occur. For this reason we

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believe it is highly relevant to dedicate this chapter to reviewing the research and management practices specific to this geographic region. This is important because transport times and distances, rest, feed and water intervals (due to regulatory differences), road conditions, trailer design, animal genetics and extreme (cold and hot) weather conditions in NA are unique compared to those of other continents and countries. Understanding regional differences will be important when it comes to setting global welfare standards and harmonizing trade so these issues do not become barriers to commerce or achieving optimal animal welfare. Although not discussed in this chapter there is new research on the effect of cattle transport on greenhouse gas emissions that should be kept in mind. For example, Kannan *et al.* (2016) indicated that the majority of energy consumption and greenhouse gas emissions are associated with sending the finished cattle to slaughterhouses (41%), followed by bringing feeder cattle to feedlots (38%). This type of research has future relevance for cattle welfare and meat quality with regards to how cattle are transported as well as the effects that associated changing environmental conditions may have on cattle transported under more extreme (hot or cold) weather conditions.

The goal of this chapter will be to provide an overview of the transport process and related governing factors and to review the relevant literature on the effects that both transport management (handling, distance, ventilation etc.) and animal (fitness, behaviour) factors have on animal well-being and meat quality.

Transport Process

Transportation is a critical component of modern cattle production and marketing. Typically, NA cattle are transported by road at least once and up to five or more times during their lifetime, which may include transportation from their ranch of origin to either a different location within the same farm or sold through auctions or directly to feedlots for growing (backgrounding) where they may be transported to fattening (finishing lots) and finally to processing plants for harvest (Schwartzkopf-Genswein *et al.*, 2012; Smith *et al.*, 2004). Economics continue to play a large role in defining the conditions of transport. For example, in the past decade there has been a trend towards the establishment of fewer but larger growing/finishing and slaughter facilities, resulting in increased transport distances under more variable conditions (Schwartzkopf-Genswein *et al.*, 2012; Speer *et al.*, 2001). Likewise, the ability to buy or sell cattle at higher prices in distant markets (within and between NA counties) is a common practice which may increase transport duration and frequency. In addition, as fuel prices continue to rise, transporting the maximum number of animals within a single journey is important in keeping costs per unit of transport down; however, this also has the potential to increase loading densities and overcrowding of animals.

The entire transport process includes the events of loading, time on the truck (in transit and stationary periods) and unloading. Many different factors can contribute to both positive and negative welfare and meat quality outcomes throughout this process. These include driver experience and training, quality of handling, duration of transport and rest stops, trailer design and ventilation, animal behaviour and fitness for travel. In addition, the transport process is governed by both regulation and industry guidelines specific to each country that can further impact the factors listed above. Each of these contributing factors will be discussed separately in the following sections.

Transport Management Factors

Regulations and codes of practice

The transport of animals is the most frequently regulated aspect of animal production. Canada, the US and Mexico all have some regulations or codes of practice that provide specific cut-off points which define appropriate feed, water and rest intervals, transport durations and loading densities.

Currently, regulation regarding NA travel times and distances for cattle are less stringent than other countries in the EU, as well as Australia and New Zealand. In Canada, the maximum transport time is 52 hours before cattle must reach their final destination (CARC, 2001). In the USA, cattle can be in transport up to 28 hours according to the 28 Hour Law (USDA, 1997); however, to our knowledge, this law is not enforced. Mexico has no known regulation regarding transport duration. The regulated transport durations used currently in NA are drastically different from those of the European Union (EU) which state a maximum eight-hour journey time, but with special provisions for food, water and rest this may increase to 14 hours with a maximum trip length of 30 hours (European Commission,

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2005). Recommendations by the European Food Safety Authority (EFSA, 2011) recommend that adult cattle not be transported longer than 29 hours and should be rested for a 24-hour recovery period with access to food and water after that point.

Currently there are no regulations regarding rest stops for the USA or Mexico. However, Canada does require that animals be offloaded for a minimum period of 5 hours after 48 hours (unless they can reach their final destination in 52 hours) of transport. Although not readily available, cattle rest-stop locations do exist in the USA and Canada. A common well-used rest point for western Canadian beef calves transported to markets in eastern Canada is Thunder Bay, Ontario. Rest-stop locations provide pens where the cattle can lie down and have access to feed and water for a minimum of 5 hours and up to 24 hours. The NA scenario is very different from that of the EU where numerous government-run rest-stop locations exist within and between some European countries to accommodate animals transported for more than 8 hours after which they must be rested for one hour and then may be transported another 14 hours. At this time, little is known about the effectiveness of rest stops and or optimal rest durations for cattle. Research is required to determine if cattle actually acquire adequate water, feed and rest during these periods and if the additional handling-associated loading and unloading is more detrimental than leaving them on the truck (with access to food and water).

Canada also has laws that dictate food animals should be handled in a way that avoids distress or pain. These laws also specify the segregation of incompatible animals, the provision of food and water, mandatory rest intervals during transport and special rules pertaining to the transport of unfit (e.g. downer) animals, young or pregnant animals (CFIA, 1998). In addition, the use of bedding is a regulatory requirement in Canada on journeys over 12 hours (Health of Animal Regulations, 2010). The USA and Mexico currently do not have similar laws governing transport. Instead, they rely on voluntary compliance to industry codes of practice that serve as guidelines for best management practices.

Both Canada and the USA also have regulations governing how often drivers need to stop for rest. Appropriate rest for drivers is important because of the potential relationship between driver fatigue and accidents, particularly rollovers with fully loaded trucks (Woods and Schwartzkopf-Genswein, 2008).

Currently the transport regulations in all NA countries are at least 35 years old and are in need of reassessment, particularly in light of changing priorities including welfare concerns, and new research findings, as well as alignment with global standards, in particular those of the World Organization for Animal Health (*Office International des Épizooties: OIE*). It is important that as new regulations are made and old regulations are revised they are formed from science-based information rather than emotion or pressure from special interest groups. It should be noted that some regulations may not need to be altered while others need to change drastically and scientific assessment will provide the necessary information from which all stakeholders can make appropriate well-informed decisions.

Driver experience and training

The successful transport of cattle poses particular challenges and requires particular driver skills. A livestock transporter must be knowledgeable and consider many factors to ensure optimal animal care for the animals he/she is transporting. These factors include understanding the rules and appropriate paperwork for national and international transport as lack of compliance with these rules can result in quarantine or return of the animals to their place of origin, drastically increasing the time animals need to be en route to their final destination (Schwartzkopf-Genswein *et al*., 2008). The identification of and preparation for risk factors prior to transport are essential and include animal, equipment, weather and road condition factors. Knowing the fitness of an individual on each truck and their transport history may help to reduce downer animals or mortality. For example, when transporting thin cull cows or very young calves the distance travelled and environmental conditions must be considered. Pre-planning can help to ensure animal welfare and can include obtaining information about current road conditions, construction and detour routes, scheduling border arrivals and pending road closures due to inclement weather (Schwartzkopf-Genswein *et al*., 2008). Recent research has shown that cattle transported across the Canada/USA border experience average delays of 3.03 hours, which was the total duration of delay for reasons including border crossing, weather, etc. (González *et al*., 2012a). Although infrequent, the study reported maximum delay lengths of 15 hours, which could have significant

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impact on the animals, particularly for compromised animals or in hot weather.

Many studies have shown that poor driving quality is a major factor contributing to animal stress, increased falling and injury during transport and reduced meat quality (Eldridge, 1988; Kenny and Tarrant, 1987a,b; Tarrant *et al*., 1988). Recent research has shown that there is a link between years of livestock hauling experience and animal live weight loss. González *et al*. (2012a) documented the experience of the drivers (< 2 years, 3–5 years, 6–10 years and > 10 years) and found that weight loss at unloading was lower in cattle transported by truck drivers having six or more years of experience hauling livestock compared to those with five years or less. Although driving quality was not assessed in that study the data suggest that experienced drivers may be more competent at stopping, starting and cornering practices that minimize animal stress. In addition, they may have better animal-care and -handling skills and be more vigilant about risk factors. The importance of frequent inspection of the livestock and of careful driving cannot be overemphasized. In NA, large beef plants are collecting more and more data on the performance of trucking firms and drivers. Data collected at one large slaughter plant indicated that one trucking firm had more dark cutters.

Today most large livestock transport companies have mandatory training programmes such as the Master Cattle Transporter Training (TBQA) programme in the USA and the Canadian Livestock Trainer (CLT) programme in Canada (Schwartzkopf-Genswein *et al*., 2008). These programmes provide training on animal behaviour, comfort and monitoring, handling and driving practices, vehicle maintenance, regulations and assessing risk factors. Studies have shown that offering training in proper handling techniques to slaughter-plant personnel has improved animal welfare during lairage and slaughter (Grandin, 2006). Grandin (2001, 2007) noted that without continual monitoring, the use of good handling practices can decline. Assessing the effectiveness of transporter training will be important in continuing to improve aspects of the training process or identify additional training points to ensure high standards of animal care during transport.

Handling at loading and unloading

Regardless of geographic location the assembly and loading (unloading) of cattle for transport is a known stressor (Broom, 2005). The amount of loading/unloading stress can vary according to the quality of handling (gentle versus rough), experience of the handler and animal, and the animal's condition and temperament (Burdick *et al*., 2010) as well as the quality of the handling facilities (Grandin, 2001). Studies suggest that intensively and extensively raised cattle could respond quite differently to loading/unloading. For example, beef cattle raised on pasture and unaccustomed to handling had higher heart rates and cortisol levels during restraint and handling compared to frequently handled dairy cattle (Lay *et al*., 1992a,b).

In this phase of the transport process cattle are exposed to novel surroundings which include negotiating ramps onto or within the transport vehicle. Grandin (2007) noted that problems at loading are usually a combination of poor knowledge of cattle behaviour, overloading and poor design or maintenance of ramps at the farm. Healthy cattle in good condition are agile and can generally navigate ramps of highly variable configuration. However, to avoid animal balking it is recommended that the angle of loading ramps for cattle do not exceed 20–25° and that ramp cleats be spaced no more than 20 cm apart (Grandin, 1990). It is also suggested that concrete stair/step-style ramps have a maximum rise of 10 cm and tread length of 30–45 cm (Grandin, 1990; Grandin and Deesing, 2008).

Several studies have shown that loading and unloading may be more stressful than transport itself (Camp *et al*., 1981; Cole *et al*., 1988). This is evidenced by elevated (above basal levels) plasma cortisol concentrations (Kent and Ewbank, 1983, 1991; Warriss *et al*., 1995; Grigor *et al*., 2001) and heart rates (Fell and Shutt, 1986; Booth-McLean *et al*., 2007) during the first hour after loading, both of which steadily decline throughout the trip. Booth-McLean *et al*. (2007) also reported significantly higher heart rates at offloading compared to in-transit rates in beef heifers following a three-hour journey. María *et al*. (2004) found loading to be more stressful than unloading based on higher scores derived from a combined response (score) incorporating cortisol, creatine kinase and lactate measurements. Warren *et al*. (2010) reported that only 2.2 % of the drivers unloading cattle at a Canadian slaughter plant received a poor handling score which was related to excessive yelling and/or prodding or that resulted in cattle falling off the ramps within the trailer. Although this percentage is low, it is understandable because many large slaughter plants audit animal-handling practices at the time of unloading

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and are aware of the positive effects that good handling practices have on meat quality (Grandin, 2001, 2007). It should be noted that, currently, on-farm audits are scarce and therefore handling quality may be more variable, with potential to be poor, depending on the individual management styles of the producers and transporters loading the cattle. More information is needed on the effects of transport delays on cattle to identify practical cut-off points particularly during extreme weather conditions.

Significant information regarding best handling practices and facilities for loading and unloading has been published (Grandin 1997, 1998a,b, 2001, 2007). It is recommended that loading and unloading procedures should be performed gently and at an unhurried pace with as little shouting and noise as possible (Grandin, 2007). It is important to move a herd species in groups and not alone because cattle separated from their group can exhibit high levels of agitation (Grandin, 2007) that may result in injury to themselves or their handlers. The use of appropriate animal-friendly handling aids such as flags or light so that cattle can see where they are going are recommended (Grandin, 2007). In addition, the type of animal must be considered so that handling practices can be modified accordingly. For example, cull dairy cows are extremely susceptible to bruising and bulls can be aggressive and dangerous. Tall animals should never be loaded into a compartment that does not allow them to stand normally without touching the ceiling and causing injury.

Good handling procedures have been shown to improve meat quality and reduce carcass bruising, which are useful indicators of animal welfare (Eldridge and Winfield, 1988). While it is intuitive that good handling results in better welfare (fewer indicators of stress, injury and death) and carcass and meat quality (less bruising and dark cutting), science-based information on these relationships as they relate to transport is scarce. As cattle transport cannot occur without handling, the ability to isolate the effects of handling during loading and unloading from transport is one likely reason for the lack of information in this area. In one of the few studies assessing pre-transport handling, Brunel *et al.* (2018) assessed rough and gentle handling on 12–18-month-old *Bos indicus* bulls that were either transported for 24, 48 or 72 hours on indicators of stress, and immune responses. They found cattle handled roughly had greater cortisol concentrations and neutrophils and lower numbers of lymphocytes indicating greater stress and reduced immunity compared with those handled gently. Roughly handled cattle also had increased creatine kinase and fructosamine concentrations indicating some muscle damage and depletion of energy reserves, which was exacerbated following 72 hours of transport.

Loading density

There is strong economic motivation to load cattle as densely as possible (without reducing welfare or meat quality) because the cost of cattle transportation in NA is calculated as units/cwt/km (Whiting, 2000). However, as too little (or too much) space during cattle transportation may pose potential risk for compromised animal welfare or meat quality (Eldridge *et al.*, 1988; Eldridge and Winfield, 1988; Tarrant *et al.*, 1988; Tarrant *et al.* 1992), loading density standards were created. If cattle are overloaded on a truck at a density of 585 kg/m^2 bruising greatly increases because an animal that falls down will not be able to get back up due to tightly packed cattle (Table 9.1). Cattle loaded up at the highest density have decreased welfare, reduced carcass weight and increased bruising (Eldridge and Winfield, 1988).

Table 9.1. The effect of stocking density during 24-hour road journeys on plasma constituents and carcass bruising in 618 kg Friesian steers. Values for plasma cortisol, glucose and creatine kinase (CK) are the difference between the pre- and post-transport values. (From Tarrant *et al.*, 1992 and Tarrant and Grandin, 1993)

	Stocking Density (kg/m^2)			
Plasma constituent	448	500	585	Level of statistical significance (P)
Plasma cortisol (ng/ml^{-1})	0.1	0.5	1.1	<0.05
Plasma glucose (mmol/l)	0.81	0.93	1.12	<0.15
Plasma CK (units/l)	132	234	367	<0.001
Carcass bruise score	3.7	5.0	8.5	<0.01

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Loading density is defined as the space available to an animal when placed into a trailer compartment expressed as kg of bodyweight per m^2 or m^2 per animal. Randall (1993) was the first to publish loading densities guidelines for cattle, which were developed mathematically from equations derived to predict the length, width and height of cattle ranging in weight from 50 to 600 kg. Randall (1993) recommended the use of this equation for trips greater than 5 hours:

$$A = 0.01W^{0.78}$$

where A = the area of the space ($m^{2)}$ and W is the weight of the animal (kg). The Farm Animal Welfare Council recommends 360 m^2/kg as the maximum stocking density for cattle and their formula is:

$$A = 0.021W^{-0.67}$$

Petherick and Phillips (2009) and González *et al.* (2012b) concluded that an allometric coefficient (*k*-value) calculated as m^2 per animal/bodyweight$^{0.6667}$ was a better indicator of an animal's space allowance than m^2 per animal because it does not require the consideration of animal weight for making comparisons within and between studies. The EU also recommends the use of this allometric coefficient for cattle and sheep (EFSA, 2011).

In NA, loading densities are not regulated but instead are based on guidelines that are provided within industry codes of practice in both the USA and Canada. Recommended loading densities vary slightly between Canada and the USA (USDA, 1997; CARC, 2001). Unfortunately, studies assessing the effects of loading density on animal welfare outcomes support that these recommendations result in either acceptable (or unacceptable) animal welfare and/or meat quality standards are lacking. Management factors including horns, animal age and condition, transport distance, weather and trailer compartment size should be considered when loading cattle (Swanson and Morrow-Tesch, 2001; Schwartzkopf-Genswein *et al.*, 2008). To accommodate some of these factors Transportation Codes in the USA (USDA, 1997) and Canada (CARC, 2001) have recommended increases of 5–10 % more space.

Transport Surveys

In a survey of commercial transportation conditions of cattle shipped from Alberta to other Canadian provinces and the northern and midwestern USA, González *et al.* (2012b) found loading densities to be greater for calves (< 275 kg; 0.015 and 0.026 *k*-value) and feeders (275 to 500 kg; 0.016 and 0.028 *k*-value) compared to fat (>500 kg; 0.018 to 0.038 *k*-value) and cull (0.019 to 0.047 *k*-value) cattle. They also found large variations in loading densities by trailer compartment ranging between 0.011 and 0.156 *k*-value (González *et al.*, 2012b). For example, the belly (0.0179 *k*-value in Canada and 0.0180 *k*-value in the USA) and the deck (0.0186 *k*-value in Canada and 0.0185 *k*-value in the USA) compartments had greater loading densities compared to the nose (middle-front compartment), doghouse (upper-rear compartment) and back of the trailer. Additionally, they documented that more weight could be loaded onto trucks having a greater number of axles (e.g. quad-axle *versus* tri-axle trailers), which could result in very high loading densities. Due to their lighter weight, feeders and calves are at greater risk of being overcrowded because transporters can load more animals before axle weight restrictions are exceeded. Likewise, fat and cull cattle, which are heavier, are at risk of being transported with too much space, particularly in the nose and the doghouse compartments. An important finding from this study was that large deviations exist between commercial loading densities being used and the recommended loading density charts published for both Canada and the USA. For example, cattle in the nose, back and doghouse were reported to have 44.0, 3.9 and 60.4% more space, respectively, while cattle in the belly and deck had 7.5 and 5.5% less space than recommended by CARC (2001) and USDA (1997). A similar finding was reported by Warren *et al.* (2010) who tracked 1363 loads of beef cattle destined for an Ontario slaughter plant where loading densities were documented to be at or above the recommended space allowance 49% of the time. More research will be required to assess if the loading densities used by the NA beef cattle industry are more or less favourable for welfare and meat quality than the recommended values.

Australian studies have documented that freedom of movement was severely restricted at 585kg/m^2, with only 16 changes of position observed per group of cattle/1 h of transport, compared with 109 per group/1 h at 448 kg/m^2 (Tarrant *et al.*, 1988). Similar results were obtained on long road journeys (Tarrant *et al.*, 1992). Exploratory, sexual and aggressive behaviours were inhibited at high stocking

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densities with the exception of mounting and pushing, which increased in frequency with stocking density. The preferred orientations adopted by animals during long-distance transportation were frustrated as the stocking density was increased. Thus in addition to reducing mobility, an increase in the stocking density also prevented cattle from facing in the preferred direction. These effects may combine to increase the rate of loss of balance and falling.

An Australian study assessed the effects of age and stocking density on the welfare of young dairy calves (Jongman and Butler, 2014). The calves were 3, 5 and 10 days old and were transported 12 hours at space allowances of 0.2, 0.3 and 0.5 m^2 per calf. The study concluded that space allowance should be at least 0.3 m^2 per calf, while creatine kinase concentrations suggested more space (0.5 m^2) per calf may be beneficial. It was noted that straw bedding within the truck was also beneficial in reducing some of the negative effects of reduced space on lying behaviour.

At low stocking densities, e.g. half loads, cattle will travel very well unless subjected to poor driving techniques such as sudden braking or swerving and emergency stops. Eldridge and Winfield (1988) transported steers of 400 km live weight on road journeys of 6 hours at high (0.89 m^2/animal), medium (1.16 m^2/animal) and low (1.39 m^2/animal) stocking densities. Bruise scores at the high and low stocking densities were four and two times greater, respectively, than the medium space allowance (8.2, 4.6 and 1.9 bruise scores, respectively; $P < 0.01$). These results show that the medium stocking density was superior to the low density and indicate that an optimum density may be defined by such experiments. The medium stocking densities used by Eldridge and Winfield (1988) can be found in Grandin (1981a), Animal Transportation Association (1992), Federation of Animal Science Societies (1999) and Lapworth (2004). These medium stocking densities used by Eldridge and Winfield (1988) were very similar to the stocking density formula published by Randall (1993).

Tarrant *et al.* (1992) and Tarrant and Grandin (1993) showed that bruising was lower at 448 kg/m^2 compared to 585 kg/m^2. Mendonca *et al.* (2016) showed that bruising at stocking densities between <370 kg/m^2 and >431 kg/m^2 were higher. Bruises were lower outside this range. A possible explanation may be rough roads in Brazil, where cattle stocked more loosely could not brace against each other.

Transport duration and distance

Transport duration (rather than distance) more accurately reflects the total time cattle have been confined on a vehicle which includes waiting to depart after loading, in transit and stationary periods as well as waiting to offload. The majority of NA research on cattle transportation relates to journey duration/distance because of its obvious link to live weight loss or shrink.

Studies have documented typical transport durations in NA. Cernicchiaro *et al.* (2012a,b) reported calves destined for commercial feedlots within the USA were transported an average of 698 ± 4.4 km. González *et al.* (2012a) reported the mean distance travelled for loads considered by the industry to be long haul in Canada (> 400 km) was 1081 ± 343 km (maximum of 2560 km), whereas time animals spent on the truck averaged 15.9 hours with a maximum of 45 hours. They also found that only 5% of the loads they tracked exceeded 30 hours (maximum length legislated in the EU). Warren *et al.* (2010) reported average transit durations of 4.6 hours for cattle being transported for slaughter to Ontario with minimum and maximum durations of 0.3 and 68.3 hours, respectively. They found that approximately 86% of all the loads were in transit ≤ 8 hours

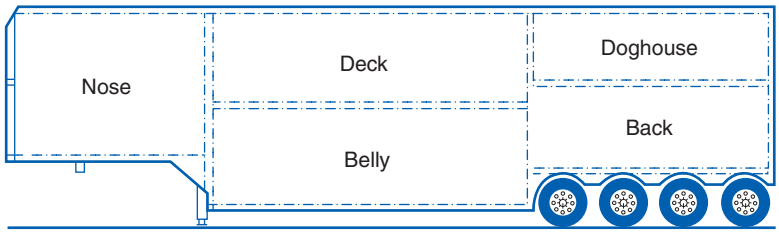


Fig. 9.1. Compartment layout in a typical pot belly transport trailer. (Adapted from Merritt Equipment Co., Denver Colorado)

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while approximately 9% were in transit between 8 and 16 hours. These studies suggest that transport durations in NA generally do not exceed the maximum regulated times of either 28 or 52 hours.

Delays during loading and unloading may also add stress to the transportation process. González *et al*. (2012a) documented that the time taken to load and unload cattle was 20 and 30 min on average, with a maximum of 5 and 3 hours, respectively, while Warren *et al*. (2010) reported a 25-min average wait. Warren *et al*. (2010) also noted that there were several occasions where truck drivers waited for more than one hour to unload. They concluded that, overall, there were no negative effects of either loading or unloading delay on cattle condition based on visual evaluations at the time of unloading. In addition, if delays, such as departure and unloading as well as border stops (crossing the Canada/US/Mexico border), are minimized this could have a large impact on transport duration as average delay lengths have been reported to be 3.03 hours (González *et al*., 2012a).

Both authors agree that information on transportation durations experienced by cattle (usually of poor condition or quality) that are sold and resold through the auction markets are absent, as this type of information is almost impossible to track. Likewise, information on unfit animals such as cull cows was not readily captured in any of the studies mentioned above and it is our belief that these scenarios are where some of the largest welfare issues still exist.

Trailer design

North American commercial cattle are typically transported in 16.2-metre long, five-compartment (nose, deck, belly, doghouse and back), double-decked aluminum trailers (Fig. 9.1). Information on the design of loading/unloading ramps and stock crates of single- and double-deck trucks and trailers are available (Anon, 1977). In most developed countries, adequate loading ramps are available. However, in some developing countries, cattle are forced to jump off the truck because no ramps are available. Ramps should be used and they can easily be built from locally available materials.

Practical experience in NA has indicated that there are fewer bruises in trailers that had doors that opened the full width of the trailer for unloading. Stock carried by rigid vehicles tend to experience a rougher ride than those transported by an articulated trailer. This is mainly because rigid-body trucks, which are smaller and easier to handle, are generally driven faster than large articulated vehicles (Anon, 1977).

Vibration stress can also be reduced by the installation of pneumatic suspension (Singh, 1991). The systems must be kept in good repair, because damaged pneumatic suspension may produce higher vibration than a vehicle with leaf springs (Singh, 1991). Practical experience has shown that a well-maintained pneumatic suspension system will reduce stress. In NA, a high percentage of livestock vehicles come with factory-installed pneumatic suspension. Using accelerometers, Kehler (2015) found that the nose, back and doghouse compartments of commercial transport trailers had the highest acceleration values in both the lateral and horizontal axis. However, the vertical acceleration did not differ by compartment. These trailer accelerations were found not to be associated with carcass bruising in finishing-weight heifers and steers destined for slaughter.

Van de Water *et al*. (2003a,b) reported calves subjected to vibrations at a frequency of 2 Hz became more stressed compared with vibrations of 12 Hz. These same researchers also found that calves riding in the front of the truck had higher cortisol levels. Over-inflated tyres will also increase vibration in a livestock truck (Stevens and Camp, 1979). Drivers over-inflate tyres to prolong life, but this practice is probably detrimental to livestock.

More information and scientific study regarding the effects of existing and new trailer designs on ventilation and on cattle welfare and meat quality are required. Future studies should also focus on air quality and internal ramp and compartment construction, which may help to reduce animal injury and carcass bruising. In addition, trailer designs accommodating feed and water provision must be assessed for their practicality and animal welfare and meat-quality benefits compared to the use of rest stops where cattle are fed and watered but must be handled.

Trailer ventilation and microclimate

European research has been instrumental in documenting the importance of trailer microclimate, suggesting it is one of the largest threats to animal welfare during transport (Mitchell and Kettlewell, 2008). Internal trailer conditions or microclimate

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(temperature, relative humidity and temperature humidity index (THI)) can be affected by many factors including ambient conditions, loading density, airflow and animal factors, such as respiration, sweat and excretions, which can either increase or decrease the amount of heat and moisture within the trailer (Curtis, 1993). There is a good description of the temperature humidity index in Schuetze *et al*., 2017). Microclimate within transport trailers can be highly variable and may depend on the compartment, location within the compartment, whether the truck is moving or stationary and what type of passive ventilation is used (Mitchell and Kettlewell, 2008; Goldhawk *et al*., 2014a). The thermal environment within the trailer requires efficient heat exchange, which can be achieved by various ventilation strategies (Mitchell and Kettlewell, 2008). In the summer, data loggers installed in trailers indicated that the temperature relative humidity index was hottest in the nose and lower in the tail compartment (Troxel *et al*., 2016). During summer in the southern USA, the temperature and humidity index was in the danger zone a high percentage of the time (Troxel *et al*., 2016).

Transport trailers in NA are manufactured with a variety of perforation patterns used for ventilation and most trailers have two roof hatches that can be opened for increased ventilation. The doors at the back of the trailer are typically solid. Ventilation within these trailers is passive and results in non-uniform air circulation at animal head level (Honkavaara, 1998). Heat can build up rapidly in a stationary vehicle. Vehicles should be kept moving and stopping should be kept to a minimum. Even during cool weather, a beef animal's temperature will rise when the vehicle is stationary (Stevens *et al*., 1979). Muirhead (1985) found that there are areas of no air movement in a moving truck. Honkavaara (2003–2004) stated that new designs of transport vehicles in Europe made it possible to transport cattle 8–14 hours with little effect on stress levels or welfare. Enclosed trucks with mechanical ventilation are more commonly used in Europe. However, in many countries, mechanical truck ventilation would not be practical. Failure to maintain the mechanical system in a fully enclosed vehicle could result in death.

Weather is an important factor in cattle transport as conditions can vary greatly even within a single journey. For example, cattle transported from southern Alberta to Northern California can experience temperatures ranging between –30 to 30°C. Cattle transport vehicles in NA are not climate-controlled and consequently the potential to have negative impact on animal welfare and meat quality is great, particularly under extreme environmental conditions. González *et al*. (2012a) found temperatures during transportation within Canada and the USA ranged between –42 and 45°C, both of which are outside the thermoneutral zone for beef cattle (Curtis, 1993). The condition extremes they reported were rare and more reflective were the average temperatures during the coldest (–5.2°C) and the warmest (23°C) months (González *et al*., 2012a). It should be noted that cattle are homeothermic, allowing them to acclimatize and adapt to their environment and reduce negative effects on animal welfare (Curtis, 1993). Abrupt changes in the outside temperature during transport can be more detrimental than constant exposure to either high or low temperatures (Randall, 1993).

In NA, ventilation is controlled during cold weather with winter boards. Boards refer to plastic, fibreglass or plywood pieces inserted to cover the trailer perforations, which alter air exchange between the interior and exterior of the trailer. Boards can be used on the entire surface of the trailer or only on a portion to allow airflow as recommended by CARC (2001) and USDA (1997). González *et al*. (2012a) reported that only 0.63% of all trucks surveyed in a western Canadian study used winter boards. Lack of boarding in their study was attributed to an industry belief that boarding can cause increased morbidity (due to increased humidity in the trailer) in calves and feeders. In contrast, Warren *et al*. (2010) reported more frequent use of boards under southern Ontario conditions, documenting that 79% of surveyed cattle liners had some winter boarding followed by 37, 34 and 21% for fall, spring and summer, respectively. They found that boarding reduced the incidence of dark cutters during winter transport. Practical experience in very cold areas in Canada indicates that the front and rear of the trailer should be covered first because the middle of the trailer stays warmer (J. Woods, personal communication). The effects of boarding on calf health as well as the incidence of frostbite at the time of slaughter for fat and cull cattle should be studied. Boarding used on trucks transporting cull cows were found to increase ventilation within trailers during travel and decrease ventilation during stationary periods (Goldhawk *et al*., 2015), which may be attributed to increased air speed created by fewer or smaller openings.

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Goldhawk *et al*. (2011) assessed trailer microclimate at high and low loading densities during summer transportation of feeder cattle and found that ambient temperature and not loading density was the best predictor of internal trailer microclimate. A Swedish study indicated that during the summer, the temperature inside a truck was 6°C higher than the outside temperature (Wikner *et al*., 2003). During a 15-hour summer journey, Stanford *et al*. (2011) documented that the belly and the back compartments of the cattle liner had lower THIs than the upper deck and doghouse compartments. They concluded that the lower THIs on the lower compartments were related to their reduced exposure to solar radiation while the highest THI in the nose compartment was related to reduced airflow directly behind the tractor. In similar studies, Goldhawk *et al*. (2014 a,b) and Bryan *et al*. (2010) found that trailer THI was greater at animal level than at the ceiling level of each trailer compartment and during stationary periods compared to in-transit periods. An increase of 1°C in the difference between average animal-level temperature in transit and the mean ambient temperature during the transport (18 h) of feeder cattle transport was associated with a 0.11% of BW increase in shrink and a 0.006 ng/ml increase in post-transport cortisol concentration, suggesting that increased trailer temperatures can have a negative impact on welfare (Goldhawk *et al*., 2014b). Events where animal-level THI was classified as above 'danger' lasted for only an average of 10 minutes in beef calves transported an average of 7 hours from a ranch to a feedlot (Goldhawk *et al*., 2014c).

Giguere (2006) and Friend *et al*. (2007) compared commercial cattle liners (control) in Texas with liners that were designed to increase internal airflow using aluminum scoops on the outside of the trailer. They found during an 11–12-hour summer journey the trailer scoops increased ventilation and reduced trailer temperatures (0–4°C) and ammonia concentrations. Cattle in the ventilated trailer also lost less weight compared with cattle in the control trailers (4.7 and 5.8 kg, respectively).

These previous research findings have important implications for monitoring trailer climatic conditions to assist drivers in making informed decisions about how to manage cattle under extreme hot and cold climatic conditions. More study regarding the effects of airflow and wind speed direction, ambient conditions, perforation patterns and other design features that control heat and moisture within the trailers is required.

Bedding

Bedding is required for transports greater than 12 hours (Health of Animal Regulations, 2010) in Canada; however, its use is highly variable according to the driver and trucking company. This finding is likely related to the additional cost (~ $30–70 per load) of using it as well as the time required to add clean bedding to, or remove soiled bedding from, the trailer. There are no regulations for the use of bedding in the USA. Bedding typically includes the use of woodchips, sawdust or straw and is recommended as a best practice for shipping calves or cull cows when ambient temperatures fall below 10°C (USDA, 1997; CARC, 2001). González *et al*. (2012a) reported that bedding was used in only 22.7% of loads they surveyed. Bedding use was found to be variable by season with the most frequent use during spring and winter followed by fall and summer (32.7, 28.8, 25.1 and 17.6% of all loads, respectively). Bedding use was less frequent with fat (20.2%) and cull (41.9%) cattle compared to feeders (56.3%), calves (67.4%) and breeding cattle (75.0%). These data suggest that animal condition, value and season are the most significant factors dictating if bedding is used. Lack of bedding on the floor of transport trailers can cause abscessed toes (Sick *et al*., 1982) which results in lameness.

Animal Factors

Animal age, size and condition

Cattle are typically grouped by their age, size and condition for transportation in NA. Common group types include calf, feeder, fat, cull and breeding stock. It is well known that transport can adversely affect the welfare of a calf more than a mature (>17–19 months of age) animal. This is related to the fact that calves are exposed to novel and stressful events, including weaning, vaccination, castration, dehorning, ear tagging, handling, mixing with unfamiliar cattle etc. around the time they are transported (Grandin, 2001) and have an immature hypothalamic–pituitary axis (Eicher *et al*., 2006). Consequently, there is an increased incidence of morbidity and mortality once they arrive at the feedlot (Fike and Spire, 2006). The same concerns would apply to old or cull animals and the potential for welfare and carcass quality issues with this category of animal is high because of their low economic value (Grandin, 2001).

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Some NA studies have documented that the adverse effects of transportation on animal welfare varies by animal type. For example, mature or fat cattle (> 500 kg) transported ≥ 400 km for slaughter had fewer quantifiable welfare (shrink, death, lameness, becoming non-ambulatory) issues compared to calves, feeders and culls (González *et al*., 2012c,d).

In the same study cull cattle were found to be at greatest risk of poor welfare during long-haul transportation because they had the greatest probability of becoming lame at the time of loading and unloading and being declared non-ambulatory or dead at the end of the journey compared to calves, feeders and culls (González *et al*., 2012d). Similarly, calves were found to be more likely to become non-ambulatory and/or die compared to fat and feeder cattle (González *et al*., 2012d). Feeder cattle were twice as likely to die during transportation as fat cattle, had greater shrink (5% versus 8% of BW, respectively) and were exposed to longer transportation durations compared to fat cattle, due to Canada/USA border-crossing protocols (González *et al*., 2012d). The authors concluded that fat cattle are in better condition (higher body condition score) and have a more robust immune system, resulting in better health compared to calves and feeders (González *et al*., 2012b,d). Similarly, Cernicchiaro *et al*. (2012b) reported that shrink had a greater impact in lighter-weight calves in terms of their risk of bovine respiratory disease morbidity compared with heavier-weight calves. They concluded that heavier cattle could recover faster from transport due to their resilience to stress compared to lighter-weight calves. Another study assessing the effects of transport duration and feed withdrawal on dairy calves (5–9-month-old male Holstein-Friesian) found that calves were most affected by the time of feed (Fisher *et al*., 2014). Calves in that study were transported for either 6 or 12 hours, transported for 1 hour to a holding facility and kept for 6 hours, and then transported an additional 5 hours, or not transported. All calves were restricted from milk intake for 30 hours. The study concluded that 6- and 12-hour transports including those that were held at the holding facility did not differ in indicators of stress (blood biochemistry and metabolism) when compared to the untransported control animals. However, the effects of milk deprivation for 30 hours resulted in reduced blood glucose concentrations, suggesting that time of feed needs to be carefully managed in young transported dairy calves.

In one of the only studies conducted on the stress associated with the transport of pregnant heifers Kang *et al*. (2017) found that 17-month-old Holstein heifers in early gestation (2–3 months) transported 100 km had increased cortisol and haptoglobin concentrations and immunological responses (percentage monocytes and granulocyte-lymphocyte rations); however, it did not affect reproductive performance (pregnancy and parturition) or calf growth.

Restlessness

Restlessness is defined as the frequency of changes in position cattle make in the vehicle. Restlessness increased with social regrouping on the truck, but not with motion (Kenny and Tarrant, 1987a,b). Changes in position are frequently triggered by social interactions, such as chin-resting and mounting, and also, when the truck was moving, by driving events, particularly cornering.

Standing orientation and lying down

The most common direction for cattle to face on a truck is either perpendicular or parallel to the direction of motion, with the diagonal orientation infrequently used (Kenny and Tarrant, 1987a,b; Eldridge *et al*., 1988; Lambooy and Hulsegge, 1988; Tarrant *et al*., 1988, 1992; Gallo *et al*., 2000). This may indicate that cattle have a preferred orientation to improve security of balance on a moving vehicle. Bisschop (1961) found that cattle align themselves across the direction of travel during rail transport; however, Kilgour and Mullord (1973) found no clear preference by young beef cattle during road transport.

On long journeys, the most common standing orientation was perpendicular to the direction of travel, and there was a strong bias against diagonal orientations (Tarrant *et al*., 1992). Cattle tend not to lie down in trucks while they are moving (Warriss *et al*., 1995). In one-hour and four-hour journeys to slaughter, no animals lay down in 18 loads of Friesian steers or bulls transported at relatively high stocking densities (Kenny and Tarrant, 1987a,b; Tarrant *et al*., 1988).

Reports on behaviour during rail transportation noted heightened activity immediately after loading, and characteristic standing and lying behaviour in moving and stationary vehicles (Bisschop, 1961). Gallo *et al*. (2000, 2001) indicated that during long journeys (up to 36 h), adult cattle start to lie down or fall down after 12 hours of transport. On long

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road-plus-ferry transport, the proportion of lying adult cattle increased with time, whereas young cattle (6–12 month) laid down earlier (Aguayo and Gallo, 2005). Experiments in the USA with railcars equipped with hay and water troughs indicated that the animals would eat and drink during transport provided they had sufficient space to move to the feeders (Irwin and Gentlemen, 1978).

At high stocking density, especially approaching maximum density, cattle occasionally went down, apparently involuntarily. Towards the end on long (24-h) road journeys with Friesian steers, several cattle lay down during the final 4–8 hours of the journey. This was observed at all stocking densities where animals were trapped down and unable to rise. The highest stocking density is the maximum amount of cattle that can be out on a truck when it is still easy to close the rear gate. Honkavaara (1998) noted that one restless animal was sufficient to cause continuous movements of the group; as a result, no animal could lie down during transport.

However, when cattle were transported in stock crates designed to hold two animals per pen, an animal would often lay down after two to three hours of transport (Honkavaara, 1993). This may indicate a preference for lying down when circumstances permit. Young, 5–10-day-old calves will lie down during transport. Providing sufficient space to allow calves to lie down greatly reduces physiological measures of stress (Todd *et al*., 2000). For long trips across Europe, about 20% of adult cattle lie down while the vehicle is moving (Marahrens *et al*., 2003). These animals have been provided with enough space to lie down.

Maintenance of balance

Loss of balance on moving vehicles is a major consideration in cattle transport, in view of the hazards associated with large animals going down during transport and the risk of injury or suffocation. Observations show that minor losses of balance occur regularly and that cattle respond quickly by shifting their footing to regain balance.

The relationship between loss of balance and driving events during 24-hour journeys with Friesian steers was studied by Tarrant (1981) and Tarrant and Grandin (2000). Eighty per cent of losses of balance were accounted for by braking, gear changes and cornering (Tarrant *et al*., 1992). Similar results were obtained for Friesian bulls and steers on shorter road journeys (Kenny and Tarrant, 1987a,b; Tarrant *et al*., 1988).

Cornering is the driving event that caused most losses of balance in cattle transported at high stocking density, whereas breaking was a greater hazard at lower densities. These data show that losses of balance are under the direct control of the driver. Eldridge (1988) observed that the heart rate of beef heifers was lower, indicating reduced stress, when the vehicle was travelling smoothly on highways compared with that on rougher country roads or suburban roads with frequent intersections.

Factors likely to influence security of balance during unsteady driving are the slipperiness of the floor surface and the availability of support from adjacent structures, including vehicle sides and partitions – and other animals. It may be advisable to withhold water during the last six hours before loading (Wythes, 1985), thus resulting in a drier truck floor, giving cattle a better footing during the journey.

Falls

The major risk in cattle transport is that of cattle going down under foot. This risk is greatly increased at the highest stocking density (Tarrant *et al*., 1988, 1992), especially during journeys exceeding 12 hours (Gallo *et al*., 2000, 2001; Valdés, 2002). The normal response to a loss of balance is a change or shift of footing in order to regain balance. Shifting was inhibited at high stocking density and there was a corresponding increase in struggling and falling at 585 kg/m^2 stocking density.

These unstable situations were caused either by driving events – typically cornering or braking – by standing on a fallen animal or by strenuous and usually unsuccessful attempts to change position in a full compartment. When cattle went down at high stocking density, they were trapped on the floor by the remaining cattle 'closing over' and occupying the available standing space. Several unsuccessful attempts by fallen animals to stand up were observed. A 'domino' effect was created when standing animals lost their footing by trampling on a fallen animal. The substantial increase found in carcass bruising at the highest stocking density was explained by these observations (Table 9.1).

Live weight loss

The loss of live weight (shrink) and carcass yield during transportation of cattle is of both welfare

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and economic concern. Shrink is one of the most commercially tracked variables due to its ease of collection and use as an indicator of the conditions during transport. The amount of shrink animals experience during transport is related to their level of hydration and body and carcass weight (Warriss, 1990; Jones *et al*., 1990; Schaefer *et al*., 1992). Animals lose live weight as a consequence of excretion, evaporation and respiratory exchange (Dantzer, 1982). Most of the live weight losses during transportation may be attributed to the effect of withdrawal of feed and water; the gut contents can account for 12–15% of the animal's live weight.

Stress, physical activity, and environmental conditions during transport increase energy and water demands, and excretion of faeces and urine (Warriss, 1990; Parker *et al*., 2003). A multitude of factors can influence shrink and include: the duration of feed and water deprivation, environmental conditions, body condition, time of loading, diet composition, driving quality, gender, and management and handling procedures prior to and during transport (Warriss, 1990; Coffey *et al*., 2001; González *et al*., 2012c; Cernicchiaro *et al*., 2012b). North American cattle are not provided with feed or water during transport. To compensate for this, they must mobilize body reserves to supply extra energy and water to cope with dehydration (Schaefer *et al*., 1992). For example, in cattle hauled an average of 1023 km, almost half of the shrinkage was due to loss of carcass weight (Self and Gay, 1972). High shrink has been associated with poor performance and greater morbidity (e.g. shipping fever) after transport (Camp *et al*., 1981, 1983), lower meat quality (Jones *et al*., 1990) and greater incidence of lame, non-ambulatory and fatalities during transport (González *et al*., 2012b).

Several NA studies have documented that transportation durations ranging between two and 48 hours resulted in shrink values between 0% and 8% of bodyweight (BW) (Lofgreen *et al*., 1975; Jones *et al*., 1990; Mayes *et al*., 1979; Zavy *et al*., 1992; Schwartzkopf-Genswein *et al*., 2007; Cernicchiaro *et al*., 2012a,b). González, *et al*. (2012c) reported greater shrink for feeder cattle loaded at ranches/farms and feed yards compared to those loaded at auction markets. They also found that cattle loaded during the afternoon and evening shrank more than those loaded during the night and morning (González, *et al*., 2012c). The same study documented that shrink increased most rapidly in cattle transported for longer durations at higher ambient temperatures suggesting a synergistic effect (Fig. 9.2). They concluded that cull cattle, calves and feeder cattle appear to be more affected by transport compared to fat cattle going to slaughter because of greater shrink.

Greer *et al*. (2011) assessed the effect of long- (900 km) and short- (100 km) haul transportation on trailer microclimate and animal (slaughter weight heifers) shrink during summer months. They found that shrink was significantly affected by trailer compartment with the nose producing the highest overall loss (3.50 ± 0.19 kg) and the back compartment the lowest (2.69 ± 0.18 kg). Similarly, Bryan *et al*. (2010) reported a significant positive relationship between shrink and compartment THI.

Australian and European studies documented that fasting of 396 kg steers for 12, 24, 48 and 96 hours caused live weight losses of 6, 8, 12 and 14%, respectively (Wythes, 1982). In 24-hour journeys by road, the live weight losses in cattle were about 8% (Shorthose, 1965; Lambooy and Hulsegge, 1988; Tarrant *et al*., 1992). Recovery of bodyweight to pre-transport values took five days (Warriss *et al*., 1995).

Dehydration is a factor in loss of live weight and also carcass weight during transportation. Lambooy and Hulsegge (1988) found slightly increased haematocrit and haemoglobin values in pregnant heifers transported by road for 24 hours. The heifers had access to water and feed after 18 hours of

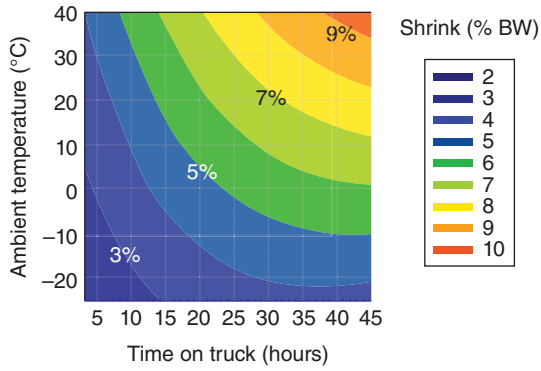


Fig. 9.2. Effect of time spent on truck and average ambient temperature during the journey on shrink of fat cattle during commercial long haul transport in North America (> 400 km). Add 1.56% of BW for feeder cattle, 2.60% for calves, and 3.56% for cull cattle to the value from the any point in the figure. Ambient temperature was the mid-point between the minimum and maximum values reported within each journey.

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Table 9.2. Effect of an eight-hour rest stop with hay and water during 36 hours of truck transport on carcass bruising and dark cutting (groups of 20 animals) (Gallo *et al.*, 2001). Rest stops may be more beneficial on long journeys to allow fatigued cattle to rest. This may help reduce the number of cattle that fall during the journey.

	Rest stop	Continuous 36-hour trip
Carcasses with bruises penetrating muscle	0	6
Carcasses with pH > 6.0	3	5
Fallen cattle in the truck upon arrival	0	3

transport, and water uptake per animal ranged from 1–6 litres. Shorthose (1965) calculated that the approximate rate of carcass weight loss in steers was 0.075%/day for transport and holding times lasting from three to eight days. In 24-hour road journeys under cool ambient conditions (4–16°C), there was evidence of dehydration, as shown by increases in red blood cell count, haemoglobin, total protein and packed cell volume (Tarrant *et al.*, 1992; Warriss *et al.*, 1995). Providing water *ad libitum* to fasted livestock reduces shrink (Hahn *et al.*, 1978).

Rest stops may be more beneficial on long journeys to allow fatigued cattle to rest. Gallo *et al.* (2001) found that resting reduced bruises (Table 9.2). This was likely due to reduced bruises in fallen cattle.

Rest stops

The effect of giving cattle access to water after a long journey in hot weather (25–36°C) was examined by Wythes (1982). Access to water for 3.5 hours or longer before slaughter allowed muscle water content to increase and this was reflected in heavier carcasses. Providing cattle with an oral electrolyte in their drinking water reduced both carcass shrink and dark cutting (Schaefer *et al.*, 1997). Similarly, Grumpelt *et al.* (2015) found that providing pre-transport nutritional therapy that contained selective amino acids, electrolytes and an energy source 24 hours prior to transport resulted in reduced live weight loss and improved carcass yield in 600-kg British cross-steers transported one hour to a slaughter facility. In a major study of 4685 calves and yearlings, animals subjected to the increased stress of moving through a market had greater shrink than animals purchased directly from the ranch of origin (Self and Gay, 1972). Collectively, the physiological changes observed in cattle during transport and handling – which include changes in blood cells, blood metabolites and enzymes, electrolyte balance, dehydration and increased heart rate – suggest that treatments designed to attenuate stress should be considered as a means of protecting animal welfare and benefitting carcass quality and yield (Schaefer *et al.*, 1990, 1997). The application of oral electrolyte therapy, especially if similar in constituents to interstitial fluid, seems to attenuate these physiological changes and results in less carcass shrink and reduced dark cutting. Another potential strategy to reduce transport stress is to provide a rest stop midway through the journey. At this time little is known about the effects of off-loading to rest cattle so they may have access to feed and water. Marti *et al.* (2017) conducted a study with newly weaned beef calves transported 15 hours and provided 0, 5, 10 and 15 hours of rest with access to feed and water. They found that rest-stop periods ≥ 10 hours did not prevent short- and long-term stress after transport in weaned calves. However, the study was conducted using a stock trailer and should be replicated with commercial trucks to ensure relevance to the industry.

Bovine Respiratory Disease (Shipping Fever)

The most important disease associated with the transportation of cattle is shipping fever (bovine respiratory disease – BRD) (Fike and Spire, 2006), which is attributed to the stress caused by transporting cattle or calves from one geographical region to another. In NA, where feedlot fattening of beef cattle is common, it is estimated that 1% of cattle die as a consequence of transport stress and its aftermath (Loneragan *et al.*, 2003). Bovine respiratory disease is responsible for 50% of death losses in the feedlot and 75% of the sickness (Edwards, 1996; Loneragan *et al.*, 2003; Deering, 2006). Fourteen per cent of US feedlot cattle become ill from shipping fever (Snowder *et al.*, 2006). Feedlot cattle with shipping fever gain less weight (Morck *et al.*, 1993). A review of BRD by Miles (2009) cites the approximate cost of BRD to be greater than $500 million in the USA.

Two large epidemiological studies assessing feedlot health records from 21 and 13 central and southern US feedlots reported mean cumulative BRD

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morbidity to be 4.9% (Cernicchiaro *et al*., 2012a) and 10% (Cernicchiaro *et al*., 2012b) with a mortality of 1.3% documented for both studies. The distance travelled was significantly associated with BRD morbidity, overall mortality, hot carcass weight (HCW) and average daily gain (ADG). In addition, shrink was also found to be associated with higher BRD mortality and overall morbidity as well as reduced HCW and ADG (Cernicchiaro *et al*., 2012b). Hay *et al*. (2016a, b) reported that cattle breed may be a factor. Herefords had an increased risk compared to Angus or tropically adapted breeds and lighter cattle had a greater risk (Hay *et al*., 2016a, b).

However, in a study of 45,000 six-month-old calves transported to feedlots, Ribble *et al*. (1995) found that differences between short and long hauls explained little, if any, of the variation among truckloads of calves in the risk of fatal fibrinous pneumonia. They suggested that other elements of the transportation process might be more stressful and therefore responsible for shipping fever. Longer trips have a more detrimental effect on stress physiology (Fazin *et al*., 2005), but other factors such as fear stress, weaning stress and mixing with strange calves are likely to be contributors to stresses which increase sickness.

Shipping fever also has been reported in most European countries and Asia (Hails, 1978; Hay *et al*., 2014, 2016a, b). To reduce losses, calves hauled long distances to feedlots – where they will receive grain – should be fed a 50% concentrate diet before shipping (Hutcheson and Cole, 1986). Economic losses caused by death are minor compared with the cost of prophylactic treatment of affected cattle and poor growth in those that recover. The main symptoms of shipping fever are those of the bovine respiratory disease complex; this syndrome is characterized by fever, dyspnoea and fibrinous pneumonia, less often by gastroenteritis and only occasionally by internal haemorrhage. Fed cattle that had lung lesions from shipping fever at slaughter had gained less weight, the carcasses were downgraded for less marbling and the meat was tougher (Gardner *et al*., 1998). Other researchers have also found that the presence of lung lesions at slaughter was associated with reduced weight gain (Wittum and Perino, 1995; Wittum *et al*., 1995).

The pathogenesis of bovine respiratory disease involves a sequential cascade of events initiated by stress, which may have lowered the animal's resistance to infection (Earley *et al*., 2017). Very little research has been done on the detrimental effects on the immune system of heat, cold, crowding, mixing, noise and restraint (Kelley, 1980; Kelley *et al*., 1981).

Ruminal function is impaired by transit stress. Transport imposes a greater stress on the rumen than feed and water deprivations (Galyean *et al*., 1981). This impairment may be explained by a decrease in rumination during transport. Kent and Ewbank (1991) reported that during transport, rumination greatly decreased in three-month-old calves.

In extensively reared beef cattle, the stress of transport had a greater detrimental effect on an animal's physiology than the stress of feed and water deprivation for the same length of time (Kelley *et al*., 1981; Blecha *et al*., 1984). Similar findings have been reported in Chile, when the effects of three or 16 hours of deprivation of water and feed were compared in Friesian steers kept either confined in a pen on the farm or transported by road (Tadich *et al*., 2003). There is currently little information regarding the effects of feed and water deprivation during transport on rumen kinetics in cattle which could have important implications for both rumen and animal health. Deng *et al*. (2017) reported that transport stress in Xianan cattle transported over 1000 km resulted in increased acetic acid production, reduced pH, and propionic and butyric acids within the rumen, which was associated with fewer cellulolytic bacteria for up to 15 days after transport. They suggested that these changes may reduce intake and may have a negative effect on growth performance post-transport. Another recent study used four-year-old *Bos indicus* cattle housed in pens to study the effects of a 72-hour feed and water deprivation on rumen functionality (Leo-Penu *et al*., 2018), which provides some insight into what may happen when cattle do not have access to feed and water during transport. The study found that a 72-hour deprivation had a negative but transient effect on the rumen, which included a decrease in both bacterial and protozoal numbers at the end of the deprivation period. However, the microbiota and other measures of functionality such as volatile fatty acid production and gas production returned to normal within 96 hours after the 72-hour deprivation period. Reduced rumen functionality during the 96-hour period may have some implications for reduced feed intake and susceptibility to disease.

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The diverse microbiota of the nasopharynx plays an important role in bovine health and is also a place for pathogenic bacteria associated with BRD. Holman *et al*. (2017) assessed the nasopharyngeal microbiota in eight-month-old, disease-free, British cross-cattle, pre- and post-transport (20 km), to a feedlot. They found that the microbiota changed significantly within the 14-day period post-transport with the largest change observed between the pre-transport (d 0) measurement and two days post-transport, which included increased phylogenetic diversity. The authors concluded that the abrupt change in microbiota may be related to host susceptibility to BRD in the feedlot. A better understanding of the relationship between cattle stress, immunity and changes in microbiota will be important in developing strategies to mitigate BRD.

Stress-induced changes in host resistance may explain the physiological basis of shipping fever in cattle. Tarrant *et al*. (1992) observed an increase in total white blood cell count and neutrophil numbers and a reduction in lymphocyte and eosinophil numbers in cattle after long journeys. The immune function of *Bos indicus* steers was significantly lowered after a 72-hour trip (Stanger *et al*., 2005). Transportation of beef calves immediately after weaning can increase stress. Arthington *et al*. (2003) found that transport had detrimental effects on acute phase proteins in newly weaned calves. Crookshank *et al*. (1979) found that calves transported immediately after weaning had higher cortisol levels compared with calves that had been weaned and placed in feedlot pens for two weeks prior to transport. Both weaning and transport affect the humoral immune response in calves (MacKenzie *et al*., 1997). This was also supported by Wernicki *et al*. (2014) who found that stressors associated with transport and adaptation to the feedlot resulted in reduced weight gain, suppression of the humoral immunity (increased blood lipid peroxidation, haptoglobin and nitric oxide ion concentrations and reduced immunoglobulin) as well as increased morbidity during the first weeks in the feedlot. This illustrates the effects of oxidative stress in transported calves and its association with increased rates of BRD.

Methods of preventing bovine respiratory disease

Research on 7845 calves has shown that sickness in six-month-old calves that have been transported long distances could be greatly reduced by weaning and vaccinating the calves five to six weeks prior to long distance travel (National Cattlemen's Association, 1994; Swanson and Morrow-Tesh, 2001). Unvaccinated calves that are shipped the same day they are weaned will have more respiratory sickness and death losses (National Cattlemen's Association, 1994; Fike and Spire, 2006). Death losses due to respiratory disease were 0.16% in vaccinated calves, 0.98% in calves still bawling after being removed from the cow and 2.02% in calves bought from order buyers and auctions (National Cattlemen's Association, 1994).

The best management strategy is to prevent shipping fever. A review by Taylor *et al*. (2010) gives details on the predisposing factors for BRD. Over the last decade it has become more common for feedlot managers to contract pre-weaned and vaccinated calves from ranchers 30–45 days before shipment. Feedlot managers will pay US$20 more per weaner calf to receive these preconditioned animals (Troxel *et al*., 2006). However, some feedlots will not pay a premium for preconditioned calves and this has resulted in reluctance by ranchers to precondition as there is no economic benefit to do so. Grandin (2018a, b) and Schwartzkopf-Genswein *et al*. (2007) concluded that preconditioning calves prior to transport allowed them to better tolerate the stressors of transport and handling. This was observed in lower cortisol concentrations pre- and post-loading as well as higher percentages of time feeding and less time standing and milling in their pens immediately post-transport compared to non-conditioned calves. They also noted that the combined effect of conditioning and short-haul transport was least stressful as witnessed by the low-shrink, high dry-matter intake and ADG in the first month after transport.

Unfortunately, there is still a significant percentage of unvaccinated calves entering the supply chains. Researchers have classified these calves as either high-risk or ultra-high-risk (Booker *et al*., 2017; Wilson *et al*., 2017). These calves were obtained through auction markets and mass medication with two antibiotics will reduce death losses 50% (Booker *et al*., 2017). The solution to this problem is for producers to be held accountable for losses in these mismanaged calves. Proper preconditioning and vaccination at the ranch of origin would reduce the numbers of high-risk feeder calves. It would also have the added benefit of reducing antibiotic use.

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Bach *et al*. (2004) found that lack of preconditioning coupled with long-haul transport increased faecal shedding of *E. coli* and *E. coli* O157:H7 by calves on and shortly after arrival at the feedlot. Their results suggest that *E. coli* O157:H7 in non-preconditioned long-haul calves may have been acquired from the feedlot and that transmission of, and susceptibility of these calves to infection may have increased as a result of stresses associated with weaning, duration of transport, and relocation. They concluded that preconditioning and minimizing transport duration is an effective management strategy for reducing the risk of calves acquiring *E. coli* O157:H7 on entrance into the feedlot environment.

Practical experience shows that cattle from pastures that were deficient in minerals had more death losses than cattle that had received mineral supplements (Peltz, 1999). Supplementation of newly arrived calves with vitamin E, chromium or an antioxidant can reduce sickness and improve performance (Barajas and Ameida, 1999; Purnell, 1999; Stovall *et al*., 1999). A large dose of 1600 IU/day of vitamin E in the feed was most effective. Carter *et al*. (2005) showed that 2000 IU of vitamin E reduced medical costs but had little effect on performance. Since newly arrived feeder cattle showing signs of sickness often have reduced feed intake, they should be fed diets with increased nutrient density and be supplemented with extra vitamins and minerals to help reduce sickness (Galyean *et al*., 1999; Loerch and Fluharty, 1999; Sowell *et al*., 1999). Fike and Spire (2006) go into more detail about receiving programmes for beef calves arriving at feedlots. Takemoto *et al*. (2017) found that the transportation (1200 km) of five-month-old Holstein calves affected 38 total metabolite concentrations and 30 metabolic pathways. They indicated that withdrawal of feed and water likely affected some pathways immediately after transportation; however, other pathways were altered for three days or longer post-transport. They concluded that feed supplementation with tyrosine, niacin and propionic acid before and after transport may aid in reducing the adverse effects of transport.

When wild, extensively raised calves are transported, buyers who transport thousands of calves on trips ranging from 1000–2000 km found that the animals are less likely to get sick if they are transported within 32 hours without a rest stop (Grandin, 1997). This may possibly be due to the fact that some of the calves have not been vaccinated prior to transport. Another factor is that loading and unloading may be stressful to calves that are not accustomed to handling. Fike and Spire (2006) concluded that even small improvements in handling (that would reduce animal stress) associated with transportation of calves would reduce the degree of stress and incidence of bovine respiratory disease. In an attempt to mitigate stress in yearling (approximately 310 kg) crossbreed beef steers transported 1300 km to a feedlot, Capik *et al*. (2017) reported that meloxicam administration to healthy steers immediately before long-distance transport did not reduce the effects of transport-induced stress on leucocyte function or inflammatory markers. However, another study assessing the impact of meloxicam and long-distance transportation (16 h) on cell-mediated immunity to a vaccination with a live bovine viral diarrhoea virus (BVDV) in 13–17-month-old Brahman cross-feedlot steers concluded that the use of meloxicam prior to transport had some inhibitory effects on T-cells in transported cattle (Van Engen *et al*., 2016). Similarly, flunixin meglumine reduced the cortisol and acute-phase protein responses elicited by road transport in Angus cross-steers transported 1280 km (Cooke *et al*., 2013).

Reviews on transportation have speculated that the environmental conditions on the vehicle may play a major role in transportation stress and animal health (Eicher, 2001; Swanson and Morrow-Tesch, 2001; Mitchell and Kettlewell, 2008). White *et al*. (2009) found that calf wellness measured by morbidity within the first 40–60 days after transportation from Tennessee to Kansas was greater in calves in compartments with 15 head or less, and they tended to have reduced odds of being treated for sickness compared with cattle in compartments with 16–30 head. However, loading density was not found to be associated with increased disease risk in that study even though stocking density in some of the compartments was less than the USDA recommended density of 0.70 m^2 per animal (USDA, 1997). White *et al*. (2009) suggested that the environment within a trailer is likely not homogeneous and that the conditions within compartments may vary, thereby affecting animal health.

Management at arrival at the feedlot

Factors unrelated to transport or handling may also affect susceptibility to shipping fever. Both

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research and practical experiences show that cattle that eat and drink shortly after arrival are less likely to get sick (Schwartzkopf-Genswein *et al*., 2005). BRD can be significantly reduced by placing water troughs in the middle of a pen to prevent cattle in adjacent pens from sharing a trough (Hay *et al*., 2016a, b). To facilitate drinking in extensively raised cattle that are used to drinking out of ponds, the animals should be trained to drink from a water trough before the trip. The second author has observed cattle that died because they were afraid of a float-controlled water trough. Calves that received an adequate passive immunity from the mother's colostrum are more resistant to bovine respiratory disease (Wittum and Perino, 1995). This implies that maternal traits and adequate milk production affect susceptibility to disease due to transport stresses later in life.

Injury, mortality, non-ambulatory and lameness

By its very nature, the animal transport process has the potential to result in animal injury or death due to the physical and psychological stressors to which the animals are exposed. Likewise, the physical and physiological condition of an animal best determines its fitness for transport because of the impact it has on their ability to cope with stress.

In a study assessing welfare outcomes of 6152 loads of fat, feeder, calf and cull cows González, *et al*. (2012d) reported 0.012% became lame, 0.022% non-ambulatory and 0.011% died on the truck. Similar injury and mortality rates were reported by Warren *et al*. (2010) assessing 1363 loads of slaughter-weight cattle documenting values of 0.158%, 0.010% and 0.008% for animals found lame, non-ambulatory and dead, respectively. Mortality and injury rates of 0.04% and 0.24%, respectively, were documented for 5500 animals arriving at packing plants as part of the US Cow and Bull Beef Quality Audit (NMCB-BQA, 2007). European studies have also reported mortality rates for road-transported cattle to be 0.007% for fat cattle, 0.027% for calves (Večerek *et al*., 2006a; Malena *et al*., 2007) and 0.039% for dairy cattle (Večerek *et al*., 2006b; Malena *et al*., 2007).

Lameness is still an issue in cattle arriving at slaughter plants. Harris *et al*. (2017) reported that 2.4% of the cull beef cows and 5% cull dairy cows were severely lame. Eight per cent of the dairy cows arrived with a full udder because they had not been dried up before transport. From a welfare standpoint, this is not acceptable. In fed beef cattle, liver abscesses increased from 21% in 2011 to 31% in 2016 (Eastwood *et al*., 2017). The second author has observed abscesses where the liver has fallen apart and adhered to the body wall. This is a recent problem.

In the USA, lameness is an issue in some groups of fed cattle arriving at the abattoir. It is likely to be due to multiple factors such as breeding for carcass traits, heavier cattle at younger ages and overuse of beta agonists and higher-energy rations (Grandin, 2018a). Edwards-Calloway *et al*. (2017) reported a spike in lame feedlot cattle in the summer of 2013 of approximately 16%. The following summer, the lameness percentage was reduced by half. This may have been due to cattle feeders becoming more careful with feeding programmes. Hagenmaier *et al*. (2017) found that cattle fed beta agonists during hot weather had more stiff cattle during unloading at the abattoir. The second author observed in the summer of 2018 that cattle arriving at the abattoir from certain feedlots have more problems with both lameness and fed cattle becoming non-ambulatory. Since the publication of the fourth edition, fatigued fed cattle have become an increasing problem. This condition is described in Thomson *et al*. (2015) and Schuetze *et al*. (2017). These animals may be more likely to become non-ambulatory. The second author has observed that 10–15 years ago, fatigued, fully finished feedlot cattle were seldom a problem.

González, *et al*. (2012c) showed that the likelihood of cattle becoming non-ambulatory, lame or dead increased sharply after animals spent over 30 hours on a truck (Fig. 9.3). They also found that animal death increased sharply when ambient temperatures fell below –15°C while the likelihood of becoming non-ambulatory increased when temperatures rose above 30° C (Fig. 9.4). The authors concluded that transportation durations exceeding 30 hours should be avoided during particular climatic conditions. Warren *et al*. (2010) reported no relationships between transportation distance (most within 8 hours of the plant) and mortalities on arrival at the slaughter plant. The 2016 National Beef Quality Audit indicated that 0.9% of dairy cows arrived at a slaughter plant as non-ambualtory (Harris *et al*., 2017).

González *et al*. (2012d) found that space allowances (using the allometric coefficients; *k*-value) lower than 0.015 and greater than 0.035 were

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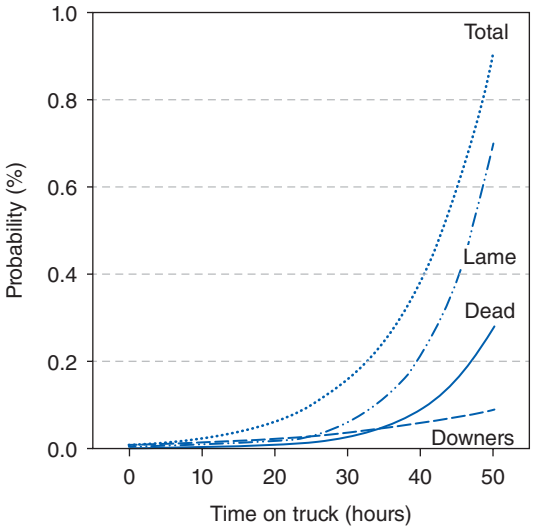


Fig. 9.3. Effect of time cattle spent on truck on the likelihood of becoming lame, non-ambulatory (downer) and dead during long-haul transport (> 400 km). Total was the sum of lame, non-ambulatory (downer) and dead animals during the journeys.

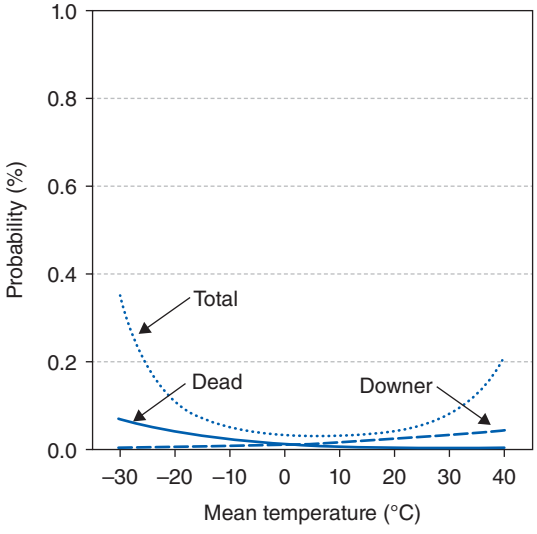


Fig. 9.4. The probability of having dead or downed cattle increases at both extremely low and extremely high temperatures.

associated with significant increases in the likelihood of cattle dying, becoming non-ambulatory or lame during transportation, particularly in the deck and belly compartments (Fig. 9.5). The same study

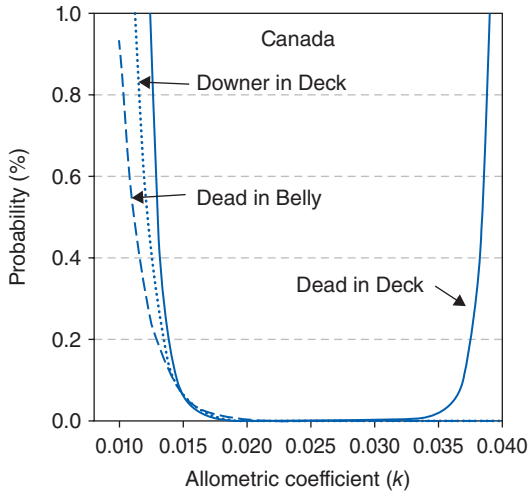


Fig. 9.5. Relationship between space allowance within Canada with the likelihood of becoming lame, non-ambulatory (downer) and dead during long-haul transport of cattle (> 400 km). Space allowance was measured through the allometric coefficient (*k*) calculated for each compartment from the formula k = space allowance (m^2/animal)/BW 0.667.

showed animals that lost 10% of their bodyweight during transport had a greater likelihood of dying and becoming non-ambulatory or lame. Mortality was greater in cattle loaded at auction markets compared to feedyards and ranches (González *et al.*, 2012d). Bad animal welfare outcomes were reported to decrease with more years of truck-driving experience (González *et al.*, 2012d). The above studies indicate that unacceptable animal welfare outcomes during transport can be minimized by taking careful consideration of journey duration, space allowance, ambient temperature and quality of driving.

Pre-transport inspection, management and planning of marketing should be done accordingly to ensure the welfare of, particularly, cull cattle (Grandin, 2001). A large study assessing the mortality rates of all classes of cattle arriving at several slaughterhouses in the Czech Republic (1935 deaths out of 1,552,574 cattle observed) found that higher mortality rates were observed in feeders and dairy cows transported shorter (<50 km and 51–100km) compared to longer distances (101–200 km and >200km), which was attributed to failure of breeders and transporters to meet necessary requirements concerning animal welfare prior to and during transport. The same study found that

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mortality was also associated with season, with the highest mortality rates observed in spring months for all cattle types while the lowest mortality rates were observed in autumn for fat cattle and dairy cows and in winter for feeders and calves (Simova *et al*., 2017).

Carcass bruising

Bruising is an impact injury that can occur at any stage in the transportation chain and may be attributed to poor design of handling facilities, ignorant and abusive stockmanship or poor driving techniques during transportation (Grandin, 1983). Improvements in cattle-loading facilities reduced bruises (Mendonca *et al*., 2016).

The most recent surveys of bruising in the USA show that in fed feedlot cattle, 39% had bruises (Eastwood *et al*., 2017). A study of 4287 fed cattle in Kansas indicated that 55% of the carcasses were bruised (Youngers *et al*., 2017). Many of the bruises were caused by tall cattle hitting their backs during loading or unloading. The latest survey of major US cow and bull slaughter plants indicated that 64% of the cows were bruised (Harris *et al*., 2017). Other recent surveys showed that 60% of cattle in Uruguay and 54% in the Great Lakes area of the USA were bruised (Huertas *et al*., 2015; Rezak *et al*., 2014). Bruises are a severe welfare problem in the developing world – 82% of carcasses have severe bruising.

There is a need to standardize and improve bruise-scoring methods. Kline (2018) found that actually weighing trim losses provides more accurate information. She found that people tend to underestimate the weight of large amounts of trimmings. She also discovered an 'iceberg' effect; a small bruise or a slightly pinkish area often had extensive bruising underneath. This showed up at the trimming station and was not visible before trimming. In five US beef slaughter plants, Kline (2018) reported that 42% of the carcasses had visible bruises. An additional 24% of the carcasses had no obvious visible bruises, but skilled trimmers cut out extensive damage under the surface. This brings the total percentage to 66%, which is similar to Harris *et al*. (2017). In both these studies, trim loss was measured. The exclusive use of visual appraisal is likely to underestimate trim loss.

Cattle should be marketed in a manner that minimizes the number of times that they are handled or restrained immediately prior to slaughter, particularly when they are transported more than 325 km to slaughter (Hoffman *et al*., 1998). Cattle that were handled roughly had greatly elevated bruising compared with cattle that were handled gently (Grandin, 1981b).

The skill of the driver and the quality of the road appear to be more important than the distance travelled. Economic incentives can greatly reduce bruising. Cattle sold by live weight had twice as many bruises compared with cattle sold on carcass weight basis (Grandin, 1981b). Producers selling on a carcass basis had bruising damage deducted from their payments. Efforts are made in some South American countries by producing regulations, written information and graphic material to educate and train producers and animal handlers in order to improve animal welfare – and thereby meat quality – through better handling (Gallo, 2004). The time required to unload cattle has also been shown to have an impact on bruising. Goldhawk *et al*. (2015) found that increasing the duration of waiting to unload cull cows at the slaughter plant by 30 minutes relative to a one-hour duration increased the odds of severe bruising by 1.18 times. The same study found that severe bruising was greater in the doghouse compartment compared to all other compartments where the odds were 3, 3.7, 2.2 and 3.8 times greater than the back, belly, deck, and nose compartments, respectively.

Stocking density is an important consideration, and high stocking density is associated with a two-fold or greater increase in carcass bruising in both short-haul (Eldridge and Winfield, 1988; Tarrant *et al*., 1988) and long-haul transport (Tarrant *et al*., 1992). A loading density of 0.02 *k*-value was recommended based on the occurrence of serious and frequent bruising (Eldridge and Winfield, 1988) as well as a reduction in falling during transport (Petherick and Phillips, 2009). No scientific data on the relationship between loading density and carcass quality in beef cattle under NA conditions have been published. Barnett *et al*. (1984) considered that cattle with elevated blood corticosteroid concentrations as a result of chronic stress could be more susceptible to bruising damage than other cattle.

Shaw *et al*. (1976) and Wythes (1985) found that horned cattle had twice as much bruising. Contrary to popular belief, cutting the tips of the horns does not reduce bruising (Ramsey *et al*., 1976). Youngers *et al*. (2017) reported that short horns with an average tip to tip span of 39.6 cm had little effect on bruising. In the Shaw *et al*. (1976) and Wythes

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(1985) studies the total tip to tip span would have been greater because the cattle would have been older. Horn buds on calves should be removed before the animal grows horns. Cutting horns on older animals is extremely stressful and painful. Cows in late pregnancy suffered more bruising and produced tougher meat than those in early pregnancy or those that were not pregnant (Wythes, 1985).

Meat quality

The World Organization for Animal Health (OIE) has recognized the importance of maintaining good animal welfare during transport as well as the fact that transportation is one of the most important pre-harvest variables with respect to meat quality and should be considered a critical control point (Speer *et al*., 2001; OIE, 2004; Broom, 2005). Meat quality concerns include increased shrink loss, dark firm dry (DFD) and carcass trim due to bruising (Speer *et al*., 2001).

Good quality beef has a final pH value close to 5.5. At pH values of 5.8 and above, both the tenderness and the keeping quality of the fresh chilled meat are adversely affected. High-pH meat is unsuitable for the premium trade in vacuum-packed fresh meats and, depending on the commercial use of the product, dark-cutting meat may be discounted by 10% or more (Tarrant, 1981). In feedlot cattle in the USA, 1.9% of the steers had heifers downgraded due to dark cutting (Smith *et al*., 2006). In South America, levels of dark-cutting beef in pasture-fed cattle can be as high as 5–10% (Amtmann *et al*., 2006).

High pH in meat is caused by an abnormally low concentration of lactic acid in the meat, which, in turn, is a reflection of low muscle glycogen content at slaughter. Post-mortem production of lactic acid requires adequate content of glycogen in the muscles at slaughter. Ante-mortem glycogen breakdown is triggered by increased adrenalin release in stressful situations (McKeith *et al*., 2016) or by strenuous muscle activity. Circumstances that trigger one or both of these glycogen breakdown mechanisms will deplete muscle glycogen, especially in the fast-twitch fibres (Lacourt and Tarrant, 1985; Shackleford *et al*., 1994), and will result in high-pH, dark-cutting meat unless a recovery period from stress is allowed.

In practice, in many abattoirs, restful conditions with access to feed cannot be provided. Experiments in Chile have shown that there is no beneficial effect on the welfare of the animals by a long lairage time at the abattoir (Tadich *et al*., 2005) and that increasing transport journey times (from 3 to 24 h) and lairage times from (3–24 h) also increase the incidence of high-pH and dark-cutting carcasses (Gallo *et al*., 2003; Amtmann *et al*., 2006).

These results are in accordance with the reductions in muscle glycogen found in the same animals, as they are deprived of feed during transport and lairage. Furthermore, the rate of post-stress muscle glycogen repletion is slower in cattle than in other species (McVeigh and Tarrant, 1982), so it is better to avoid the problem than attempt to remedy it.

On average, bulls may have more dark cutters than similar steers (Tennessen *et al*., 1984). The animal behaviour most closely associated with glycogen depletion and dark-cutting beef is mounting activity. Both fighting and mounting are stimulated by social regrouping and mixing of young bulls (McVeigh and Tarrant, 1983; Warriss *et al*., 1984; Tennessen *et al*., 1985) and by heat (oestrus) in groups of females (Kenny and Tarrant, 1988). Modifications of the loading pens aimed at reducing mounting activity during penning before slaughter have been successful in preventing dark cutting in bulls (Kenny and Tarrant, 1987c).

Social regrouping prior to transport causes a much higher incidence of dark cutters in bulls compared to steers (Price and Tennessen, 1981; Tennessen *et al*., 1981, 1985). Short periods of mixing greatly increase the levels of dark cutting in bulls, but dark cutting will increase in steers if they are mixed for more than 24 hours (Grandin, 1997). The second author has observed that steers that engaged in intense fighting required up to a week on feed to recover and to have good meat quality.

Scanga *et al*. (1998) found that dark cutting increased if there were sharp temperature fluctuations or temperature extremes 24–72 hours prior to slaughter. Practical experience in large slaughter plants has also shown that feedlot cattle spending the night in the plant lairage had more dark cutters. One of the other factors that can greatly influence the occurrence of dark-cutting beef in fed cattle is excessive use of growth promoters (Scanga *et al*., 1998).

Transportation distance and duration can significantly impact welfare and meat quality in beef cattle due to its effect on feed, water and rest intervals. Lack of feed, water and rest results in physiological changes including dehydration, energy

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depletion, ion depletion and protein catabolism (Gortel *et al*., 1992; Schaefer *et al*., 2001). Jones *et al*. (1988) assessed the effects of fasting, mixing, transportation and lairage, which mimicked what cattle are exposed to during some NA transport events. They reported no differences in meat quality including muscle pH, expressible juice or weight losses of steaks during retail display and incidence of dark cutters, between cattle only mixed and fasted for 24 hours compared to those mixed, fasted and transported for 320 km with lairage times totaling either 48 or 72 hours. They concluded that the main effect of fasting and transportation in beef cattle was a loss in carcass weight (warm carcass weight and body fat depots) and gut fill, which was greater for the transported treatments and greater for 72-hour, compared to 48-hour, treatment. Similarly Polkinghorne *et al*. (2018) found that extending the transport time of 18–36-month-old Brahman cross-cattle from 12 to 36 hours transport did not have a detrimental effect on beef eating quality (tenderness, juiciness, liking of flavour, overall acceptability), nor did the provision of a 12-hour break (with hay and water) after 24 hours of transport improve the same eating quality attributes. However, an earlier study by Jones and Tong (1989) reported that the frequency of dark-cutting beef increased as transportation distance from the farm to the slaughter plant increased, from less than 60 miles to more than 180 miles. Likewise, a recent study by Chulayo and Muchenje (2017) reported longer distances travelled by continental breed beef cattle destined for slaughter had a significant effect on meat pH, dark cutting and toughness. They also found that cattle transported for 366, 877 and 1012 km had higher creatine kinase (CK) concentrations (>3000–5000 U/l) than those transported for 1263 km (1000 U/l). Lactate dehydrogenase (LDH) was also greater in cattle that were transported 366 and 1012 km (7000 U/l) than those transported for 877 and 922 km (6000 U/l). The study cautioned that although CK and LDH are useful indicators of welfare in slaughter cattle they cannot be used to predict meat quality. Greer *et al*. (2011) reported fewer animals graded AAA when distances were less than 400 km while a greater number of animals were graded AA when cattle were shipped for more than 400.

Long-distance road or rail transport of cattle caused a small elevation of meat pH and a corresponding increase in the incidence of dark cutters (Wythes *et al*., 1981; Tarrant *et al*., 1992; Gallo *et al*., 2003). This was reversed by resting and feeding for two days or longer before slaughter (Shorthose *et al*., 1972; Wythes *et al*., 1980). Short road journeys are not likely to cause dark cutting (Eldridge and Winfield, 1988), except where trauma occurs; for example, when the animal goes down (Tarrant *et al*., 1992). Warnock *et al*. (1978) also found much higher meat pH values in the carcasses of 'downer' cows compared with those in cows that did not go down (6.3 versus 5.7). Other effects of transport on meat quality include an increase in toughness (Schaefer *et al*., 1990) and a decrease in palatability (Jeremiah *et al*., 1992; Schaefer and Jeremiah, 1992). The sensory quality of veal was lower after long-distance transport of 20-week-old calves (Fernandez *et al*., 1996). Chulayo *et al*. (2016) assessed 100 cattle of various breeds and classes (heifers, cows, bulls) arriving at a South African abattoir and found that greater transport distances (400–800 km versus less than 400 km) resulted in greater stress responses (cortisol and heat shock proteins), reduced glucose in all animal classes leading to reduced meat quality parameters (dark cutting, pH and toughness). In addition, the importance of pre-transportation nutrition and its role in reducing meat-quality aberrations on long journeys cannot be overlooked (Schaefer *et al*., 2001).

Conclusions

It is interesting to note that since the first edition of this book, the most significant welfare concerns for cattle during transport have remained unchanged. These concerns include, the transport of unfit (sick, emaciated, debilitated) cattle, rough or inhumane handling, poor driving quality, overloading (particularly in lightweight and young animals) and excessive transport distances with long periods between food, water and rest. Of particular concern is excessive or moderate transportation durations experienced by cattle (usually of poor condition or quality) that are sold and resold through the auction markets. Unfortunately, there are still significant numbers of weaned beef calves being shipped to auctions that have not been preconditioned and vaccinated.

Current research indicates that cattle welfare is reduced if transport is more than 30 hours and therefore efforts should be taken to restrict journeys to 24 hours. However, if journeys greater than

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30 hours are necessary, cattle should be rested and provided with feed and water before they continue on to their final destination. Likewise, loading densities lower than 0.015 and greater than 0.035 (allometric coefficient) should be avoided since poor welfare outcomes such as death, lameness and being non-ambulatory increase significantly at these space allowances. In addition, more care should be taken when transporting cattle at ambient temperatures below –15°C or above 30°C, which increase the likelihood of death and becoming non-ambulatory, respectively. Information on trailer microclimate suggests that the nose compartment has the poorest ventilation and care should be taken during stationary periods under hot temperatures as the trailer THI can increase rapidly under these conditions. Identifying and mitigating transport-related welfare problems will fully depend on continued education and research to find solutions relevant to the conditions of transport.

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10 Handling and Transport of Cattle and Pigs in South America

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Summary

This chapter offers a short description of the importance of livestock production chains for South American countries, and covers initiatives used in Brazil, Chile and Uruguay to reduce bruising and other damage to beef and pork carcasses. It is shown that after training truck drivers and handlers, and improving facilities and equipment, the percentage of damaged carcasses was halved. The results also showed that when cattle passed through markets on the way to slaughter they had four times the risk of having meat of a high pH (>5.8) compared with cattle that were shipped direct. Another advantage of the adoption of low-stress handling methods is less stress on the stock people. When better methods are used for handling cattle, corrals can be built from less expensive and more economical materials; this section also provides details of a low-cost corral layout, showing that solid fences that block the animal's vision can be constructed from vertical bamboo strips attached to a wire or wood plank fence. The second section covers extensive new handling research with Nellore cattle, which are more reactive than the British and European breeds. The six tips for handling Nellore are: (i) No shouting or hitting; (ii) Move them through the race before procedures; (iii) Only one animal in the race at a time; (iv) Small groups brought to the corrals; (v) Cows immediately exit to pasture after procedures; (vi) Use a lead horse in the pasture. The third and fourth sections cover new research in Chile and Uruguay with the British and European breeds.

Keywords: bruises, corrals, electric prods, loading trucks, stunning, welfare

Introduction

Farming activities are a major contributor to the economy of South American countries (Duff and Padilla, 2015). In this sector, meat production has a prominent role, particularly the production of beef, poultry and pork (FAO, 2009; Rioja-Scott, 2017). In order to supply both internal and external markets, a huge number of farm animals are handled, transported and slaughtered every year. In the past, most of these activities were carried out with little consideration for the welfare of the animals.

A series of research and extension initiatives have now been carried out in Latin American countries. Several surveys have been conducted in different countries that aimed to identify the main problems faced by farm animals during handling and transport. Based on the results of these surveys, strategies have been developed to implement good animal welfare practices in the field, including the development of guidelines for these good animal welfare practices in Brazil (http://www.grupoetco.org.br/downloads.html, https://www.embrapa.br/suinos-e-aves/bes/

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embarque-e-transporte); Chile (http://www.bienestaranimal.cl/material-difusion) and Uruguay (http://www.bienestaranimal.org.uy/documentos.html). Additionally, the work developed since 2009 by the World Animal Health Organisation (OIE) through the Collaborating Centre for Animal Welfare Chile–Uruguay, with the addition of Mexico in 2013, has disseminated a series of good livestock handling practice recommendations through the development of training courses and practical material for improving the welfare of farm animals under regional production systems (Huertas *et al*., 2014). Moreover, there has been great progress in many Latin American countries in terms of adopting the OIE standards through the implementation of new legislation (Gallo and Tadich, 2017).

These initiatives have also promoted the adoption of animal welfare standards in existing quality assurance schemes. Good practices of animal welfare are now considered an important component in all production meat chains, covering all the stakeholders (farmers, transporters and slaughterhouse workers). A good example is the initiative launched by the Brazilian Ministry of Agriculture, Livestock and Food Supply to promote pig welfare (MAPA, 2018). It was embraced by most of the leading companies in the Brazilian pig production chain, and it is characterized by the adoption of collective (group) gestation systems (ABCS, 2014; Dias *et al*., 2015). Nevertheless, the emphasis on the relationship between good animal welfare status and good meat quality is still a key feature for making improvements in animal welfare and handling procedures in Latin America (Paranhos da Costa *et al*., 2012).

The main strategy has been the production of local applied research to support the new South American regulations on welfare in farm animals, as well as training farmers, transporters, slaughterhouse workers and other animal handlers involved in the food producing chain (Gallo *et al*., 2010). In this chapter, the different strategies that have been implemented in Brazil, Chile and Uruguay to improve the welfare of the animals and the quality of meat are reviewed.

Carcass Bruises and Skin Lesions as Indicators of Animal Welfare in South America

Carcass bruises are indicators of suboptimal welfare conditions during transport and pre-slaughter practices. Several actions have been developed in some South American countries to address the effects of cattle and pig transport and handling on carcass and meat quality (Paranhos da Costa *et al*., 2012). The major aim is the reduction of bruises in cattle carcasses and skin lesions in pigs.

Surveys run in Brazil, Chile and Uruguay with cattle (Paranhos da Costa *et al*., 1998; Gallo *et al*., 1999; Strappini *et al*., 2008, 2010; Huertas *et al*., 2015) and with pigs in Brazil (Dalla Costa *et al*., 2007, 2009, 2016 and 2017; Jacinto, 2017) have shown that a high percentage of slaughtered cattle and pigs suffered with bruises and skin lesions, respectively. In Brazil, for example, the percentages of cattle carcasses with bruises reached 84.2% in the Pantanal region of the state of Mato Grosso do Sul (Andrade *et al*., 2009), 92.1% in the state of Minas Gerais (Andrade and Coelho, 2010), 62.2% and 83.8% for entire males and cows assessed in the state of São Paulo (Pellechia, 2014), and 75.7% in the Federal District (Cruz, 2017). The lowest percentage of cattle carcasses with bruises was reported by Mendonça *et al*. (2017) in a survey conducted in the state of Rio Grande do Sul. There were bruises in 40.0% and 56.7% of male and female carcasses, respectively. Some of these authors identified that the most frequent cause of cattle carcass bruising was long-distance transport and poor handling practices at various stages of the pre-slaughter procedures.

The frequency of skin lesions on Brazilian pigs was also usually high. As shown by Dalla Costa *et al*. (2009 and 2016) the occurrence of skin lesions increased progressively throughout the pre-slaughter process and affected more than 90% of the animals when assessment was carried out just before slaughter. The authors described the injuries as associated with management procedures, such as the position of the animal inside a truck compartment and the duration of pre-slaughter fasting. A similar situation was also reported by Jacinto (2017). Most of the pigs (73%) had skin lesions. The causes of the lesions were poor handling procedures (45%), fights (28%) or a combination of both (27%). However, the results from Dalla Costa *et al*. (2017) showed a large reduction in the percentage of pigs presenting skin lesions just before slaughter. The authors concluded that lesions dropped to 62% due to improvements achieved by adoption of good handling practices during loading, transportation, unloading and reduction of fighting in lairage. The use of air-ride suspension improved carcass quality (Dalla Costa *et al*., 2017).

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In Uruguay, training programmes and the distribution of guidelines through the cattle production chain have been carried out since 2004 (www.bienestaranimal.org.uy). It is now possible to assess the effectiveness of these initiatives by comparing meat quality audits conducted in Uruguay (INIA, INAC and Colorado State University, 2003; INIA, 2017; INIA and INAC, 2009; Brito *et al*., 2017) on the beef production chain. According to these audits, there was an impressive reduction in the percentage of carcasses with bruises (from 60.4% to 31.8%) between the first and second audit. Unfortunately, in the third audit there was a large increase in the number of bruised carcasses and they reached 72.9% of the slaughtered animals (INIA, 2017). This increase triggers a warning light, since the improvements achieved during the period between the first and second audits was probably lost. People did not continue to use the lessons from the training programmes and the animal welfare recommendations when handling cattle. In the future, preventing deterioration of handling practices will require a continuous programme of both training and supervision of transporters and abattoir workers.

There are, however, in the three countries initiatives aiming to reduce handling problems during pre-slaughter procedures (MAPA, 2016, 2018; SAG, 2018). Independent of the country, commercial systems that include several intermediaries, prolonged transportation and long waiting times under fasting conditions clearly result in even greater prevalence of carcass bruising, skin lesions, meat colour problems and unsuitable pH of the meat (Paranhos da Costa *et al*., 2012).

Update on Brazilian Research on Cattle Handling Methods

The next part of this chapter is divided into three sections. The first section will cover Brazilian research conducted by the research group led by Mateus Paranhos da Costa. The second and third sections will cover research in Chile and Uruguay conducted by Carmen Gallo's and Stella M. Huertas's research groups. This work mainly covers the *Bos taurus* British and European breeds of cattle that are raised in these areas.

During his extensive work on Brazilian ranches with Nellore cattle, Paranhos da Costa developed five basic handling principles. They are designed to prevent the more excitable, fearful Nellore cattle from becoming agitated during handling. Good handling practices reduce the risk of accidents to both people and cattle.

Cattle handling guidelines for Nellore cattle

Principle 1: Eliminate shouting, hitting, dogs, mixing of groups and electric prods. Figure 10.1 shows that bruising was cut in half when handling was improved (Paranhos da Costa *et al*., 2008). Use flags to drive animals during handling. Flags should be used to guide animals and not to be constantly waved. Improved handling reduced cortisol levels (Lima *et al*., 2018).

Principle 2: To prevent excitable Nellore cattle from becoming stressed, only 100 cows are brought near the corrals at a time. A further procedure to

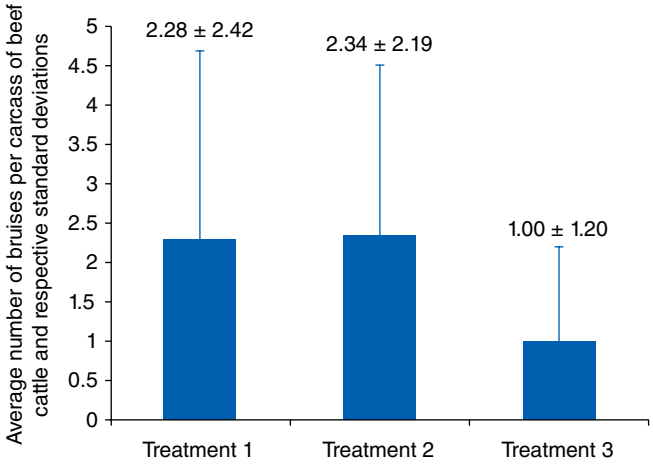


Fig. 10.1. Means (± SD) of bruises per carcass of beef cattle according to the type of management adopted for cattle loading at a farm in the state of São Paulo. Treatment 1 = routine farm management; Treatment 2 = routine farm management but without using electric prods; and Treatment 3 = good handling practices including no shouting, no electric prodding or hitting, and no mixing of groups of animals. (Adapted from Paranhos da Costa *et al*., 2008)

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keep the animals calm is that only 25 cattle at a time are brought into the active working area.

Principle 3: Before doing procedures, all cattle are moved once through the races every time they are handled. A further procedure to prevent agitation caused by waiting in the single-file race (chute) is that only one animal is put in the race at a time. A flag is used to quietly guide each animal out of the crowd pen.

Principle 4: When the cows exit the race after having vaccinations or other procedures they immediately move to the pasture. They exit through a pen where they are rewarded with feed. They are not held in a post-working pen close to the handling facility. They are free to leave after they have eaten some of the reward feed.

Principle 5: When the Nellore cattle are moved through pasture alleys or brought in and out of a pasture, a lead horse is used (Fig. 10.2). Doing this provides better control of cattle driving.

Improved Stockperson Welfare on the Farm

There are scientific publications reporting the results achieved by initiatives to promote animal welfare on farms (ranches) in South America. Nonetheless, there are many examples, collected from livestock people, that show the advantages of adopting good cattle handling practices. For instance, in the year 2000, one of the authors started working in a beef cattle farm at Três Lagoas (Mato Grosso do Sul state, Brazil), where Mr Joaquim worked as a cowboy. He was around 65 years old, and the farmer did not expect that he would be able to adapt to the new way of work, but he succeeded. After three months of training he was interviewed and asked his opinion about the adoption of good handling practices. His answer was:

> Before, at the end of the day, I used to go home very tired, going straight to bed just after a shower and dinner. Usually, I used to sleep thinking of the next day's work, which would be started very early, at six



Fig. 10.2. A lead horse is used to calmly bring Nellore cows into the corrals. (Photo: Courtesy of Temple Grandin)

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in the morning. Today it is different; I go home, and after a shower and dinner, I still have energy to watch TV and to talk with my wife.

A similar report was collected during a practical course in the north of Uruguay, where a cowboy asked for an opportunity to express his feelings and experiences about cattle handling (he had attended a previous course); he picked up the microphone and said to his colleagues: 'In the past I used to be very nervous and displeased after everyday working with cattle, and now I feel more relaxed and less tired after working with them.' It was clear that the man was proud of his work, which is not so common among livestock people working in the old traditional way. Both of the statements above summarize the importance of adopting improved cattle handling practices: they have positive effects on animal welfare and also provide a better quality of life for the livestock people.

The Benefits of Good Stockmanship on Cow-Calf Farms

The Brazilian research group has published many studies since the previous edition of this book in 2014. Two studies by Ceballos *et al.* (2018a,b) clearly show the importance of good practices. Never miss the opportunity to promote positive interactions with animals. Trained handlers had a more positive attitude towards the cattle and were less likely to allow handling practices to deteriorate over time (Ceballos *et al.*, 2018a,b). Nellore heifers handled quietly also had the advantage of less defecation (Ceballos *et al.*, 2018b). Cattle that were much less reactive were cleaner, which facilitates artificial insemination. Another study (Rueda *et al.*, 2015) found that excitable Nellore cattle took longer to handle and the cows had higher flight speeds and reduced pregnancy rates. Nellore cattle that are handled frequently for rotational grazing became calmer and less reactive (Ceballos *et al.*, 2016). Animals that are rotated between pastures every four days had lower flight speeds compared to animals rotated every 20 days (Ceballos *et al.*, 2016; Góis *et al.*, 2016). Researchers have also found that Nellore calves maintained for a short period of life (45 days during dry season) in feedlot pens, and after that being moved back to the pasture, were less reactive than those kept all the time on pastures (Vasconcelos *et al.*, 2018). Such experience will probably help the animals to settle down in a feedlot pen later in life.

The more reactive Nellore cattle have lower performance in a feedlot (Bravo *et al.*, 2016). The calmer individuals have better weight gain (Braga



Fig. 10.3. Temple Grandin and a Brazilian cowboy stroke a newborn Nellore calf on Orvalho das Flores ranch, in Brazil. It was found that this method reduced reactivity in piglets (de Oliveira *et al.*, 2015), and improved dairy calves' health (Magalhães Silva *et al.*, 2014). This research will determine if this will be effective for beef cattle. (Photo courtesy Temple Grandin no Brasil/Enilson Arneiro)

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et al., 2018). This replicates the findings of research on *Bos taurus* cattle (Voisinet *et al*., 1997; Petherick *et al*. (2002).

Stroking young calves

Paranhos da Costa and his research group are also conducting research on stroking newborn Nellore calves. This is a gentle version of the foal imprinting method. It needs to be emphasized that it is done gently. Some foal imprinting methods have been very rough. It will be interesting to determine if this produces a calmer adult animal (Fig. 10.3). A similar treatment on non-weaned piglets reduced fearfulness when they matured (De Oliveira *et al*., 2015).

Low-stress weaning

Cow-stress weaning should be carried out when the calves are eight months of age. The calves should be kept close to their mothers for at least three days after separation. Either fence-line or across-the-road weaning is used (Fig. 10.4).

Low-cost Corral Layout

There is still a need for further developments of facility design for small producers, who usually do not have the financial resources for big investments. One initiative in Brazil (see Paranhos da Costa and Quintiliano, n.d.) is the recommendation on how to build a low-cost cattle corral. In summary, the authors discussed the necessity of putting aside the idea that the corrals must have a large capacity for cattle 'storage' and that they should always be built to withstand extreme pressure (exerted by cattle) by using heavy materials. This change in concept must be adopted after the implementation of good handling practices in the corral, taking into account the behaviour and welfare of people and animals to define the day-to-day work on the farm. Calm cattle are easy to handle and, because of that, there is no need for strong structures to manage them. As an example, a blueprint for a low-cost corral is presented in Fig. 10.5, while Fig. 10.6 illustrates the use of bamboo as an alternative material to build the solid shields in the areas of intensive handling.



Fig. 10.4. Fence line low-stress weaning across a road of Nellore cows and calves at Orvalho das Flores ranch in Brazil. Both the cows and calves remained silent with no pacing or bellowing. (Photo: Courtesy of Temple Grandin)

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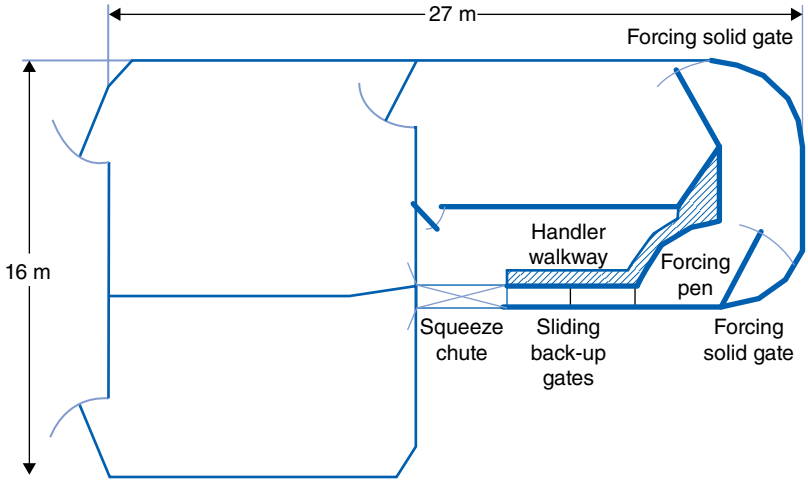


Fig. 10.5. An example of a blueprint for a low-cost corral. The thick blue lines represent solid shields (combining wire or wood fences with bamboo) and the thin blue lines represent wire fences. Similarly, wood gates with a solid shield are represented by a thick blue (opening) line, and (plain) wood gates by a thin blue (opening) line. The cross-hatched area is a catwalk that runs alongside the race. A handler with a flag standing on this catwalk can easily move the cattle from the crowd pan into the race. The design is by Paranhos da Costa and Quintiliano (undated).



Fig. 10.6. Pneumatic steel paddles that act as a 'funnel' and are activated to cover the door frames, both inside the cage and in the main door. (Photo: Courtesy of Temple Grandin)

Genetics and Nellore Behaviour

Valente *et al.* (2016, 2017) and Sant'Anna *et al.* (2014) found that temperament traits in Nellore cattle are moderately heritable. Temperament is a complex trait which is influenced by both the environment and genetics. A genome-wide association study has been conducted on Nellore (Valente *et al.*, 2016). They identified nine genome regions associated with the results of the exit speed test.

Some others interesting Brazilian research: crossbred Girolando cows (1/2 Holstein × 1/2 Gyr, and 3/4 Holstein × 1/4 Gyr) show that the calf protection behaviour and reactivity during milking are separate traits (Soares *et al.*, 2018); in the Canchin breed of cattle (a cross between Charolais and *Bos indicus*), the more reactive cattle had a smaller cannon bone (Ribeiro *et al.*, 2018). These results are similar to a study done by Lanier and Grandin (2002); and sometimes the genetic background of the cattle will have unexpected effects. When flight speed was measured, Caracu cattle exited more slowly from the squeeze chute but they had higher cortisol levels than more reactive cattle, such as Nellore (Miranda *et al.*, 2018).

Research Update from Uruguay on Bruises, Pasture Systems and Truck Design

The OIE recognizes the important role played by all the various stakeholders in changing perceptions of

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animal welfare, by raising public awareness and promoting communication and co-operation as drivers of overall change in the Americas (Huertas *et al*., 2014).

Recognizing that transport is one of the most stressful interventions, the training of animal handlers and transporters was emphasized, showing them the consequences of inadequate handling with audiovisual material prepared on site. Research results have helped to develop new legislation or to make changes in the existing legislation related to animal welfare (Gallo and Huertas, 2015). Replacement of sticks and electric prods with flags during truck loading reduced carcass bruises (Huertas *et al*., 2018a).

Despite great efforts made in recent years along the supply chain, it was a disappointment to observe the recent increase in the prevalence of carcass bruises reported in the third Uruguayan quality audit of beef (INIA, 2017). Strappini *et al*. (2012b) found a 'slight' agreement among observers for the number of bruises scored per anatomical site. Possibly INIA (2017) overestimated bruising. Although, the audits tried to use the same procedure, the observers were not the same and the training may not have been sufficient.

However, it should be taken into account that in different studies conducted in Uruguay, no bruises of grade 3 were found. Grade 3 bruises involve muscles and bones (Crosi *et al*., 2015; Gibernau *et al*., 2018). Also Strappini *et al*. (2012b) found a 'fair' agreement for the degree of bruise severity. The fact that there are no bruises of grade 3 could indicate that although there is much work to be done, at least there seems to be more awareness about the welfare of the animals along the chain.

Reduction in Electric Prod and Stick Use

A survey performed in 2016 in Uruguay showed that 70% of the veterinarians who work in the field with production animals had attended at least one animal welfare (AW) course. They also stated that 25% of the farms they visited had knowledge related to AW and properly implemented good animal handling practices. Although the use of flags increased to 77% according to veterinarians, the use of electric prods and sticks was still high (more than 40%) and more than one was used (Prieto *et al*., 2017).

A study peformed in the country showed that in 40% of the loadings a flag was used but also other non-recommended devices to move animals, while in all the unloading in the slaughterhouses, only flags were used (Huertas *et al*., 2018a).

This is a continuous improvement, so let's continue insisting on maintaining high welfare standards, raising awareness throughout the chain and, if possible, applying economic penalties.

Initiatives to Promote the Welfare of Animals on Farms

Animal production systems that combine trees or shrubs with pasture are considered silvopastoral systems (SPS). These systems have the potential to improve animal productivity, increasing the biological and economic efficiency of livestock farms while contributing to the ecological sustainability of these systems (Broom *et al*., 2013).

This integration between grass and trees seems to be beneficial, providing shade, shelter, food and water permanently to animals, which all contribute to the animal's welfare. This situation constitutes a valid alternative to conventional farming in many Latin American countries (Calle *et al*., 2012; Broom *et al*., 2013).

Despite having several types of SPS, these systems seem to have in common a beneficial impact on the welfare and productive performance of beef cattle, but most of the results so far are obtained from tropical regions and with *Bos taurus indicus* breeds (Ibrahim *et al*., 2010; Molina *et al*., 2008; Murgueitio *et al*., 2011).

Aiming to clarify the existence of these benefits in temperate regions such as Uruguay, where European breeds are more common, research was conducted on extensive beef farms. Beef cattle were placed on either SPS or Natural Grassland (NG), to compare animal health, welfare indicators and bodyweight (BW) during 2015 and 2016. In Uruguay, almost all forestry enterprises use *Eucalyptus* spp. and fewer *Pinus* spp. Most producers, traditionally farmers, let animals graze within the paddocks with trees, with the perception that this is relatively profitable (Sanz *et al*., 2007).

Preliminary results showed no differences for good health indicators such as injuries, lameness or integument alterations (hairless patches and lesions/swellings); signs of disease such as nasal discharge, ocular discharge, hampered respiration and diarrhoea (Huertas *et al*., 2017).

Significant differences were found between farms and visits for bodyweight ($p < 0.01$), but no differences were found between treatments ($p = 0.176$).

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The weight of animals in SPS seems to have less variability compared to those in NG. This study illustrates that well-managed farms have more productive cattle. Also, farmers can benefit from the additional income generated by the wood production yet maintain their traditional cattle farming lifestyle.

Environmental conditions

Advantages of some mixed-production models like silvopastoral systems, which integrate forestry plantations with extensive beef production, have become common with the potential to increase the productivity per hectare (Broom *et al*., 2013).

Preliminary results of researches performed in Uruguay showed that during the summertime, temperature and humidity index (THI) was higher in SPS than in NG, in some cases reaching alert levels; however, no heat-stress behaviour was observed in the animals, while in winter there were no differences, either in THI or in animal behaviour (Huertas *et al*., 2018b).

The animals in SPS dedicated more time to grazing in summer than the animals in NG systems. The reduction of sun radiation in the SPS could account for this. In SPS, the effective grazing surface is smaller than NG due to the presence of the trees, yet no significant differences were found in animal performance in both groups; however, animals in SPS showed less variation in bodyweight during the study period. The botanical species diversity index was higher in SPS in comparison with NG (1.69 and 1.55, respectively), but in both systems botanical species of agronomic interest and of a great adaptability were presented and quantified (Huertas *et al*., 2018b).

Initiatives to Promote the Welfare of Animals during Transport in South America

There are two aspects to consider that can affect the welfare of transported animals: the knowledge and commitment of truck drivers and the quality of the vehicles. The design of vehicles, their materials, condition and improper handling during loading and unloading can cause traumatic lesions (bruises) of different degrees of depth and location in the carcass. This fact, besides showing welfare deterioration, is the cause of great economic losses (Huertas *et al*., 2015).

To compare the current reality with that of the last decade, different surveys based on protocols already developed (Huertas *et al*., 2010, 2015) related to animal-welfare knowledge of truck drivers and the characteristics of cattle transport and its relationship with animal welfare were performed in Uruguay. Results revealed that of almost 300 truck drivers surveyed, 80% declared that they received training. However, the use of the electric cattle prod is still around 50% in loading and unloading at slaughterhouses. Flags were used in less than 35% (Gibernau *et al*., 2018; Huertas *et al*., 2018a).

Over the years, the fleet of vehicles to transport livestock has been changing and possibly affects the welfare of animals. The average year of the vehicles is 2008 (ranging between 2005 and 2015). The materials most used for the construction of the vehicles are aluminum (12.5%) and steel (87.5%). All of the trucks had a guillotine-type door (Huertas *et al*., 2015).

The frequency of different types of trucks in 2017 were: 60% articulated truck with three axles and one deck; 20% articulated truck with five axles and two decks; 12.5% articulated truck with double trailers; and 7.5% non-articulated truck with three axles (Gibernau *et al*., 2018). Note that the double-deck truck is relatively new in Uruguay. However, some rough roads may not be appropriate for this type of vehicle, which could cause more problems for the animals. More research is needed.

From a total of 10,400 transported animals, the average prevalence of carcass bruises was 60%. An average of 33% had a bruise in one single zone, 26% in two zones, 15% in three and 26% in four or more zones. Regarding the depth, an average of 82% of the lesions were grade 1 (superficial, generally removed by carcass dressing); 27% were grade 2 (medium, with some muscle involved); and 0% were grade 3 (the deepest). The most frequent zones affected were the coxofemoral joint (29.3%), back zone (19.6%) and rib cage (15.7%) (Crosi *et al*., 2015; Huertas *et al*., 2018a; Gibernau *et al*., 2018). These results are in line with the latest findings in the quality audit performed by the Meat Institute of Uruguay (INAC, 2017), where no bruises of this degree of severity were observed.

Although grade 3 bruises did not appear, indicating that probably animal handling has improved, the total percentage of injuries remains high. It is necessary to continue with training courses for personnel, the proper maintenance of facilities and ensuring that good vehicles are employed.

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A system for livestock protection during transport: PROGAT

Bruises in beef cattle during loading, transport and unloading manoeuvres are of great relevance, causing animal suffering and great economic losses to the entire sector (Huertas *et al*., 2015). Although, the average distance of transport is 240 km in 5 hours, the prevalence of bruises reaches 60%. There were no mechanisms in the country or in the world that contribute to protect animals from possible impacts against the sharp edges of vehicles during loading, transport and unloading.

With the aim of providing a solution to this global problem, and applying the knowledge of the automotive and metal-mechanic industry, a device was designed and constructed that consists of an elastic strip placed inside the trailer of a truck and steel paddles that act as a 'funnel' that are pneumatically activated to cover the door frames, both inside the cage and in the main door (Fig. 10.7). The system is operated by the truck driver and easily washable with water under pressure.

The device was tested for statistical validation, comparing 19 pairs of identical trucks (brand, model, year, maintenance) with similar cattle for slaughter. One vehicle carried the device and another did not. Both vehicles started from the same farm, on the same day and time and followed the same route, arriving together to the same slaughter house. Trained observers recorded the loading and unloading of 1177 animals and, after slaughter, the presence of bruises, their location and depth (Huertas *et al*., 2010).

The results showed that animals transported in a truck with the PROGAT device had a significantly lower proportion of bruises ($p < 0.001$) than those in the conventional vehicle (Huertas *et al*., 2018c). A small proportion of bruises was observed in the rump area (where the cuts of greatest commercial value are situated) as well as in the ribs and on the shoulder. No degree 3 bruises were recorded in the



Fig. 10.7. Pneumatically operated PROGAT device that closes the gap between the loading ramp and the back of the trailer (Huertas *et al*., 2018c), after the trailer is loaded the air cylinder retracts the flap. The rounded surface of the PROGAT device prevents bruises from cattle striking the centre divider.
(Photo: Courtesy of Temple Grandin)

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Fig. 10.8. Double-deck articulated cattle lorry that is used in Brazil. It has a deck that can be raised up and down, which eliminates internal ramps. Brazil allows taller vehicles than does North America or Europe. (Photo: Courtesy of Temple Grandin)

vehicle with PROGAT. The data showed that animals transported in a conventional vehicle were 1.6 times more likely to show at least one bruise ($p < 0.001$). It is concluded that the PROGAT device installed in a vehicle transporting cattle constitutes a protection against bruises.

Articulated lorries are becoming more common in both Brazil and Uruguay. Figure 10.8 shows a new double-deck lorry for cattle. It has a deck that can be raised and lowered.

Welfare of Weaner Calves and Cull Cows during Transport and Marketing in Chile

Carmen Gallo's Research Group in Chile has conducted new studies on weaner transport. Selling cattle through livestock markets is still common in many South American countries (Gallo and Huertas, 2015). This is an inherently stressful process, because animals are taken away from their environment, loaded, unloaded and transported more than once. They are kept confined in an unknown environment; hence time off for food and water (fasting) increases. At livestock markets animals are handled by either unknown or untrained handlers. The animals are exposed to at least twice as many physical and psychological stressors compared to calves sold directly from farm to farm (Gregory, 2008).

De Vries (2011) studied the human–animal relationship (HAR) in 40 stockpersons at the Chilean livestock markets. The results revealed that some characteristics of the market design were associated with a negative HAR, the occurrence of narrow entrances, dark structures and dirty or wet floors being the main points of concern. These factors hinder animal movement and induce the use of unwanted driving aids, like the stick, by stockpersons. Most of the stockpersons (65%) observed had a negative HAR. Since 2013 (Chile, 2013a,b) it is compulsory by law that livestock transporters and stockpersons at farms and livestock markets go through a training course in animal handling and there has been some improvement. However, some forbidden and bad handling practices can be still observed and there is need for better enforcement of the law.

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The negative effects of passing through cattle markets have been evidenced on the carcasses of steers and cows; the presence of bruises with tram-line appearance, characteristic of those caused by sticks, were reported frequently (Strappini *et al*., 2012a). The high number of bruises found in cows sourced from markets can be associated with the quality of the HAR in Chilean markets (De Vries, 2011) as well as with the fact that animals going through markets are exposed to at least twice as many handlings.

The short- and long-term effects of transport and fasting on welfare and production have not attracted so much attention in calves as in cattle ready for slaughter, and are more difficult to measure. In Chile, around one million cattle go through livestock markets annually, and over 30% of them are calves, this being the main category sold. Another large category commercialized at these premises is the 'cow'.

Transport and marketing of weaner calves

Recently, the transport of weaned calves (150–250 kg live weight) to Chilean livestock markets was described through a survey applied to 287 transporters at 20 livestock markets by Bravo *et al*. (2018a). Eighty per cent of the transporters had been trained as animal handlers during transport, which is in line with the new regulations which make this training compulsory in Chile in order to increase the competence of drivers (Chile, 2013b).

According to Bravo *et al*. (2018a) the mean transport time from origin (farm) to the market was only 75 minutes (although it ranged between 5 minutes and 13 hours), and from the market to destination (usually another farm where calves are fattened) only 45 minutes (5 min to 40.5 h); however, including the time spent in the market pens (without food and water), calves completed at least 12 hours fasting, and frequently up to 24 hours. In 36% of all loads it was observed that calves were mixed with cattle from other categories and in 5% of the cases they were even mixed with other species. Space availability was 0.91 m^2 per calf and the most frequently used bedding material was sawdust (60%), followed by sand/earth (12%) and rubber flooring (11%). There was absence of bedding material in 9% of the loads.

Loading animals onto livestock vehicles is one of the most stressful processes associated with transport (María *et al*., 2004). Quantifying the frequency of behavioural events associated with handling during loading and unloading can provide objective measures of welfare at livestock markets. Weaned calves brought to 20 livestock markets were observed during unloading at arrival to the market (n=1252), and during loading after the sale (n=1344). Infrastructure for unloading/loading cattle was considered, in general, adequate (non-slippery floor, slope ≤ 25% and lateral protections). Personnel handling the animals were transporters themselves and also people hired by the market; the main driving aids used by them were wooden sticks and plastic pipes, whereas flags were rarely observed. Electric goads were only used in 12% of loadings, as shown in Table 10.1. Improper handlings like hitting and pricking were much more common during loading than unloading in calves as well as in cows (Bravo *et al*., 2018b; Sánchez *et al*., 2018b).

Short-distance transport and fasting of weaner calves

In order to determine the possible welfare consequences for calves of going through the cattle markets, we studied the effects of a short transport and a total of 24 hours' food and water deprivation on live weight, some blood variables related to stress, maximum eye temperature (MET) measured using infrared thermography, and tympanic temperature (TT) (Bravo *et al*., 2016). Ten Angus calves of 146.1 ±19.1 kg live weight were transported for three hours at a space allowance of 1 m^2 per 270 kg. Maximum eye temperature (MET) was obtained with a thermographic infrared camera (FLIR i5, FLIR Systems, Wilsonville, Oregon) and temperature (°C) was adjusted according to environmental t° and humidity. To register tympanic temperature (TT°), i-buttons (Maxim Integrated Products Inc., California) were fitted into the calves' ears before loading. MET, TT, live weight, cortisol, glucose, CK, haptoglobin and betahydroxybutirate were measured in blood samples before loading, after unloading and after completing 24 hours fasting in pens (no water, no food) to simulate the conditions during commercialization of calves through livestock markets. Statistical analysis was done using a linear mixed model (time as a fixed effect and the individuals as random effect). Fifty per cent of the total live weight loss occurred during the 3 hours of transport, whereas the other 50% occurred during the period the calves were fasting in the pen (Table 10.2). The significant increase in betahydroxybutirate after 24 hours fasting (with transport included) indicates

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Table 10.1. Behavioural events of calves and cull cows, and handling events observed during unloading and loading at 20 cattle markets in Chile.

	CALVES		CULL COWS	
Behavioural events	Unloading (*n* = 1252)	Loading (*n* = 1344)	Unloading (*n* = 1011)	Loading (*n* =484
Falling	1.7	1.4	5.6	2.7
Slipping	11.7	4.7	14.5	11.2
Jumping	6	4.2	1.4	0.4
Going back	0.2	5.7	0.5	14
Balking	2.8	3.7	7.3	7.2
Vocalizing	7.3	0.4	2.9	1
Mounting	2.4	1.8	0.2	0
Agression	0.2	0.1	0	0
Defecating	0.3	0.8	1.4	2.1
Handling events				
Hitting	3	46.1	11.2	52.5
Pricking	6.8	72.3	12.1	54.8
Kicking	2.2	2.4	2.3	0
Tail twitching	0.1	0.5	0	0

Table 10.2. Means and standard deviations of variables measured before loading (T1), after 3 hours' transport (T2) and after completing 24 hours of food and water deprivation (T3) in weaned calves.

Variables	T1	T2	T3
Live weight (kg)	146.1 (± 19.1)a	141.1 (± 18.6)b	136.1 (± 18.5)c
Timpanic T° (°C)	37.15(± 0.6)a	37.7 (± 0.37)b	–
Maximum eye T° (°C)	34.72(± 0.70)a	36.30 (± 0.52)b	34.48 (± 0.59)a
Cortisol (µg/dl)	1.55 (± 1.1)a	2.28 (± 1.1)a	2.29 (± 1.1)a
Glucose (mmol/l)	3.68 (± 0.33)a	4.38 (± 0.43)b	3.97 (± 0.32)c
β-HB (mmol/l)	0.26 (± 0.07)a	0.22 (± 0.09)a	0.35 (± 0.12)b
Creatine Kinase (U/l)	242.9 (± 59.7)a	398.4(± 147.4)b	189.3(± 49)a
Haptoglobin (mg/ml)	0.16(± 0.04)a	0.15(± 0.02)a	0.26(± 0.21)a

a, b, c: means not followed by a common letter differ statistically from each other (Tukey test, P < 0.05).

that, even with this short time, the calves had to make use of their body reserves. Cortisol and haptoglobin did not change significantly during the 3 hours of transport ($p > 0.05$). G, CK, TT° and MET increased after transport ($p < 0.05$) and returned to initial values during fasting in pens. No correlation was found between MET and blood variables; however, a moderate correlation was found between MET and TT ($r = 0.5288$). The increase in MET and TT° could reflect body temperature increase due to stress and physical exercise during transport.

It was concluded that even in this controlled replication of the marketing process, where calves were handled calmly, without being mixed with unfamiliar animals or exposed to unfamiliar environment, there was a significant effect of the transport and fasting on the calves, which was measurable through MET, TT, blood indicators such as CK, glucose, betahydroxybutyrate and live weight. The live weight loss is economically important because calves are traded based on their live weight at the livestock markets (Bravo *et al*., 2016).

Long-distance Transport and Fasting of Weaner Calves

In Chile, prolonged transport of cattle, particularly weaned calves, is still an important issue due to geographical conditions and the fact that calves are bred on some farms and fattened elsewhere. One of the regions producing calves is Aysén, in the Chilean Patagonia, and they have to be transported

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in trucks on ships (roll-on roll-off). Bodyweight losses and long recovery times add economic losses to the producers, and certainly have an impact on the welfare of the calves due to the long transportation journeys (Gallo, 2008).

Werner *et al.* (2013) described the bodyweight changes and some blood constituents related to stress response after a 63 hours transport of recently weaned calves (approx. 240 kg) in the Chilean Patagonia. The high cortisol concentration values found before transport ($P < 0.05$) suggest that the handling process prior to transport (herding from distant fields, regrouping in pens before loading and weaning) which are common practice in extensive systems in Patagonia, was already stressful for the calves, being that this mean cortisol value was the highest throughout sampling stages (Table 10.3). Similar results, showing highest cortisol levels before loading, have been reported in lambs produced, handled and transported under similar conditions in the Chilean Patagonia (Tadich *et al.*, 2009).

The significant bodyweight loss of calves during long-distance transport, reaching 14% after the 63 hours journey (Werner *et al.*, 2013), is consistent with the high betahydroxibutyrate concentration found after transport. This indicates that food reserve depletion represents an important factor for young animals transported this long, and that the weight lost was not only gutfill. This, besides affecting animal welfare, adds long-term economic losses to the producers. In fact, a live weight recovery period of four weeks was found by Werner *et al.* (2013), and it is probably related to the fact that after transport the calves ate and drank less than required in the new environment and hence continued mobilizing body reserves until the third week after transport. This is consistent with the findings of Knowles (1999).

As transport duration cannot be shortened due to the typical Chilean geography in the Patagonian region and the scarcity of proper routes, conditions of transported calves should be improved by using specialized livestock vehicles that can provide more comfort, as well as access to water and food during the journey. Feeding and providing access to water during journeys longer than 24 hours has become compulsory since October 2013 in Chile (Chile, 2013b). However, this also means that space allowance must be increased, so that animals have the possibility to have access to food and water provided, and also to lie down. Navarro *et al.* (2019) compared one of these journeys with calves (240 kg live weight) with a low space allowance (0.66 m^2/head) and a 30% higher space allowance (0.86 m^2/head), and found that the extra space increased the time that animals spent lying down, standing up, eating and ruminating, all considered important activities for animal welfare during long-distance transport. Even though in this study the animals were fed with a bale of fodder twice a day per pen, this was apparently insufficient to satisfy their metabolic demands, because the calves had an increased blood concentration of betahydroxybutyrate and a decrease in glucose concentration after unloading; the CK value was also increased after unloading (949 U/l) indicating physical demands during the trip.

Negative Effects of Prolonged Fasting of Steers before Slaughter

A negative effect of prolonged fasting times (due to transport and/or lairage) on meat quality has been described earlier by several South American authors in cattle at slaughter (Amtmann *et al.*, 2006; Gallo *et al.*, 2003; Romero *et al.*, 2013). Fasting is an important practical issue in regions where steers undergo long-distance transport to slaughter plants, pass through livestock markets or have long lairage periods at the slaughterhouses, as is still the case in Chile and other South American countries (Gallo, 2016a,b; Gallo and Huertas, 2015).

In fattening steers (340 kg live weight) fasting for 24 hours reduces by 22–27% the glycogen content in muscle, as verified through muscular biopsies of the *Longissimus lumborum* muscle (Apaoblaza and Gallo, 2014). In steers ready for slaughter, no fasting helps maintain a higher muscle glycogen content and higher glycolytic potential; no fasting was also found to help in increasing glycogen debranching enzyme (GDE) activity post mortem (Apaoblaza *et al.*, 2017).

Although in many countries there are now regulations regarding transport and slaughter of livestock (Gallo and Tadich, 2017), fasting times remain long in many South American countries for diverse reasons. At a slaughterhouse in Colombia, we observed 99 trucks arriving with 336 cattle with a mean transport journey of 15.5 hours, and cattle had to wait a mean of 6 hours on the truck between arrival at the slaughter plant and unloading (Ramírez and Gallo 2012; Romero *et al.*, 2013). This happens in Colombia because loaded cattle trucks arrive at night and dawn, and stockpersons arrive at 7 am to start unloading. In the case of Chile, unloading of cattle occurs usually within 20 minutes of arrival at

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the slaughterhouse. However, in Chile cattle are kept in lairage usually for over 12 hours, because they are brought from the farms the evening or night before the expected slaughter; moreover, this time without food is increased by often passing through a livestock market before that or by long-distance transport. These facts and the fattening system based mainly on pasture affect the concentration of glycogen before slaughter increasing the risk for high pH (Apaoblaza *et al*., 2017). Reducing fasting times due to transport and lairage at markets and slaughterhouses is a low-cost and easily modifiable variable, but it requires a well-planned transportation and slaughter schedule, worked out between farmers and slaughterhouses.

Transport and Welfare of Cull Cows Passing through Markets

Sánchez *et al*. (2018a) evaluated the welfare status of 1495 cull cows at 15 cattle markets in Chile in terms of their health and body condition, finding that 45% of them had a low body condition (Welfare Quality® = 1); 30% were lame; 21.3% had mammary problems; 4.2% had other lesions (skin lesions, eye carcinoma, fractured tail or legs); 3% were pregnant at visual appraisal; 15.2% arrived with their calves and were weaned at the market. The low body condition and bad health status of the cull cows passing through the cattle markets reflect that their welfare is already compromised when leaving the farms. The delay in culling until the economically optimal time can also carry a welfare cost.

Lameness and mastitis have been recognized as important culling causes and both health problems are linked to welfare due to the pain they cause, hence cows transported to livestock markets are at great risk of experiencing stress and poor welfare. From an animal welfare perspective, it is extremely important to handle weak cows, particularly those with mastitis and lameness, carefully, because these animals will be in pain and distress, and this condition will follow or even aggravate during marketing, transport and slaughter (Gallo and Strappini, 2017). These animals should not go through auction markets, and special conditions should be offered to them during transport (more space availability, bedding etc.) in order to avoid further detrimental conditions during this period. Transporting these cows directly to slaughterhouses instead of selling them through cattle markets could improve their welfare.

Transport time for cows from the farm to the livestock market was found to be 1.23 hours, and from the market to destination was 2.26 hours. After the sale, 46% of the cull cows were transported back to farms and 54% to a slaughterhouse. Based on these observations, a mean time without food and water for cows passing through livestock markets was estimated to be 12.32 hours including transport and the time spent in the market pens (Sánchez *et al*., 2018b).

Cull cows (n = 1425 at 15 livestock markets) were observed during unloading at arrival at the livestock market and at loading after sale (Sánchez *et al*., 2018b). Handling and behavioural events were registered as shown in Table 10.1 (Bravo *et al*., 2018b). The means of the frequencies of handling and behavioural events in cows were registered, as shown in Table 10.1. Comparatively, culled cows showed more behavioural events like falling, slipping, balking and defecating, whereas weaned calves jumped and vocalized more during loading and unloading.

All behavioural events observed in the cows, besides vocalizations, were higher than acceptable, according to Grandin (2010); hitting and pricking cows was significantly higher during loading than unloading, and forbidden actions like kicking were still observed. According to these results, the handling of culled cows at cattle markets further compromises their welfare and it is necessary to take corrective action like training stockpersons at the market and reducing time spent at the premises.

Space requirements for cattle during transport

The OIE (2018) standard for the transport of animals by land indicates that the space required on a vehicle or in a container depends upon whether or not the animals need to lie down or stand. When they lie down they should be able to adopt a normal lying posture and when they are standing they should have enough space to adopt a balanced position. The Chilean regulation for transport, however, has adopted some standards from other regulations, without considering space recommendations according to the needs of the types of cattle we produce – mainly dual-purpose breeds with black-and-white, as well as red, Holstein and Friesian crosses.

Tabilo and Gallo (2016) measured the space anatomically occupied by 26 typical dual-purpose cattle of different ages and live weights (between 45 and 642 kg), using a dorsal view through temporized

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cameras placed at a defined height, every five minutes for 24 hours in pens, and obtained photographs of the animals in three positions: standing, sternal recumbency and sleeping (Fig. 10.9). A one-metre yellow line was painted on the back of each animal and photographs were ruled in squares according to this standard using the AutoCAD 2014 program. The squares were measured and counted with the Paint Microsoft Windows version 6.1 to obtain the area occupied by the animal's body in each position (Fig. 10.10) and a regression equation was established between weight and area occupied.

When results for the standing position were compared to an equation that uses the minimum permitted space allowance in Chile, which is also the most common space allowance used commercially (1 m^2 for 500 kg; Gallo *et al.*, 2005), it was found that the standing space allowance for smaller cattle is being underestimated, whereas for adult cattle it is overestimated (Fig. 10.11). However, when using the formula recommended by international authors (Fig. 10.12), our results for standing animals definitely underestimated the space requirements because they do not include the space necessary for animals

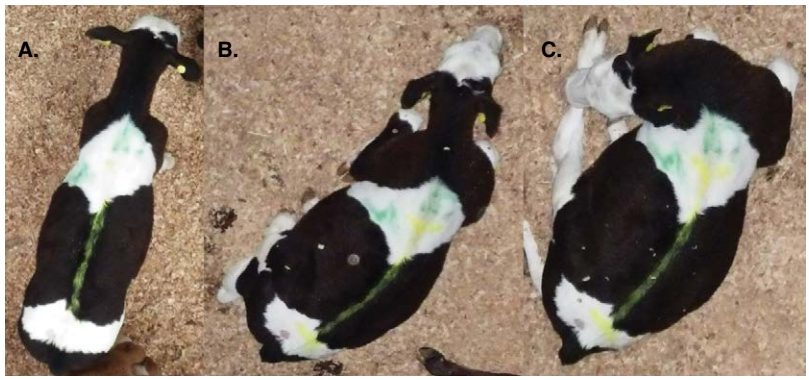


Fig. 10.9. Photographs of a 93 kg live weight calf in the three positions that were photographed. (A) standing; (B) sternal recumbency; (C) sleeping. Yellow line painted on the calf's loin as a reference standard for 1 m length to further rule in squares. When the calf is lying down, much more space is required. (Photo: Barbara Tabilo)

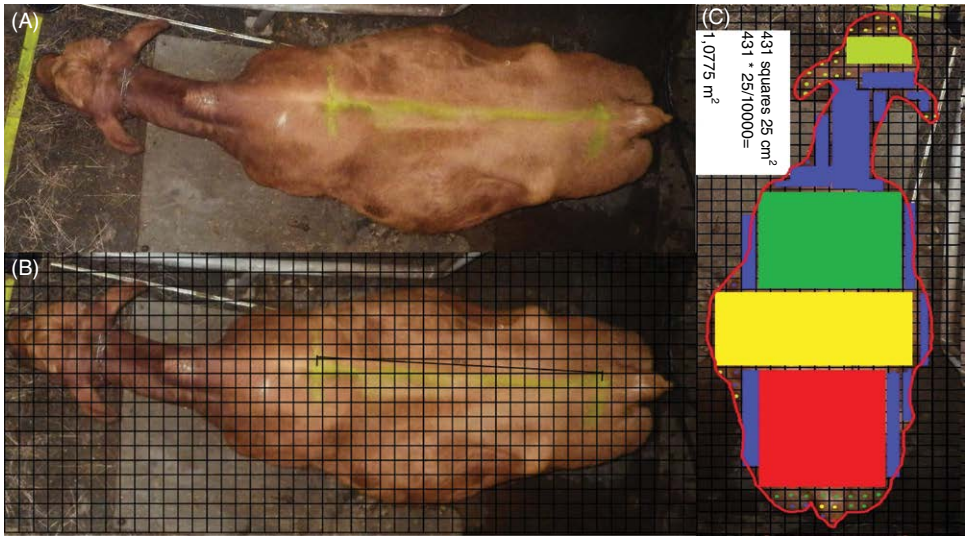


Fig. 10.10. (A) Image of 642 kg live weight cow stand; (B) same image rule in squares; (C) image coloured for counting and measuring the squares. In images A and B, the reference standard for 1 m length is painted as a yellow line for square ruling. (Photo: Barbara Tabilo)

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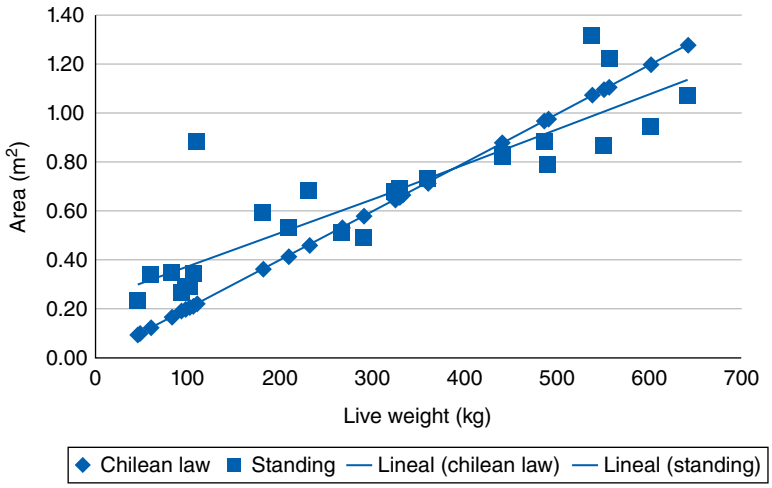


Fig. 10.11. Regression lines obtained for space occupied by cattle of different live weights in the standing position and for minimum space allowed according to the Chilean transport regulations. (From Tabilo and Gallo, 2016)

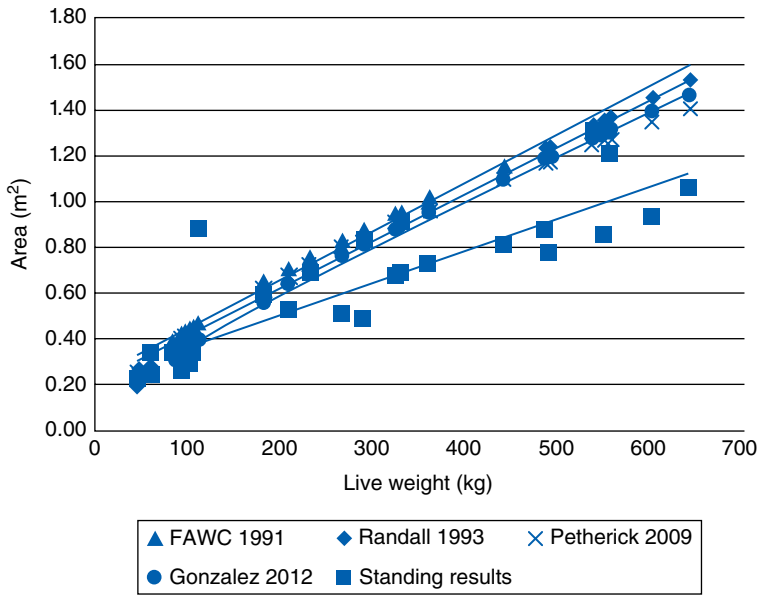


Fig. 10.12. Regression lines obtained between weight and space occupied by cattle of different live weights in the standing position by Tabilo and Gallo (2016) and recommended by other authors.

to keep their balance during transport, in addition to the space occupied by the standing animal. This study allowed us to provide a formula to objectively define the space requirements for the common dual-purpose breeds used in Chile and for different categories of cattle for transport. More research is needed in order to relate the behaviour of cattle of different ages and weights during transport with the space required, particularly considering short- versus long-distance transport. The minimum space required for animals should be based on dimensions and activities during transport (Randall, 1993).

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11 Behavioural Principles of Sheep Handling[1]

Geoffrey D. Hutson[2]* (updated by Temple Grandin[3])

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Summary

Sheep handling, behaviour during handling and the stressfulness of different handling procedures are reviewed. There are both individual and breed differences in responses to isolation from other sheep. Isolation is also highly stressful for sheep which, as a species, have intense following and flocking behaviour. The use of dogs in handling yards increases cortisol levels and sheep have good memories for aversive procedures. To prevent sheep from fearing the regular stockperson and facilities, it is recommended that painful procedures are performed in a different facility by different people. Shearing and drafting (sorting) was more stressful than drenching or dipping, and this may be partially explained by isolation and separation from other sheep. Positive methods should be used for moving sheep, such as trained lead sheep, food rewards, gentling and habituation to handling facilities. This will help to increase habituation and lower fear. Sheep will not habituate to long-term unpredictable and uncontrollable aversive events that make an animal constantly vigilant for danger and may create a chronic stress state. Constantly changing ear positions is a sign of a negative emotional state.

Keywords: cortisol, handling, isolation, sheep, stockmanship, stress

Introduction

The relationship between humans and sheep is probably more than 6000 years old (Hulet *et al*., 1975). No doubt, the original relationship was one-sided, with humans hunting herds of wild sheep for food and clothing, but gradually, during the process of domestication, hunting changed to herding and herding changed to farming. This transition from hunter to farmer has brought about a change in behaviour and attitude towards sheep, so that humans are now responsible for the day-to-day care and well-being of sheep flocks. However, the transition has been incomplete, and many of the techniques of the hunter/herder are still used during sheep handling.

Extensively raised Australian sheep are handled at least twice a year for two essential treatments – shearing and crutching (shearing of the breech and hindlegs to prevent fouling by faeces) – and generally they are handled more often. Sheep movement is usually prompted by the use of fear-evoking stimuli, and the treatment is usually stressful and aversive (Hutson, 1982b; Hargreaves and Hutson, 1990a, 1997). The handling procedure involves mustering (gathering), often with dogs and motorbikes, movement through yards, races and sheds and, finally, administration of a treatment that often involves isolation, manipulation and restraint. Treatments can be apparently mild, such as classing, drafting (sorting), drenching, dipping, vaccination and jetting (spraying), or more prolonged and stressful, such as foot trimming, castration, tail docking and shearing.

In more intensively raised sheep in France, the UK and many other countries, sheep have more frequent contact with people. In the more reactive breeds of sheep, gentling by contact with a familiar stockperson

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[1]This chapter is dedicated to the memory of Ron Kilgour, whose pioneering work on sheep behaviour, welfare and handling stimulated much of the research that is reviewed here.

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who has handled them in a positive manner reduced stress when a lamb was isolated from its flock mates (Rault *et al*., 2011; Caroprese *et al*., 2012). Today, there is much more emphasis on good stockmanship and the use of low-stress handling methods.

Behavioural Characteristics Important for Handling

Kilgour (1976) described the sheep as a '[d]efenseless, vigilant, tight-flocking, visual, wool-covered ruminant, evolved within a mountain grassland habitat, displaying a follower-type dam–offspring relationship, with strong imitation between young and old in establishing range systems of tracks and best forage areas, showing seasonal breeding, and a separate adult male sub-group structure. He claimed that most of the behaviour seen in sheep on farms could be traced to one or other of these characteristics. This description of the sheep is best encapsulated in three words – flocking, following and vision, and to these one more – intelligence – can be added. These four characteristics form the basis for all principles of sheep handling. The following sections discuss these four characteristics and three others that are perhaps less important in their contribution to sheep handling behaviour: olfaction, hearing, and vocalization and separation distress.

Flocking

The ancestral sheep adapted to mountain grasslands have evolved by natural and artificial selection into breeds occupying diverse habitats and varying climates. The social organization of sheep in the wild is probably exemplified by the feral Soay sheep on St Kilda, a small, remote Hebridean island to the north-west of Scotland. Grubb and Jewel (1966) found that ewes tended to form large groups with fairly well defined home ranges. Males associated in smaller numbers (two to three) and at mating moved from group to group of ewes. Young males left the groups of ewes at about one year old to form their own male–male groups.

In domestic flocks, this normal social organization is disrupted by the removal of lambs before natural weaning and by keeping sheep in flocks of uniform age and sex. Despite these disruptions, sheep still aggregate to form flocks. Crofton (1958) studied aerial photographs of domestic sheep and found that the distance between individual grazing sheep varied, but they were oriented so that an angle of about 110° was subtended between the head of each sheep and the two others in front of it. This angle corresponded to the angle between the optic axes of the eyes and implied that sheep grazed that way because that was the way their eyes were pointing. No doubt, vision is important in maintaining contact within the flock, but the 110° angle seems to be fanciful and has not been confirmed by other studies. However, Crofton's conclusions that sheep aggregate and that vision is important in social spacing remain valid.

Sheep maintain social spacing and orientation, even when confined in pens. Hutson (1984) found that standing sheep oriented themselves so that they were parallel to and facing in the same direction as their nearest neighbour. Further, sheep lay down parallel to and next to the sides of open-sided pens, but selected positions at random in covered pens.

Various factors will affect flock behaviour and structure while the animals are grazing, including breed, stocking rate, topography, vegetation, shelter and distance to water (Kilgour *et al*., 1975; Squires, 1975; Stolba *et al*., 1990; Lynch *et al*., 1992). The adaptive advantages of this behaviour are clear; it provides more efficient exploitation of seasonal food resources and protection from predators. Sheep respond to the sight of a predator by flocking and flight (Kilgour, 1977; Hansen *et al*., 2001; Dwyer, 2004). In the wild, they have long flight distances, but in confined spaces, this distance will vary according to the space available for escape. When confined in a 2-m-wide lane way, the flight distance of sheep to an approaching man was 5.7 m compared with 11.4 m in a 4-m-wide lane way (Hutson, 1982a). Flight distance was not affected by flock size, density or speed of approach of the 'threat', and individual sheep had longer flight distances than flocks.

One consequence of this social structure is that sheep have the opportunity to form stable relationships. Hinch *et al*. (1990) and Rowell (1991) reported that long-term social bonds may form between lambs and their mothers. Sheep may also develop a group identity. When groups of strange sheep have been mixed, they have kept to their own groups for several weeks before full integration occurred (Arnold and Pahl, 1974; Winfield *et al*., 1981).

Effect of isolation

The concept of a socially stable flock has important consequences for handling. Kilgour (1977) noted

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that, when separated from a group, an individual will run towards other sheep, irrespective of the position of the handler or dog. A sheep isolated from the flock may also show signs of tonic immobility or escape, depending on the type of restraint (Syme, 1985). Syme (1981) found that 30% of Merino sheep responded either physically or vocally to less than 5 minutes of isolation from the mob. Further studies have shown that the amount of vocalization that occurs during isolation from other sheep varies between different breeds of sheep (Wolf *et al*., 2008). Sheep that vocalize more when isolated tend to stay closer together when they are in a group of sheep (Ligout *et al*., 2011). Sheep with more lateralized brains spent more time together than sheep that had less lateralized preferences in a Y-maze (Barnard *et al*., 2016). Another interesting finding is that sheep that vocalize with the same sound frequency (tone of voice) stay with each other (Doyle *et al*., 2016). Isolation was less stressful if the sheep could see another sheep within 2 m through a wire mesh panel (Yates *et al*., 2010). Kilgour (1977) suggested that four or five sheep were required in a group before the group showed signs of social cohesion.

Penning *et al*. (1993) found that sheep in small groups spent less time grazing and that a minimum group size of three, preferably four, was required for studies of grazing behaviour. Boissy and Dumont (2002) found that individual sheep were less likely to separate from a group to graze at a preferred feeding site when they were with one companion than when they were in a group of five. Also, the frequency of vigilance behaviour increased when the group size was small (Dumont and Boissy, 2000), probably to maintain social contact with the rest of the group. When resting and feeding, Spael ewes, which were bred for wool, will space themselves more closely together than Nor-X ewes during feeding and resting (Jorgensen *et al*., 2011). The Nor-X is a heavy, rapid-weight-gaining meat sheep and possibly the wool sheep were expressing more wild-type anti-predator behaviour. Merino sheep bred to be more active during an open arena test were less fearful and had lower plasma cortisol than Merinos selected for less activity (Beausoleil *et al*., 2008). It is likely that sheep that are more fearful will flock more tightly together. Dodd *et al*. (2012), in reviewing the measurement of behavioural reactivity testing in sheep, concluded that there is a need to standardize the temperament scoring methods used.

Following

The following response of sheep is present at birth, when a newborn lamb will follow its dam during her daily activities. This response may play an important part in maintaining ewe–lamb contact, especially if the ewe has twin lambs. However, when following behaviour was tested experimentally using a surrogate ewe in a circular runway, there was great variability in the response (Winfield and Kilgour, 1976). Some lambs followed the surrogate ewe and others did not follow at all. The response was strongest for lambs between four and ten days of age, which suggests that the initial generalized following response may be replaced by a more specific response to the dam.

To demonstrate the strength of following behaviour in British market-weight lambs, one lamb was allowed to move up a race. To prevent the next lamb from following, it had to be held very tightly by a person (T. Grandin, personal communication, 2012). This following of conspecifics persists for the life of a sheep. Scott (1945) described allelomimetic behaviour – any type of activity that involves mutual imitation – as being very common in sheep. This includes waking and running together, following one another, grazing together, bedding down together and bouncing stiff-legged past an obstacle together. Behaviour within the flock also tends to be synchronized, with sheep feeding, drinking, resting and ruminating at the same time. This synchronization of behaviour by grazing herbivores might be the result of social facilitation (Rook and Penning, 1991).

Leadership also occurs in sheep flocks, and this may be related to independence (Arnold, 1977). Individual sheep have been consistently identified among the leaders or among the tail-enders in small sheep flocks (Squires and Daws, 1975). Hutson (1980a) identified about 10% of sheep in small flocks as leaders. It is unlikely that these sheep deliberately led the flock, but they moved independently of other sheep and were then followed by them. Leadership will also depend on the setting, the size and composition of the flock and the purpose of movement (Syme, 1985). Maybe leaders are the more bold and less fearful sheep. There are definite individual differences in fearfulness. Active sheep that explored more areas during an open arena test and entered more zones in the arena had lower plasma cortisol (Beausoleil *et al*., 2008). Sheep can also be trained successfully to lead other

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sheep. Bremner (1980) used operant conditioning techniques to train sheep to walk through yards, push open and unlatch gates, accept leash restraint and lead mobs of sheep. Trained leaders are now being used by large sheep operations in the USA (T. Grandin, personal communication, 2012).

Vision

Sheep have excellent eyesight, as noted by Geist (1971): 'A popular myth circulates in North America that sheep vision is equal to that of a man aided by 8-power binoculars'. A wide visual field is a common characteristic of ungulates and may be an adaptation by prey animals to enable early detection of predators (Walls, 1942). In sheep, the angle between the optic axis and the midline is about 48° (Whitteridge, 1978), which indicates that the sheep should have a wide, although not panoramic, monocular field and a binocular field of about 60°.

Piggins and Phillips (1996) measured the visual field of Welsh mountain and Cambridge sheep with a retinoscope and recorded a monocular field of 185° with binocular overlap of 61.7°. In practice, Hutson (1980b) found that the visual field of Merino sheep ranged from 190° to 306°, with a mean of 270°. The main causes of obstruction to rearward vision were ears, horns and wool growth. The binocular field of sheep, where the field of vision from each eye overlapped, ranged from 4° to 77°, with a mean of 45°. The main obstruction to the binocular field was the snout. The retina of sheep, then, is designed for scanning their surroundings when they are grazing; it also has a horizontal streak of maximum sensitivity (Shinozaki *et al*., 2010).

Stereoscopic vision is the perception of three dimensions in space. For an animal to have good stereoscopic vision, it is essential that it has good binocular vision but, in addition, the optic nerve fibres must decussate incompletely at the optic chiasma. Clarke and Whitteridge (1973) worked out the projections of the retina on the visual cortex of sheep. In area 18, they found an overlap of about 30° on each side of the midline, and most cells with fields up to 25° out were driven binocularly. In addition, visual acuity – as estimated from peak retinal ganglion cell density – was twice as high as that of the cat. Clarke and Whitteridge (1973) suggested that highly developed stereoscopic vision probably forms the basis for the sure-footedness of ungulates. Tanaka *et al*. (1995) determined visual acuity scores in three sheep that ranged from 0.085 to 0.19. These values indicate that sheep could resolve visual detail at about one-twelfth to one-fifth the standard threshold for humans.

Depth perception is the discrimination of a drop-off or depth downward as opposed to straight ahead. Depth can be detected using several cues: an animal may detect a difference in the density of light from similar surfaces at different depths; head movements or a change in position as the animal looks will produce motion parallax and an animal may possess true stereoscopic vision. Walk and Gibson (1961) and Lemmon and Patterson (1964) tested sheep on the visual cliff test and found good perception of depth. One-day-old lambs placed on a sheet of glass without visual support showed an immediate protective response – freezing, stiffening the forelegs and backing off the glass.

Sheep also possess some form of colour vision, but it is not known to what extent they rely on colour for environmental discriminations. Morphological evidence suggests that the sheep is a dichromat. Jacobs *et al*. (1998) used electroretinographic techniques to study the spectral sensitivity of cones in the sheep retina. Two cone types were identified: an S cone with a spectral peak of 445.3 nm and an M/L cone, with a spectral peak of 552.2 nm. The authors concluded that the sheep has the requisite photopigment basis to support dichromatic colour vision. A similar conclusion has been drawn for other ungulates, including cows and goats (Jacobs *et al*., 1998), and pigs (Neitz and Jacobs, 1989).

The behavioural evidence for colour vision does not concur totally with the morphological evidence and suggests that colour sensitivity may favour the longer wavelength end of the spectrum. Alexander and Stevens (1979) found that ewes could distinguish coloured lambs from grey-shaded lambs if the lambs were red, orange, yellow or white, but ewes with blue, green or black lambs performed poorly. Munkenbeck (1982) used an operant conditioning technique to demonstrate that sheep could discriminate wavelengths at 30 nm intervals in the range 520–640 nm. Tanaka *et al*. (1989a,b) also used an operant conditioning technique to demonstrate that sheep could distinguish between the three primary colours and the same shades of grey. However, 11 sessions (330 trials) were required to reach the criterion on the red discrimination and 20 sessions (600 trials) for blue, and one subject failed to discriminate between green and grey after 64 sessions (1920 trials).

Thus, the limited behavioural evidence supports colour vision in the yellow–orange–red end of the

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spectrum, but provides conflicting evidence for the blue–green end of the spectrum. It should also be kept in mind that in behavioural tests of colour vision it is notoriously difficult to effectively eliminate non-colour cues (Neitz and Jacobs, 1989). More recent research on dichromatic vision in grazing animals is reviewed in Chapter 5 (Grandin).

Kendrick and Baldwin (1987) and Kendrick (1991) have investigated visual recognition in the sheep using single-cell electrophysiological recording techniques. They investigated the responses of single neurons in the temporal cortex of sheep to various visual images. A small population of cells responded specifically to images of dog and human faces. Other cells responded to the sight of a human shape rather than to the face. These cells did not distinguish between humans, their sex, what they were wearing, whether the back view or front view was presented, or whether the head and shoulders were covered. Therefore, decisions about an appropriate behavioural response to a potential predator could be made quickly at the level of sensory analysis.

There is no doubt though that sheep could also learn these discriminations. Baldwin (1981) has demonstrated that sheep can perform complex visual discrimination learning tasks in the laboratory using geometrical symbols, and Kendrick *et al.* (1995) have shown that sheep can discriminate in a Y-maze between the projected images of faces of different sheep and humans. Davis *et al.* (1998) used an operant conditioning technique to demonstrate that sheep can discriminate between individual humans. Y-maze experiments with horizontal and vertical grids show that sheep have excellent visual acuity (Sugnaseelan *et al.*, 2013).

Olfaction

Olfaction is less important to sheep in handling situations, although they have a well-developed olfactory apparatus and are able to make keen olfactory discriminations. Olfactory recognition of the newborn lamb may be established within 30 minutes of parturition (Keller *et al.*, 2003). Baldwin and Meese (1977) demonstrated that sheep were able to distinguish between conspecifics using a range of secretory and excretory products. Blissitt *et al.* (1990) found that rams could discriminate between fresh oestrous and non-oestrous urine odours.

Sheep will avoid grazing pasture contaminated with faeces (Cooper *et al.*, 2000), and the odour of dog faeces appears to have an innate repellent effect. Arnould and Signoret (1993) reported that sheep refused to eat food contaminated with dog faecal odour and did not habituate to this with repeated exposure. Geist (1971) claimed that the sheep's sense of smell was well-enough developed for the animals to be able to scent a man 350 yards away under favourable conditions. Despite this extravagant claim, the distance over which olfactory discriminations are effective probably limits the usefulness of this sense in handling situations. Alexander (1978) found that ewes could distinguish their own lambs from aliens at close quarters, but when the lamb was more than 0.25 m away, the ewes could no longer make the discrimination. Franklin and Hutson (1982a) reported that interdigital gland secretion did not influence the path choice of sheep moving through a Y-maze.

Hearing

Wollack (1963) investigated auditory acuity in three sheep using a conditioned leg flexion response. Auditory sensitivity increased at frequencies from 10 to 10,000 Hz, with a slight decrease around 1000 Hz, and a rapid decrease from 10,000 to 40,000 Hz. Ames and Arehart (1972) determined auditory threshold curves by electroencephalogram (EEG) changes and behavioural responses and found maximum sensitivity at 7000 Hz. Shillito (1972) showed that the dominant frequencies in a lamb's bleat and a ewe's rumble were between 1000 and 4000 Hz and not at the peak sensitivity of hearing. Maximum sensitivity of hearing may therefore be attuned to the auditory detection of predators and danger, rather than to the calls of other sheep. When sheep were isolated from their flock mates, there are more ear posture changes than in sheep eating hay (Reefman *et al.*, 2009).

Habituated sheep show little response towards sonic booms and jet aircraft noise. Espmark *et al.* (1974) found the strongest reaction to sonic booms in standing sheep, who flung up their heads and started running, forming a 'bunch' with other sheep and moving off together. However, the sheep quickly adapted, so that after three exposures (five booms/day) they barely responded. Some sheep still reacted with a short and fast run, but then immediately resumed their previous activity. The sheep showed little or no response to subsonic aircraft noise ranging from 75 to 109 dB. Novel sudden events are stressful, but when sheep were able to predict when

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a sudden event would occur they had lower heart rate and were less likely to stop eating (Greiveldinger *et al.*, 2007).

Ewbank and Mansbridge (1977) also found that grazing lowland sheep tended to run together in response to simulated sonic booms at their first few exposures, but quickly adapted. In contrast, hill sheep scattered, but they, too, adapted. Weisenberger *et al.* (1996) reported that the heart rates of captive mountain sheep exposed to simulated jet aircraft noise increased but returned to resting levels in one to three minutes, and Krausman *et al.* (1998) reported increased heart rates in mountain sheep in only 14% of overflights by F16 aircraft and a return to preflight levels within two minutes.

Ambient noise during transport also appears to have little effect on sheep. Hall *et al.* (1998) reported that sheep showed no orientation away from the noise source (a generator) and no behavioural changes indicative of discomfort.

When ears of sheep are rapidly changing position, this is an indicator of a negative emotional state (Reefman *et al.*, 2009; Coulman *et al.*, 2015b). A passive ear posture with no movement is a sign of being relaxed.

Sheep learn auditory cues

Grazing systems where livestock are moved daily or every few days can be very beneficial to pastures. One disadvantage of these systems is the labour required to move fences. The use of a 'virtual fence' where the sheep wears a collar is an alternative. Sheep can easily learn to stop approaching a boundary when they hear a warning tone. This enables them to learn where the boundary is and avoid a shock (Marini *et al.*, 2018a,b).

Vocalization and separation distress

Sheep do not give a vocal alarm call and vocalize only in specific situations such as: (i) isolation from the flock (Torres-Hernandez and Hohenboken, 1979) and from other sheep (Deiss *et al.*, 2009; Rault *et al.*, 2011); (ii) during the courtship of oestrous ewes, when rams utter a low-pitched rumble (Banks, 1964); and (iii) in ewe–lamb recognition (Alexander and Shillito, 1977; Dwyer *et al.*, 1998). There are genetic differences within a breed and variability between breeds in the number and intensity of vocalizations when a single sheep is isolated (Boissy *et al.*, 2005; Wolf *et al.*, 2008). Sheep that were high vocalizers when isolated also had a higher body temperature (Deiss *et al.*, 2009), and socially isolated animals had higher levels of plasma cortisol (Guesdon *et al.*, 2012). Further, there are genetic differences in how sheep react to isolation; in sheep that were selected for temperament differences, fearful nervous animals that become behaviourally agitated during isolation had significantly higher levels of cortisol secretion than did calm animals (Hawken *et al.*, 2013).

Searby and Jouventin (2003) have pointed out that the vocal signature of ewes and lambs is similar, because it relies only on the mean frequency and spectral energy distribution (timbre) of the call. The simplicity of this system is probably linked to the roles played by vision and olfaction in corroborating the vocal information. Sheep vocalizations have no attractive effect on movement along races (Franklin and Hutson, 1982b).

Vocalizations have been shown to be a useful indicator of handling problems in beef slaughter plants (Grandin, 2001). Bellowing in cattle during handling and restraint is associated with aversive events such as the use of electric goads or excessive pressure from a restraint device (Grandin, 2001). In contrast, the low frequency of vocalization in sheep and the inhibition of vocalization in the presence of predators (Dwyer, 2004) may explain why sheep do not vocalize during aversive handling procedures. The only defence that sheep have against predators is flocking. They are defenceless compared with cattle, and they may have evolved to remain silent to avoid attracting predators. Sheep will struggle during painful or stressful procedures but, unlike cattle, they seldom vocalize when they are subjected to painful procedures. Therefore, vocalization is not a useful measure for assessing the aversiveness of handling and restraint procedures in sheep.

Intelligence

Many farmers deride the intelligence of sheep with remarks such as 'sheep are stupid', although this apparent stupidity can nearly always be attributed to the overriding presence of the protective flocking instinct (Kilgour and Matthews, 1983; Hutson, 1994). There have been many studies confirming the above-average learning ability of sheep. They can be conditioned easily in classical conditioning experiments. Liddell and Anderson (1931) were probably the first to use sheep in such experiments.

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They conditioned sheep to make reflex leg movements in response to the beat of a metronome after eight to nine pairings of the metronome with an electrical shock.

Sheep can also be conditioned to perform operant responses and will press panels with their muzzles to make shape discriminations (Baldwin, 1981), or push through a weighted door to obtain food (Jackson *et al*., 1999), operate foot treadles to obtain sodium solutions (Abraham *et al*., 1973) and push cards off buckets to make colour discriminations (Bazely and Ensor, 1989). They can reach high rates of response on fixed-ratio schedules for preferred foods (Hutson and van Mourik, 1981; Hutson and Wilson, 1983) as well. Vision may be the dominant sense for learning. Sheep can easily learn visual directional cues in an operant task, but they were not able to learn auditory directional cues (Morris *et al*., 2010).

In general, sheep perform well on tasks involving discrimination between left and right turns in U- and T-mazes (Kratzer, 1971). Liddell (1925, 1954) found that individual sheep could learn to run through a simple maze in a few trials. The maze consisted of three parallel alleys, one of which was a cul de sac. The sheep was required to find its way up the central alley and then down one of the outer alleys to a food reward. However, when the problem was made more difficult by reversing the position of the blind alley at every trial, the sheep could not learn to run through the maze without error for four consecutive trials. This was despite continued testing of some of the sheep three times a week for three years. Hunter *et al*. (2015) found that sheep could learn to change the route in a maze when the reversal was not done on every trial. Sheep could retain knowledge for 22 weeks (Hunter *et al*., 2015). Nevertheless, Liddell reported that some of the sheep found running the maze to be a 'self-rewarding activity'. Studies by Hosoi *et al*. (1995) have shown that sheep exhibit a strong lateral preference in simple T-mazes, pay little attention to either intra- or extra-maze cues and probably do not use maze cues for decision-making.

The speed and duration of learning in sheep quite clearly depends upon the nature of the task. Discrimination learning for natural objects such as food and the faces of socially familiar animals is much faster than for geometrical symbols, novel objects such as bottles or socially unfamiliar animals (Kendrick, 1998). Learning to associate symbols or novel objects with food can take 10–40 trials, and learning is often only retained for a few hours or days (Kendrick *et al*., 1996). In contrast, individual sheep can remember 50 other different sheep faces for over two years (Kendrick *et al*., 2001), and once lambs have learnt that wheat is a palatable food, they can retain this information for up to 34 months (Green *et al*., 1984). Kendrick (1998) has suggested that the sheep's brain is adapted to efficiently learn associations between natural objects and reward, but not novel associations between artificial objects and reward.

Sheep appear to have excellent spatial learning ability. Sandler *et al*. (1968) found that crossbred ewes learned the solution to a simple detour problem in a single trial. Lee *et al*. (2006) reported that sheep have the ability to learn and retain the spatial memory of a relatively complex maze after three trials. Hutson (1980a) found that sheep in a group could learn a route through yards in a relatively small number (four or five) of trials.

In contrast, Rushen and Congdon (1986a) suggested that the increased transit time taken by sheep to move along a race towards repeated aversive treatments reflected the limited learning abilities of the sheep. This surprising conclusion is not justified by their experimental results, though, as one trial was sufficient to demonstrate an aversion to the most severe treatment. A more likely explanation for the results obtained is that repetition of the treatment itself was responsible for the increase in transit times, and that cumulative experience of aversive treatments influenced these times. Sheep will remember an aversive experience for at least 12 weeks (Rushen, 1986a), and for up to one year (Hutson, 1985a).

When sheep have been tested on their natural spatial memory for tasks involving food-finding they have performed extremely well (Rook *et al*., 2005). Edwards *et al*. (1996) reported that sheep had the ability to retain information on the spatial distribution of a food resource after just a single exposure. Maximum efficiency was achieved in three to four trials. Sheep could learn the location of a food patch both with and without cues, but learned faster when a cue was present. Associations with cues appeared to act independently of memory of spatial locations (Edwards *et al*., 1997). When the location of the cue and food patches was switched randomly, sheep used spatial memory first to find the new location (Edwards *et al*., 1996). Sheep can use their spatial memory under even more complex conditions, and learn the location of

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hidden food in featureless environments with only distant landmarks (Dumont and Petit, 1998).

Sheep are also capable of single-trial learning, even at the cellular level. Kendrick (1990) reported that cells in the hypothalamus respond to the sight – but not the smell – of known palatable foods, but not to non-food objects. Initially, the cells do not respond to the sight of an unknown food but, if a sheep eats the food just once and likes it, the cells will respond the next time it is seen, even if the sheep has not seen it for a month or more. Similarly, Provenza and Burritt (1991) have demonstrated single-trial learning in lambs for conditioned aversions to palatable foods treated with the toxin lithium chloride. Naturally occurring plant compounds, such as oxalic acid, can also induce conditioned aversions after a single exposure (Kyriazakis *et al*., 1998). Food aversions can even be conditioned in anaesthetized sheep, which suggests that non-cognitive feedback processes are involved (Provenza *et al*., 1994).

In summary, sheep have excellent learning ability, can be easily conditioned, perform sensory discriminations, acquire aversions, can learn simple mazes and have a good short- and long-term memory.

Implications of the Behavioural Characteristics of Sheep for Handling

The four most important characteristics of the sheep that contribute to its handling behaviour – its flocking behaviour, following behaviour, vision and intelligence – form the basis of all behavioural principles of sheep handling. These principles will be considered in relation to the three key elements of an integrated sheep handling system: the design of the handling environment; the handling technique; and the reason for being handled – the handling treatment.

Design of the handling environment

Hutson (1980c) recommended that the most crucial design criterion was to give sheep a clear, unobstructed view towards the exit, or towards where they are meant to move. This often becomes more evident by taking a sheep's-eye view of the facility. Most of the behavioural principles of sheep handling are probably related to this criterion. Hence, sheep movement is generally better on the flat, rather than uphill or downhill (Hitchcock and Hutson, 1979b), away from buildings and dead ends (Kilgour and Dalton, 1984), in wide, straight races (Hutson and Hitchcock, 1978) and in well-lit areas (Hitchcock and Hutson, 1979a). Sheep will stop and investigate any novel visual stimulus or change in appearance of a race.

Therefore, shadows or discontinuities on the ground (Hutson, 1980c), changes in race construction material or changes in floor type – e.g. from slats to concrete (Kilgour, 1971) – should be avoided. Handling facilities should be painted one solid colour to avoid contrasts (Grandin, 1980). Judicious use of covered and open panels can direct movement and vision. Ramps should have covered sides and movement inside sheds should be across the direction of the floor grating so that sheep can obtain a better grip with their feet and cannot see through the floor or perceive heights (Hutson, 1981a). Scobie *et al*. (2015) found that solid sides may encourage sheep to jump fences. They suggest experimenting with removable solid panels to determine the best flow.

Another design principle is to take advantage of the natural tendency of sheep to want to go back to where they came from. Many modern sheep handling facilities are designed with a round crowd pen that makes a full half-circle, 180°, turn (Grandin and Deesing, 2008; Grandin, 2015). When the sheep enter the handling race, they are headed back in the same direction they came from. The round crowd pen has an 8 ft (2.5 m)- to 10 ft (3 m)-long gate that forms the radius of the crowd pen. Sheep entering a race may have an initial preference to turn right (Anderson and Murray, 2013), but practical experience has shown that always moving the sheep through the handling facility in the same path and direction is much more important than this preference.

Learning, flocking and following behaviour also affect design. Thus, sheep should always be moved through yards and sheds along the same route and in the same direction as they will learn where they are meant to go (Hutson, 1980a). Sheep flow is better in wide races where they can move as a group rather than in single file (Hutson, 1980b). The sight of stationary sheep will slow down sheep movement through an adjacent race (Hutson, 1981b), but sheep will also be attracted by the sight of other sheep or alternative visual stimuli, including mirrors, films, photographs and models of sheep (Franklin and Hutson, 1982c).

Dogs should be used cautiously, if at all, in confined handling situations, because sheep turn and

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face dogs when they cannot escape from them (Holmes, 1980). A five-minute exposure to a barking dog is used as a standard stimulus to induce stress in laboratory studies of sheep and elicits an abrupt elevation in adrenocorticotrophic hormone (ACTH) and cortisol concentrations (Cook, 1997; Komesaroff *et al*., 1998).

Handling technique

Humans have two conflicting roles in sheep handling; one is to act as a forcing stimulus and the other is to administer the treatment. The findings of Whateley *et al*. (1974) suggest that sheep react to these different roles. They found that the relative ease of handling of different breeds reflected that breed's tolerance of humans and dogs, but that breeds that handled well in paddocks and yards resisted physical restraint. Hansen *et al*. (2001) have also reported breed differences in the responses of sheep to predators, including stuffed carnivores, a man, and a man with a dog.

The human as a forcing stimulus

The traditional motivation used to move sheep is the repeated application of fear-inducing stimuli. Sheep handlers use dogs – the natural predator of sheep – or auditory and visual signals, such as shouting and waving, to frighten sheep into moving. Baskin (1974) describes herders waving arms and clothing, throwing rocks and even hoisting their caps on sticks to appear unusually tall. The aim is to frighten the animals and stimulate the flight response.

However, fear-inducing stimuli do not always have the desired effect of prompting movement. Webb (1966) studied a range of stimuli and devices for driving sheep, including coloured and flashing lights, white noise, sinusoidal sound, electric shock, a mechanical sweep and air blasts. Sheep ignored the lights and sound and did not react violently to any of the shocks. Lambs quickly lost their fear of the sweep. Some lambs jumped over the pipe delivering air blasts and the stimulus could not prevent other lambs following.

McCutchan *et al*. (1992) evaluated a mild electric shock as a prompt for sheep movement in a single-file race and found that sheep responded in an unpredictable manner to the stimulus. Some sheep moved forward, some reversed and some did not respond. Vandenheede and Bouissou (1993, 1996) have shown that rams were less fearful than ewes, but that wethers (castrated males) were more fearful than rams in various test situations. The OIE (World Animal Health Organisation) recommends that electric goads should not be used on sheep.

It appears that the effectiveness of a forcing stimulus declines as the sheep approach the area where they are treated. More force is then applied, and both handler and sheep become more aroused in an escalating, vicious-circle effect. Occasionally, the sheep must be physically moved to the treatment area. The most likely explanation for this effect is the dual role of the human handler in forcing and treating the sheep. The human is trying to apply more fear to make sheep move towards a fearful stimulus. In addition, increased force will result in greater arousal and less predictable and erratic responses from the sheep, including stopping, freezing, feeling, balking, sitting, turning, reverse movement and jumping (Holmes, 1984; Syme, 1985; Vette, 1985).

The use of leader sheep and other low-stress methods

Alternative techniques that utilize different motivations – such as the flocking/following response or positive rather than negative reinforcement – should be used. For example, Bremner *et al*. (1980) have successfully trained sheep to lead other sheep, and Hutson (1985a) has reported that food rewards can encourage voluntary movement and improve sheep handling efficiency. Kiley-Worthington and Savage (1978) used classical conditioning to an auditory alarm to prompt the movement of dairy cows. Vette (1985) has described a novel attempt to improve voluntary sheep movement into a single-file race. A rotating circular carousel holding four to six decoy sheep stimulated sheep to move into the race. Another novel attempt, using an artificial wind, was less successful (Hutson and van Mourik, 1982).

Trained leader sheep are being successfully used in Colorado to move sheep in a slaughter plant (Fig. 11.1). Leaders are used that are specifically trained for leading in different parts of the facility. Each leader sheep has a specialist function. They are: (i) *the truck unloader* – which walks up the truck ramp by itself and then turns around and leads the sheep off; (ii) *the pen leader* – which leads sheep out of the lairage pens; and (iii) *the slaughter leader* – which leads sheep from the crowd pen and up the single-file race. The leader sheep escapes through a gate in the side of the race before it

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Fig. 11.1. Trained leader sheep leading sheep down a ramp to unload a truck. The stockperson lets the leader out of its pen and it runs up the truck ramp to lead the sheep. (Photo: Ruth Woiwode, Colorado State University)



Fig. 11.2. This trained sheep is led with a collar and lead rope and voluntarily co-operates with the stockperson. Note that the lead rope is slack. (Photo: Ruth Woiwode, Colorado State University)

reaches the stunner. New leaders are trained by tethering a lamb to an experienced leader. At a large feedlot, large groups of lambs are led by a stockperson who leads a tame sheep with a collar and lead (Figs 11.2 and 11.3). The use of leaders eliminates the need for people to force sheep to move. Trained leaders can also be used with sheep living in a paddock or pasture. Taylor *et al.* (2011) reports that trained leaders can be mixed with other sheep and the group will move when the trained leader is called by a visual and auditory stimulus. Sheep trained to approach a combined visual and auditory stimulus performed better than in response to an auditory stimulus alone (Taylor *et al.*, 2010). The sight of any sheep moving away from the group will cause other sheep to follow (Pillot *et al.*, 2010).

The human as a handler

Many years ago, the author speculated that future improvements in sheep handling would rely on an animal perspective, which implied that temperament studies should concentrate on the handler (Hutson, 1985b). For example, Seabrook (1972) reported that in dairy herds, more milk was obtained by dairymen classified as confident introverts than by non-confident extroverts. Clear differences were noted in the willingness of cows to enter the milking parlour and return from pasture with such dairymen.

Thus, it is quite evident that some people have an inappropriate personality to be animal handlers, and others will need prolonged training. Hemsworth (Chapter 16) has identified similar relationships between the behaviour and attitude of handlers towards pigs and subsequent production. There is no doubt that similar principles apply to sheep handling, even though handling itself is less frequent in sheep.

It is generally assumed that sheep handling skills are acquired by experience, although there has always been debate about whether good stock handlers are born or made (Kilgour, 1978). Ewbank

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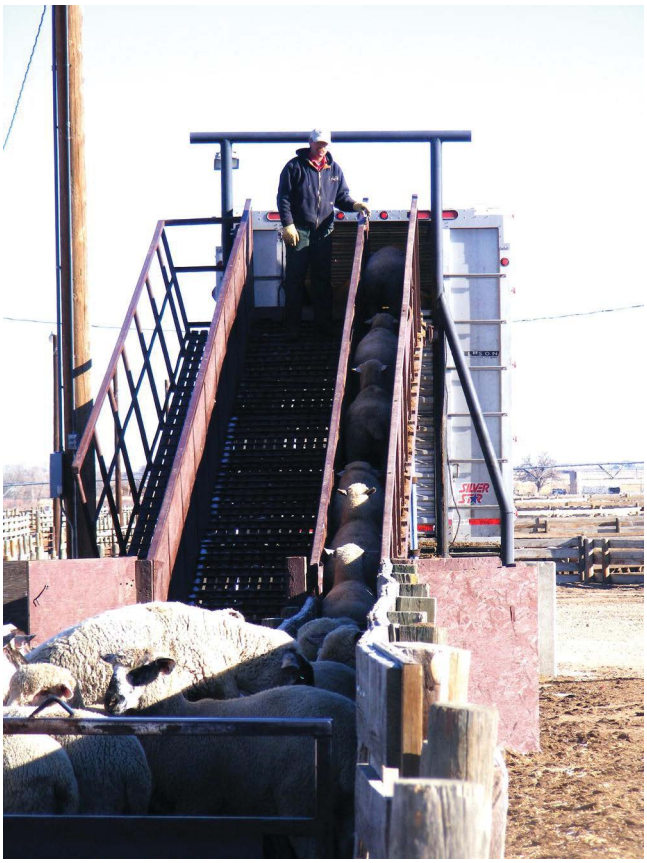


Fig. 11.3. The stockperson led the leader sheep up the truck ramp to lead the flock of sheep onto a truck. The leader walks willingly with the stockperson. (Photo: Ruth Woiwode, Colorado State University)

(1968) has suggested that they have an understanding of animal psychology that is probably based on acute powers of observation. For example, good stock handlers:

1. Make the minimum possible use of fearful stimuli (Rushen *et al.*, 1999), avoid using loud noises that animals will associate with handling procedures (Waynert *et al.*, 1999), avoid punishing animals, and use positive reinforcement such as palatable, familiar feed placed in the pen where the sheep exit from the race (Hutson, 1985b).
2. Act quickly and decisively, because if handling is fumbled, animals become more difficult to restrain (Ewbank, 1968).
3. Are aware of the flight distance of animals and utilize the strategy of reverse movement, i.e. by moving towards confined animals they can prompt movement in the opposite direction more effectively than by frightening them from behind (Hutson, 1982a); see Chapter 5 on cattle handling for diagrams of these movement patterns.
4. Are aware of the importance of arousal (fear) in animal handling and have the ability to predict animal responses in any situation (Holmes, 1984). Calm animals are easier to handle (Grandin and Deesing, 2008). Animals may also be better able to tolerate aversive experiences during handling if these are predictable. In other words, the sheep may know they are 'safe' on the pasture and that people only carry out aversive procedures in the race or shearing shed. Destrez *et al.* (2013) found that sheep will not habituate to unpredictable and uncontrollable aversive events. Further, unpredictable aversive events that occur frequently may cause a chronic stress state.

Much of the knowledge summarized above is common sense, but it is essential that these techniques are made explicit for the training of inexperienced handlers. Even relatively straightforward procedures, such as ear tagging, can cause welfare problems if they are done by unskilled people.

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The handling treatment

Facility design and handling technique are very important in sheep handling, but the main problem with obtaining efficient through-put of sheep is the nature of the handling treatment inflicted on the sheep. Hutson and Butler (1978) found that race efficiency fell from 93% to 73% after sheep had experienced inversion for 30 seconds in a handling machine. This suggested that many routine handling treatments were aversive and functioned as negative reinforcers of free movement through the handling system (Hutson, 1982b).

Research in Australia has focused on the stressfulness of various sheep handling procedures. This research has been prompted by welfare concerns and the potential introduction of new technologies – such as robotic shearing (Trevelyan, 1992). Although attempts to replace the shearer with a robot have now been abandoned, we have much more knowledge about the relative stressfulness and aversiveness of different handling treatments. Various physiological and behavioural techniques have been used to investigate these responses.

Physiological responses to handling

This discussion will be limited to handling and responses to non-painful procedures such as shearing, dipping, drenching (oral administration of medicine) and vaccination. It is beyond the scope of this chapter to cover all the new research on painful surgical procedures, but it is important for the reader to be informed about the effects of non-painful stressors on welfare. Physiological measures of stressfulness include levels of plasma cortisol, β-endorphin and glucose, and haematocrit lactate and heart rate. Kilgour and de Langen (1970) were the first researchers to measure plasma cortisol concentrations in sheep during different handling procedures. They found a great deal of individual variation but some treatments (including isolation) stressed sheep more than others. Chasing by a dog, especially when bitten, and prolonged shearing produced the highest cortisol levels. Handling sheep with dogs and barking dogs is associated with higher cortisol in both sheep and goats (Hemsworth *et al*., 2011; Zimerman *et al*., 2011). Calm dogs result in sheep that are calm with lower heartbeats (Andersson, 2015). Fulkerson and Jamieson (1982) compared patterns of cortisol release following various stressors and reported that the most severe stress was associated with shearing. Less stress was imposed by yarding and handling and there was no effect attributable to feeding or fasting. Fell and Shutt (1988) used salivary cortisol to assess acute stressors and ranked treatments in decreasing order of stressfulness as shearing, stop–start transport, steady transport, sham shearing, isolation, cold, jetting (spraying) and yarding.

β-endorphin has also been used to monitor the stress response of sheep to potentially painful handling or surgical procedures. Jephcott *et al*. (1986) found significant rises in β-endorphin after electroimmobilization in comparison with a control handling procedure. Fordham *et al*. (1989) reported that transport did not increase plasma β-endorphin concentrations in lambs above concentrations obtained after mustering with a dog. Electrical immobilization is extremely aversive and should not be used as a method of restraint (Grandin *et al*., 1986; Rushen, 1986a,b).

Heart rate has also been used as an indicator of response to handling. Webster and Lynch (1966) found a steady increase in heart rate for the week following shearing. Syme and Elphick (1982) reported that sheep unresponsive to social isolation had a lower heart rate than responsive sheep when standing alone in a race. Also, heart rate has been reported to increase in response to visual isolation, transportation, introduction into a new flock, approach of a human, and approach of a human with a dog (Baldock and Sibly, 1990).

Hargreaves and Hutson (1990a) evaluated the stress response of sheep to routine handling procedures using plasma cortisol and haematocrit values. Both parameters were significantly elevated after shearing compared with those in untreated sheep but declined to basal levels within 90 minutes of treatment. The authors concluded that sheep perceived shearing, crutching and drafting as more stressful than drenching or dipping. Drenching and dipping were the only treatments in which sheep stayed together as a group.

In a further analysis of the shearing procedure, Hargreaves and Hutson (1990b,c) used several physiological measures, including haematocrit, plasma cortisol, plasma glucose and heart rate, to assess the stress response to components of the procedure. In a series of treatments, sheep were separated from other sheep, isolated, exposed to a human, had their blood sampled, were up-ended (held in the position for shearing), exposed to shearing noise and partially shorn. Haematocrit, plasma

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cortisol and glucose increased significantly after shearing but not following isolation. Shearing was the only treatment that elevated heart rate significantly above pretreatment values. Further research by Sanger *et al.* (2011) showed that shearing significantly raised cortisol and caused hyperthermia. The response to noise alone was less pronounced than to actual wool removal. It was concluded that wool removal was more stressful than any of the other manipulations involved in conventional shearing. A study in Turkey showed there was no significant difference in stress response to either hand shearing and shearing with a clipper (Yardimci *et al.*, 2013). The same study also found that manually lifting sheep to load them onto a vehicle was more stressful than using a ramp.

Isolation may not be as stressful as initial investigations by Kilgour and de Langen (1970) suggested. Hargreaves and Hutson (1990b) did not detect a cortisol or haematocrit response to four minutes of isolation, and suggested that individual handling and familiarity with pretreatment routine may have attenuated this response. Also, the breed of sheep under study may have an effect on the stressfulness of isolation, and Kilgour and de Langen (1970) may have used a breed that reacted more strongly to isolation – most of the work done by Hutson and colleagues was done with Australian Merino sheep.

In other studies, Parrott *et al.* (1994) reported an increase in plasma cortisol in response to 60 minutes of isolation, although the magnitude of the response was less than that to standing in water or to simulated transport. Parrot *et al.* (1988a) also reported an increase in plasma cortisol in response to 120 minutes of isolation. Coppinger *et al.* (1991) and Minton *et al.* (1995) reported that isolation, coupled with restraint (binding of the legs with adhesive tape) for six hours produced a robust cortisol response in lambs – though it is known that restraint alone will produce an acute cortisol response (Niezgoda *et al.*, 1993).

Cockram *et al.* (1994) found that isolation for 24 hours produced a significant increase in plasma cortisol after 1.5, 3 and 9 hours, but not after six and 24 hours. The response diminished on subsequent exposures and was not significant at the seventh and fourteenth repetitions. The authors also noted that the response to the first period of isolation might have been affected by movement to the isolation pen and by exposure to a novel environment. Roussel *et al.* (2004) reported that ewes repeatedly exposed to the treatment of isolation for one hour, in the presence of a dog for half of the trials, habituated to the treatment; integrated cortisol responses declined significantly between trials 1, 5 and 9. Degabriele and Fell (2001) reported that sheep taken from pasture and kept in isolation for 12–19 days showed a marked decline in plasma cortisol concentration from day 1 to day 3, and that the concentration subsequently levelled out.

Clearly, it is hazardous to compare different experiments on isolation because of the different protocols and breeds of sheep used, but several points emerge from these studies. Transient isolation associated with handling treatments may not be as stressful as isolation for long periods, and sheep may habituate to long periods of isolation. Habituation may occur if sheep learn that there is an eventual escape and are able to predict the frequency and duration of the stressor (Cockram *et al.*, 1994). Hawken *et al.* (2013) found that there is a complex interaction between genetic selection for temperament and the behavioural and physiological responses to isolation.

The response to isolation may also be reduced by the presence of various stimuli, including mirrored panels (Parrott *et al.*, 1988b), and the sight of familiar sheep-face pictures (da Costa *et al.*, 2004). Boivin *et al.* (1997) noted that lambs vocalized and moved less when they were in the presence of a shepherd than when they were isolated alone. These observations support the hypothesis of Price and Thos (1980) and Rault *et al.* (2011), who suggested that humans can serve as an effective substitute for a conspecific and reduce the distress of sheep in isolation.

Relative aversiveness of different handling procedures

Behaviour has been used to assess the relative aversiveness of handling procedures in choice tests, in aversion learning tests and in approach/avoidance conflicts in an arena test. Rushen and Congdon (1986b) showed that two forced choices were sufficient for nine out of 12 sheep to discriminate between partial shearing and electro-immobilization, although the forcing stimulus itself may have influenced the outcome of these tests. Three of the sheep were indifferent.

Grandin *et al.* (1986) reported that sheep preferred restraint on a squeeze-tilt table tilted to a lying-on-the-side position to electro-immobilization. Rushen (1986b) has also compared more conventional

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treatments using the forced choice method, and ranked the treatments in decreasing order of preference as human presence, physical restraint, isolation, capture in isolation and inversion in isolation.

The willingness of sheep to move along a race towards a treatment area has been used to assess the aversiveness of handling treatments in aversion-learning tests. Hutson and Butler (1978) found that a single experience of inversion for 30 seconds in a handling machine was sufficient to make sheep hesitate about moving along the race again. Hutson (1985a) reported that the time spent pushing sheep along a race and into a sheep-handling machine increased with successive trials when sheep were restrained by clamping, and increased at a greater rate when they were both clamped and inverted.

Rushen (1986a) reported that the length of the transit times taken by sheep to move to a treatment site indicated that electro-immobilization was more aversive than physical restraint, with or without electrodes attached, and that the degree of aversion decreased with experience of electro-immobilization. Rushen and Congdon (1986a) found that simulated shearing together with electro-immobilization was more aversive than either immobilization or simulated shearing alone.

Stafford *et al*. (1996) used an aversion test with rams to show that partial shearing was more aversive than free movement and that electro-ejaculation was intermediate between the two. Long-term behavioural responses to shearing have not been assessed, but it is likely that sheep develop a lifelong aversion to the procedure. Sheep developed an aversion to sham shearing after four trials (Rushen and Congdon, 1986a), and cortisol and β-endorphin responses to shearing were significantly greater and longer in previously shorn sheep than in naïve sheep (Mears *et al*., 1999).

Fell and Shutt (1989) used an arena test to assess the aversion of sheep to the human handler after a painful surgical mulesing operation.[1] An advantage of this method is that it is not influenced by the behaviour of the experimenter, as in forced-choice tests or aversion-learning tests. Sheep were released into the midpoint of a 14 × 4-m arena three or four at a time. The handler who had held the sheep during treatment stood quietly at one end of the arena, with the remainder of the flock behind him. Upon entering the arena, the control (untreated) sheep turned and moved towards the handler, whereas the mulesed sheep turned and moved in the opposite direction. Mulesed sheep continued to show a pronounced aversion to the handler for up to 36 days after the operation, but this aversion was no longer apparent after 114 days. It is not known whether the aversion is generalized to other humans. The arena test has also been used to show that a human is more aversive facing towards rather than away from sheep (Erhard, 2003) and that a dog is more aversive than a human (Beausoleil *et al*., 2005).

Reducing the aversiveness and stressfulness of handling

A basic dilemma plagues sheep handling. Some of the standard treatments are stressful and produce pronounced aversions in sheep. For example, wool removal is a fundamental part of sheep production and yet it is the prime contributor to the stress response to shearing. How can we improve the ease of handling and the welfare of sheep during handling if there is no prospect of changing the nature of the treatment itself? There are several possibilities:

1. Reducing the severity of the treatment. Examples include replacing the function of the plunge or shower dip by using a pour-on chemical, and loading sheep onto a vehicle using a ramp, which was shown in a Turkish study to reduce blood cortisol when compared with manual loading (Yardimci *et al*., 2013).

In the case of shearing, replacing the traditional method of wool severance by comb and reciprocating cutter will be more difficult. Alterations to the method of capture and restraint of sheep during shearing may be possible, and changes to the handpiece (machine shears) that reduce heat production, vibration and wool pull might modify the stress response to shearing. Chemical defleecing research, once a bright hope (Hudson, 1980), has encountered many difficulties, including protection of the shorn sheep from sunburn and extreme cold. An Australian company, Bioclip Pty Ltd, has commercialized the use of epidermal growth factor for wool removal and, in 2002/3, approximately 200,000 sheep were shorn using this. The process is currently only available for young sheep (Australian Wool Testing Authority, 2004). Another alternative for producers who grow sheep for meat is to use breeds that do not require shearing.

2. Conducting painful or aversive procedures under different conditions. For example, it is recommended that the procedures are conducted in another location

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away from the regular handling races to prevent negative associations with the facilities. Fell and Shutt (1989) further recommended that painful procedures such as castration should be carried out by contractors rather than by regular handlers and that handling should be minimized for several weeks following treatment. The use of anaesthetics and analgesics may also reduce aversion to the handlers or the facilities.

3. Training sheep by the use of food rewards. Hutson (1985a) reported that sheep trained to run through a handling system for a food reward required less labour for subsequent handling than unrewarded sheep. Grandin (1989) demonstrated that food rewards could also be used to entice previously restrained or electro-immobilized Suffolk ewes to voluntarily enter and accept restraint in a squeeze-tilt table that tilted them to a sideways lying position.

With time, previously acquired aversions to even severe, non-painful handling treatments will diminish, and the response of sheep to a handling procedure will approach that of naïve sheep, as shown by Hutson (1985a), using Merino sheep. There is an interaction with temperament. Merino sheep are a relatively low-fear breed. In Roman sheep, stressing the pregnant ewes with unpredictable aversive handling had the greatest negative effect on the lambs from ewes with a more reactive temperament (Coulman *et al*., 2015b). Their lambs performed worse in a maze test. Cook (1996) reported a reduction in the acute cortisol response of sheep that had learned to avoid an electric shock and no change in their basal cortisol concentrations. There is still the possibility, though, that more reactive and fearful breeds of sheep may remain apprehensive of handling facilities.

4. Habituation to the handling procedure. Simple repetition of a stimulus and an animal's habituation to it may be more important than whether it is perceived as being pleasant or unpleasant. For instance, in the study mentioned above, Siegal and Moberg (1980) showed that the adrenocortical response of eight-month-old lambs decreased over ten sessions of avoidance conditioning to an electric shock. Also, sheep that had been habituated to transport were less stressed than naïve sheep (Wickham *et al*., 2012).

However, when Hargreaves and Hutson (1990e) exposed sheep to a sham shearing procedure on four occasions at two-week intervals, the stress response was only slightly reduced by repetition. The peak cortisol response to the procedure was not affected (although concentrations did decline more rapidly to baseline levels after four exposures); adrenal responsiveness to an exogenous ACTH challenge was also unaffected. Fordham *et al*. (1989) reported no change in cortisol concentrations after twice-daily jugular venipuncture of lambs for five days. Thus, repeated exposure to stressors seems unlikely to modify handling responses.

5. Gentling of animals. Hargreaves and Hutson (1990d) investigated the gentling of adult sheep as a method of reducing the aversion to subsequent handling. Gentling is often used with laboratory animals, in which repeated tactile, visual and auditory contact with a human makes them easier to handle. Sheep were gentled by being visually isolated, talked to and patted for 20 s/day for 35 consecutive days. Gentling reduced the flight distance and heart-rate response to humans, but did not reduce the aversion to a handling procedure (sham shearing).

Mateo *et al*. (1991) confirmed these results by gentling sheep for 5 min/day for 21 days. Gentling improved the approachability of sheep to humans, but did not attenuate their response to restraint or shearing. Animals have poor ability to generalize – the habituation of a horse to a blue-and-white umbrella did not generalize to an orange tarp (Leiner and Fendt, 2011). Grandin (2010) and Grandin and Deesing (2008) hypothesize that animals have specific sensory-based memories, which are stored as pictures, specific sounds or specific touch sensations.

6. Gradually conditioning sheep to humans and handling. There is some evidence that older, multiparous ewes are less fearful of humans than young, nulliparous ewes and that the experience of motherhood may play a part in this (Vierén and Bouissou, 2002). Therefore, the first handling experience is critical. Markowitz *et al*. (1998) reported that 40 minutes of positive human contact at one to three days old reduced the subsequent timidity of lambs towards people. Uetake *et al*. (2000) reported that gentling lambs for 10 min/day during the first 10 days after birth improved their subsequent ease of handling. Gentling had a greater positive effect on more reactive breeds of sheep (Caroprese *et al*., 2012). Similarly, Boivin *et al*. (2000) found that human contact, especially stroking and feeding during the first four weeks after birth, strongly influenced the approach behaviour of lambs to a familiar stockperson. Tallet *et al*. (2005) demonstrated that

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gently handling artificially reared lambs during the days following birth increased their subsequent affinity for their stockperson. Clearly, these studies indicate that early contact with humans can reduce fear and improve ease of handling. Lambs of the Roman breed perceive brushing by a stockperson who never did anything aversive to them as a positive experience (Coulman *et al*., 2015a) Tamioso *et al*. (2017) also stated that brushing by a familiar stockperson was a positive experience.

Miller (1960) found that rats trained to run down an alley for food could be induced to continue running, even when severely shocked in the goal box, so long as they had been exposed to a series of shocks of gradually increasing intensity. In contrast, animals that had received an intense shock at the outset showed a complete suppression of running. Although generalizations from rats to sheep should be treated cautiously, Miller's study has important implications for training sheep to handling procedures and indicates that training should be gradual, with initial exposure to innocuous treatments before more stressful treatments, such as shearing, are carried out.

7. Simplifying the learning procedure, so that all handling is done in one location, preferably the shearing shed, using a uniform method of restraint. More research on the role of conditioning in the acquisition and extinction of behavioural and physiological responses to humans and handling is required. In particular, studies are needed of the cues associated with the treatment, the place it is performed and the identity of the handler.

8. Finally, **resolving the conflicting roles of humans in sheep handling**. The author suggests that only dogs, machines and electrical and mechanical devices should be used as fear-inducing forcing stimuli for sheep. This would complete the transition from hunter/herder to farmer and allow humans to concentrate on their responsibility for the care and well-being of sheep. Ultimately, good stock people can minimize or eliminate fear-inducing methods and use positive stimuli to move sheep, such as lead sheep, food rewards and training. A large sheep feedlot in Colorado is using trained leader sheep that are walked on a lead to load trucks and move sheep.

Note

[1] Mulesing is a procedure that involves removing skin folds in the tail area. It is performed to reduce the likelihood of blowfly strike and is a painful procedure that is being phased out. Breeding sheep to have fewer skin folds would eliminate the need for mulesing.

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Videos of Handling and Livestock

Due to licensing restrictions on YouTube, a number of these videos are not currently available outside the US. To access them from other countries, please search for the video title followed by the word 'video' using your preferred search engine.

Sheep USA1, *How to Handle Sheep – Part I: General Principles for Handling Sheep* – shows basic behavior while handling sheep and proper working facilities. https://www.youtube.com/watch?v=GoKHTO3sWM

Sheep USA1, *How to Handle Sheep – Part II: Handling Sheep in Market Facilities* – discusses the handlers' responsibility to handle sheep properly. https://www.youtube.com/watch?v=E-ymcgD_Rbk

Curt Pate, *Sheep Handling Demonstration with Curt Pate* – shows basic moving sheep with flight zone principles. https://www.youtube.com/watch?fKqLskfppXQ

Carter Clips, *Mesmerizing Mass Sheep Handling* – aerial drone photography of hundreds of sheep being herded. You can watch how they flow. https://www.youtube.com/watch?v=DQw21ntRC4

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12 Design of Sheep Yards and Shearing Sheds[1]

Adrian Barber[2] and Robert B. Freeman[3]

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Summary

Proven designs are presented for races and yards for handling sheep. The bugle and D-yard designs take advantage of the natural tendency of sheep to go back to where they came from. The yard designs will also work well for goats. A single, easy-to-build drafting (sorting) race is also included, as well as a layout for a shearing shed that can handle large numbers of sheep.

Keywords: drafting race, shearing facilities, sheep corrals, sheep handling, sheep yards

Foreword

The classic bugle sheep yards shown in Figs 12.1 and 12.4 of this chapter have never become obsolete. They were originally developed by Adrian Barber in the 1980s and 1990s. Yards that use Barber's designs are still being constructed by sheep equipment companies. To see bugle yards in action, type the following two sets of keywords into a search engine: *video sheep yards* and *video sheep handling*. Many of the videos show beautiful aerial photos.

Unfortunately, there has been very little new scientific research on sheep yard design and movement of sheep through yards. Since 2014, I was able to find four new papers. In Adrian Barber's original bugle designs, he recommended that the inner fence, where the handler works, should be completely solid. The outer fence was partially solid because it was built from wooden planks. The planks presented a visual barrier that was 40–60% solid.

A study done by Scobie *et al.* (2015) indicated that completely solid sides made from plywood increased the percentage of sheep that jumped out. They used a pipe rail forcing pen similar to Fig. 12.2, and covering the fence encouraged New Zealand Wiltshire sheep to jump out. There may be breed differences in this tendency. In my work, I have discovered that experimentation with removable solid panels makes it possible to determine where a solid side is most effective.

Precision farming, which uses individual electronic identification and automatic drafting, can be used with the basic bugle designs. Both previous experiences and individual temperament will have an effect on sheep movement during handling. When sheep are moved through yards, the order in which mature ewes move is relatively stable (Doughty *et al.*, 2018). Sheep often get stressed when they are alone. Training a sheep to lead and to allow touching by people reduces the sheep's reactivity when it is tested alone in an open-field test (Freitas *et al.*, 2018). Chapter 11 by Geoffrey Hutson contains new updated information on sheep handling.

Temple Grandin

Introduction

There have been significant advances in the design of sheep yards and shearing sheds. Well-designed

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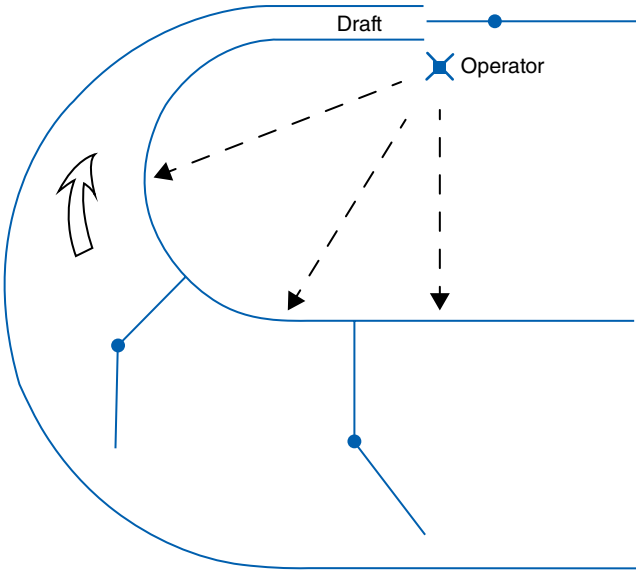


Fig. 12.1. Bugle force pen, showing operator position. The curved design provides the operator with easy access to the sheep.

facilities enable thousands of sheep to be handled efficiently, humanely and with a minimum of labour.

Sheep Yards

Main pens and force pens should be built of material that is clearly visible and strong. Fence height is 90 cm for fences inside the yard area and 1 m for fences at the outside edge of the yards. Sheep density in the main pens is 1.5–2/m^2 and this rises to 2.5–3/m^2 in the force pens.

Where a curved force pen (a bugle) (Fig. 12.1) is used to lead sheep into a drafting (sorting) or handling race, the curved approach should be constructed of solid covering material or sheeting on the inner side for the last six or eight metres. Many bugle curves work well with open panels on the outer side of the draft race and force pen. However, in some cases, it may be necessary to blind off the outer draft wall and the outside fence for the last one to three metres from the race entrance.

When the force pen leads to a handling race, it should hold a few more than one or two times the number of sheep that can fit into the race. This leaves some left over after the race is filled to act as decoys when bringing the next lot of sheep into the force pen. Generally, a force pen should not hold more than 100 sheep, otherwise there are too many to control and start up the race.

Triangular force pens are usually used in rectangular yards and can be built in single or double forms (Fig. 12.2). A single force has one fence as an extension of the drafting or handling race side, with the second fence set at a 30–40° angle. Double triangular forces have two-wing fences running back at similar angles and a central fence with a flip-flop gate at the race entrance to allow sheep entry from either side.

Drafting Race

An efficient drafting (sorting) system allows the operator to identify and draft the sheep he or she wishes to separate with a minimum of errors. To do this accurately requires an even flow of sheep. For small flocks, a two-way sort is satisfactory, but in large-scale sheep enterprises, particularly where crossbred sheep for prime lamb production are run, a three-way sort, using two gates, may be necessary. Four- and five-way sorts can be built for special purposes, such as on stud properties.

The sorting race is approximately 3 m long, with the exit point showing a clear escape route for the sheep. Where a bugle force pen leads to the draft, the straight outer fence is usually 4–4.5 m long to allow for the inflow curve.

Several points to be considered when building a drafting race are:

1. Closed-in sides.
2. Adjustable sides.
3. Tapered sides.
4. A durable floor (concrete or battens).
5. A stop gate at the outlet of the race.

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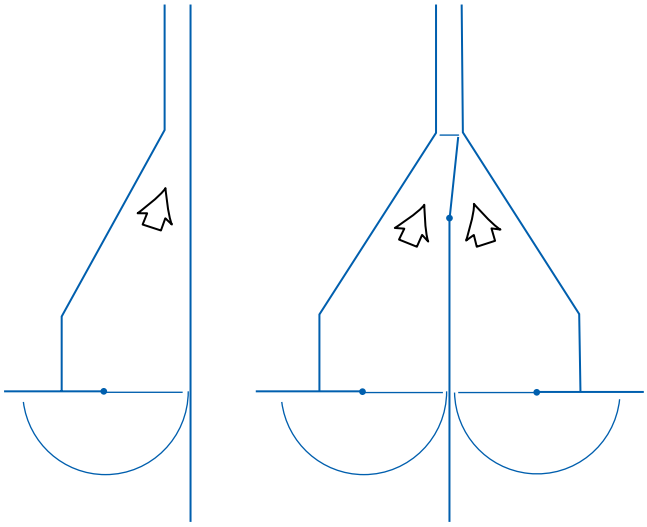


Fig. 12.2. Triangular force pens, single and double. One side is straight and the other is at a 30° angle.

6. Rubber dampers on the leading edge of the draft gate(s) to reduce noise.
7. A large-diameter vertical roller at the race entrance to prevent sheep jamming (e.g. a 200-litre drum set with its surface almost flush with the angled fence).
8. A remote-control gate.

Siting the drafting race

The direction of the drafting race should minimize the effects of sunlight and shadows. Sheep appear to run better into the sun (their shadows are behind them) and the stockworker has a better chance to see ear tags or earmarks when the sun is shining on the heads of the approaching sheep. This will not work in the very early morning if the sun blinds the sheep.

The race should be directed away from, or parallel to, the shearing shed wall so that the sheep do not get an impression of approaching a dead end. The race should also be on flat or slightly upwardly inclined ground, but not inclined downwards. Sheep in the drafted pens need to be clearly visible to other sheep still coming through the race, and thus act as decoys to encourage sheep flow. In some yard layouts, the drafting race will face a shearing shed wall. This can be satisfactory if the race is set well back and there is plenty of pen area between the race and the shed.

Side panels

In most sheep yards, the drafting race has closed sheeting on both sides to prevent outward vision by the sheep. This is to direct the sheep's attention towards the exit – sheep will actually increase speed to get through the race. However, in some yards, a race with open panels on the side opposite the stockworker has been found to work well. The sheep are encouraged to enter the race by seeing other sheep moving away from the drafting gate on the outer side.

Timber planks, steel sheeting or weatherproof plywood are suitable materials for the closed sides of the race. The sheeting must be placed on the inner faces so as to give a completely smooth surface. Bolts should be countersunk, or round-headed coach bolts should be used with the nuts to the outside.

The draft gate

The draft gate is usually 1.3 m long, but may be in the range of 1–1.5 m. Where twin gates are used to give three-way drafting, the handles should be offset from the gate top to prevent the stockworker from jamming his or her hands between the gates. The handle should also have a looped knuckle guard, which is similar to the guard loops on the handlebars of agricultural motorbikes, projecting forward to protect the stockworker's hands from charging sheep.

There is some debate on whether the draft gate should be made of open panels or closed sheeting. Reasons for using open-rail gates include:

1. The oncoming sheep can see the previous sheep moving away from the draft and are more inclined to follow.

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2. Open gates are lighter and, therefore, quicker and easier to use.
3. Open gates are less affected by winds blowing across the drafting race.

Reasons for using closed sheeting gates include:

1. Such gates act as a continuation of the drafting race, thus directing the sheep into the exit pen.
2. Closed gates prevent horns or legs from getting caught.

Remote-control sort gates

There are situations where it is an advantage to be able to draft sheep from behind, for example picking daggy (dirty) sheep. This requires some type of remote-control mechanism to operate the drafting gate (Fig. 12.3).

Sheep-handling Race

A multi-purpose handling race for drenching, vaccinating, branding, classing, jetting (spraying) and other agricultural activities is needed in the sheep yards. The handling race usually leads off the same force pen as the drafting race. Alternatively, it can be constructed as a forward extension of the drafting race.

Several different types of handling races can be built:

1. A single race of 52–64 cm wide where the stockworker is outside the race.
2. A single race of 70–80 cm wide where the stockworker is inside the race.
3. An adjustable-sided race, the width of which can be varied between 45 and 80 cm.
4. Double races, side-by-side, are satisfactory, but they must be worked correctly. A new batch of sheep is allowed to fill the first race while treated sheep are running out of the adjacent one. It can be difficult to fill one race if sheep are held in the second. The sheep will run about halfway along the race and then stop beside the other sheep they see through the rails.
5. Triple races are successful where the sheep fill the two outer races and the stockworker is in the centre race.

A suitable handling race is 9–15 m long with sides 85 cm high. One or two stop gates are included along its length to prevent lambs from crowding. The race should have a concrete or battened floor that extends 70–100 cm on either side to form a walkway at the same level as the race. Either steel or timber can be used to build the handling race. Steel rails are generally preferred as they allow greater access and vision by the operator through the race sides. One section of the race wall can be removable panels or a gate section. This provides for sheep to be diverted to other sheep handling facilities, for example a cradle-crutching unit, an automatic jetting (spraying) race or a weighing scale.

Sheep flow is often improved if the take-off point to these facilities is near the start of the race rather than at the end. If possible, a drafting gate should be positioned at the exit of the handling race to allow separation of groups of sheep after an agricultural activity, such as classing.

Bugle Yards

Bugle yards, or bugle races (force pens), work by leading the sheep around a curve while the sheep pathway narrows down to a draft or handling race (Figs 12.4 and 12.5).

Bugle yards attempt to create an improved sheep flow compared with traditional square yards. This is a debatable point that has not been proved, which indicates that sheep yard shape is not the only factor required for efficient sheep flow. Other factors, such as sunlight-and-shade effects, ground slope, building materials and position of the shearing shed, can also have an effect.

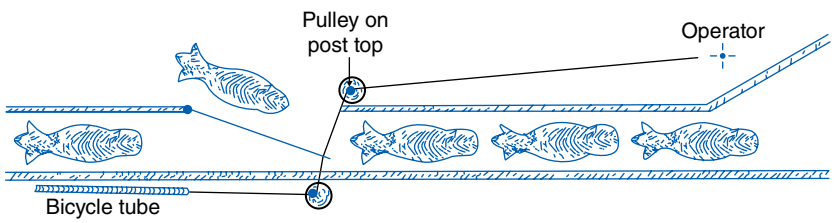


Fig. 12.3. Remote-control draft (sort) gate, with spring return.

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Bugle yards can be built with two- or three-way sorts. The main working areas of the yards are shown in the plans. Additional holding yards or mini-paddocks can be added to the sides of the plans to increase sheep-holding and working capacities to suit individual properties.

Curved-type yards can turn to either the left or the right. That is, for a given plan, there will be a matching mirror image.

The dimensions of a bugle force pen leading into a race are of critical importance in obtaining a satisfactory flow of sheep. If the curves narrow down too sharply, sheep can double up and become jammed. Conversely, if the curved entry is too wide, sheep have the opportunity to turn back away from the race.

A right-angled triangle, 4 m along the base and 2 m vertically, is used to establish the curved fences. A radius of 7.5 m from the toe of the triangle gives the inner curve and a radius of 13 m from the top of the triangle gives the outer curve. A 1.5-m radius curve leads into the sort race (see Fig. 12.4).

Three-way drafting is provided by this arrangement. Note that the centre batch of sheep does not have to travel the length of the handling race. The sheep are diverted by a panel gate behind the main sort gates into a storage pen beside the handling race. A common drafting problem in sheep yards that have the sort and handling races in line is that the centre batch of sheep being fed through the handling race may balk about halfway along. Sheep then bunch up back to the sort gates. The use of a fence, diagonal to the handling race, and an extra gate to create an additional storage pen, overcomes this difficulty.

Curved-type yards can also be drafted in two ways (right or left) at the exit of the handling race.

The side and shape of the receiving pen and position of the gates may be altered to suit different sites.

Circular Yards

The circular plan has a sheep pathway 2.5–3 m wide around the circumference of the yard, with a combined draft/handling race across the diameter (Fig. 12.6). The race allows three-way drafting at the main gates and two-way drafting at the exit of the handling race. The double bugle force pen leading to

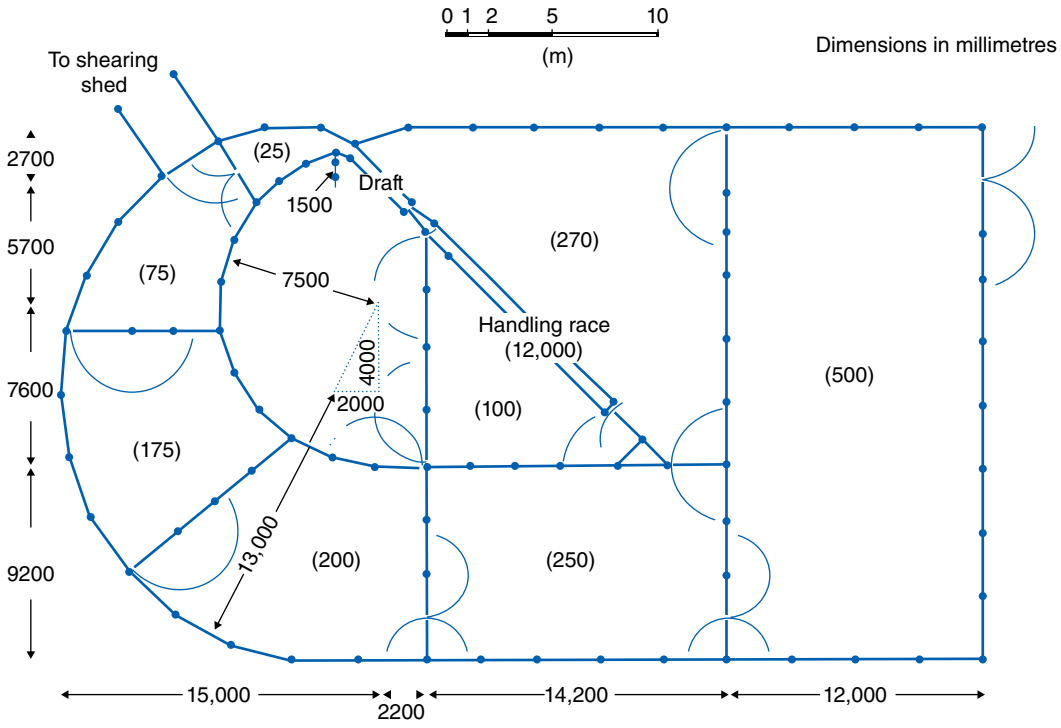


Fig. 12.4. Diagram of a bugle sheep yard.

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Fig. 12.5. Bugle sheep yards with solid sides.

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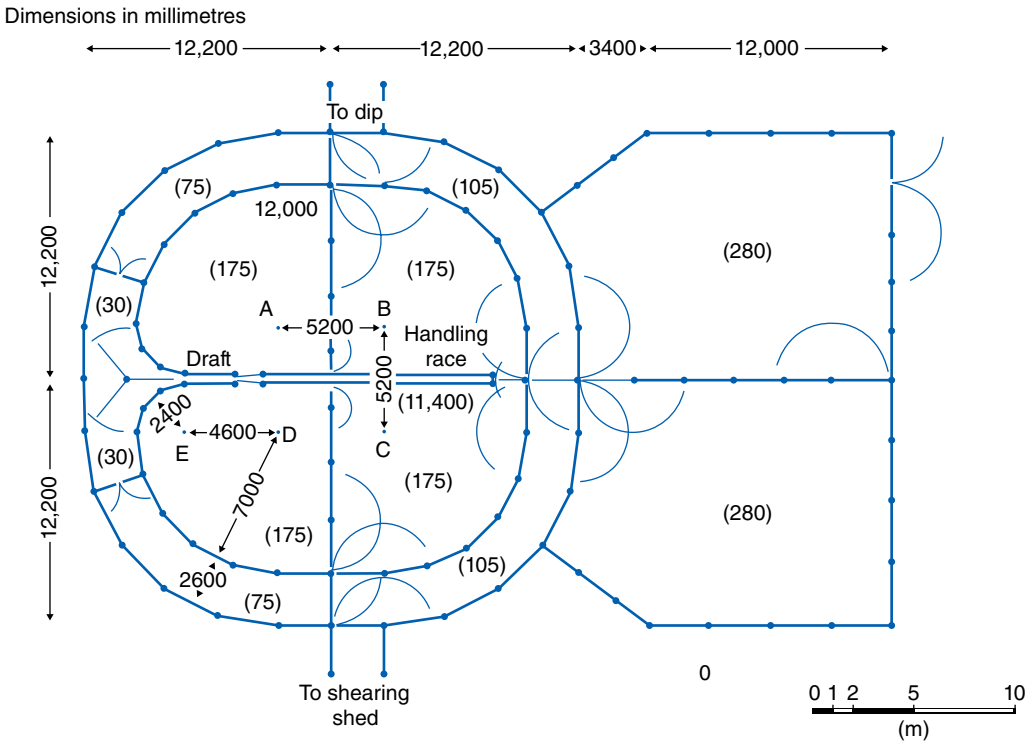


Fig. 12.6. Circular sheep yard.

the race allows for multi-mob handling for shearing or crutching. The gates can be set so that sheep can bypass the race entrance. Being symmetrical in shape, the yards can be reversed, with the race heading in the opposite direction for fitting on particular sites.

The circular design gives a high degree of flexibility of sheep movements around the yards. The plan is ideal for stud properties. The circular raceways can be readily divided into small pens for displaying rams at field days and sales.

Shearing Sheds

Older shearing sheds in Australia were designed with a centre-board layout (Fig. 12.7). Sheep are moved from the holding pens into the small catching pens. The shearers catch the sheep one at a time and pull each to the shearing board (the platform the shearers work on). After each sheep is shorn, it is dispatched by sliding it down a chute to a level below the holding pens. Some sheds have races for discharging shorn sheep.

After being shorn several times, sheep become reluctant to move from the holding pens into the catching pens. The front-fill catching pen was developed to help solve this problem (Fig. 12.8). Sheep are moved from the holding pen into a filling pen and are then moved into the catching pen through a gate near the front of the pen. Some other modern designs are the parallel-flow and diagonal-flow methods. To reduce walking distances for wool handlers, the shearing board in a modern shed is curved (Figs 12.8 and 12.9).

The woolly sheep must walk up a ramp to get into the shed, because the floor is above ground level. The ramp should be 1.5–3 m wide, with a maximum slope of 20°. The sides of the ramp should be made of closed panels to restrict vision. Sheep will shy away from a visual cliff, such as that represented by a ramp with unprotected sides. To provide sufficient height for the discharge chutes, a minimum of 1.2 m of headroom is required under the main floor.

When wood floor gratings are used, the battens should run at right angles to the direction the sheep

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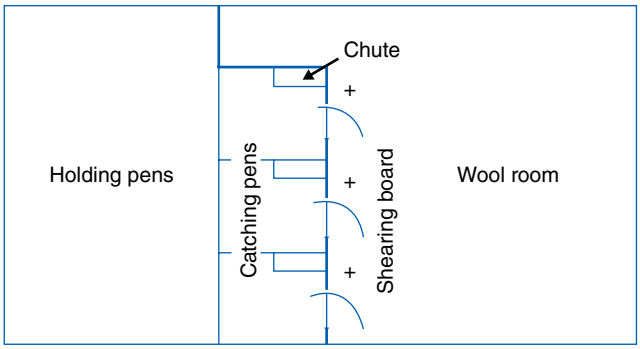


Fig. 12.7. Australian centre-board shearing shed layout.

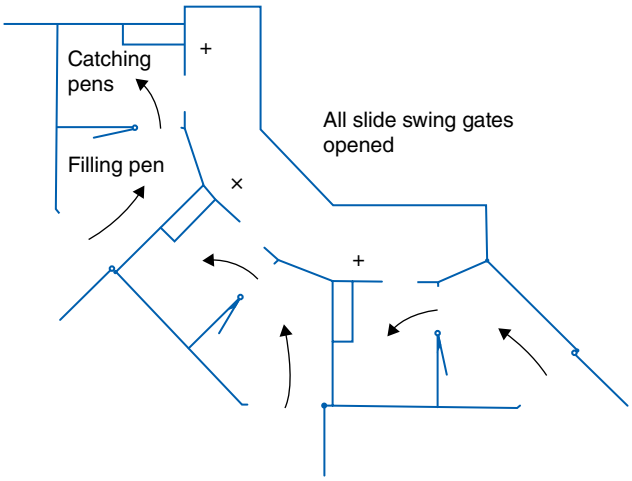


Fig. 12.8. Curved shearing board with front-fill catching pens.

are required to move. When sheep walk across the battens, it restricts their vision and helps to prevent them from seeing sunlight coming up through the floor.

A shearing shed must be large enough to shelter the daily throughput of the shed from rain. Woolly sheep can be held in an area of 2.5 sheep/m^2. Shorn sheep can be held at 3.5 sheep/m^2.

Careful attention must be paid to the design of the discharge chutes. A chute should start at a 45° angle and then change to a 20° angle at the halfway point. This design will help to prevent injuries.

Shearing sheds should have good lighting to facilitate sheep movement. Translucent plastic panels installed in the roof will provide evenly diffused lighting and will help to prevent the distorting influence of strong contrasts of light and dark shadows.

Acknowledgements

More detailed information on sheep yards and shearing sheds can be obtained in Barber and Freeman (1986), on which this chapter is based.

Diagrams of sheep yards and shearing sheds are reproduced with permission of Inkata Press.

Sheep movement can be affected by many visual factors such as lighting, shadows, reflections or position of people. See other chapters for more information on the behavioural principles of livestock handling and how vision affects movement thoughout a handling facility.

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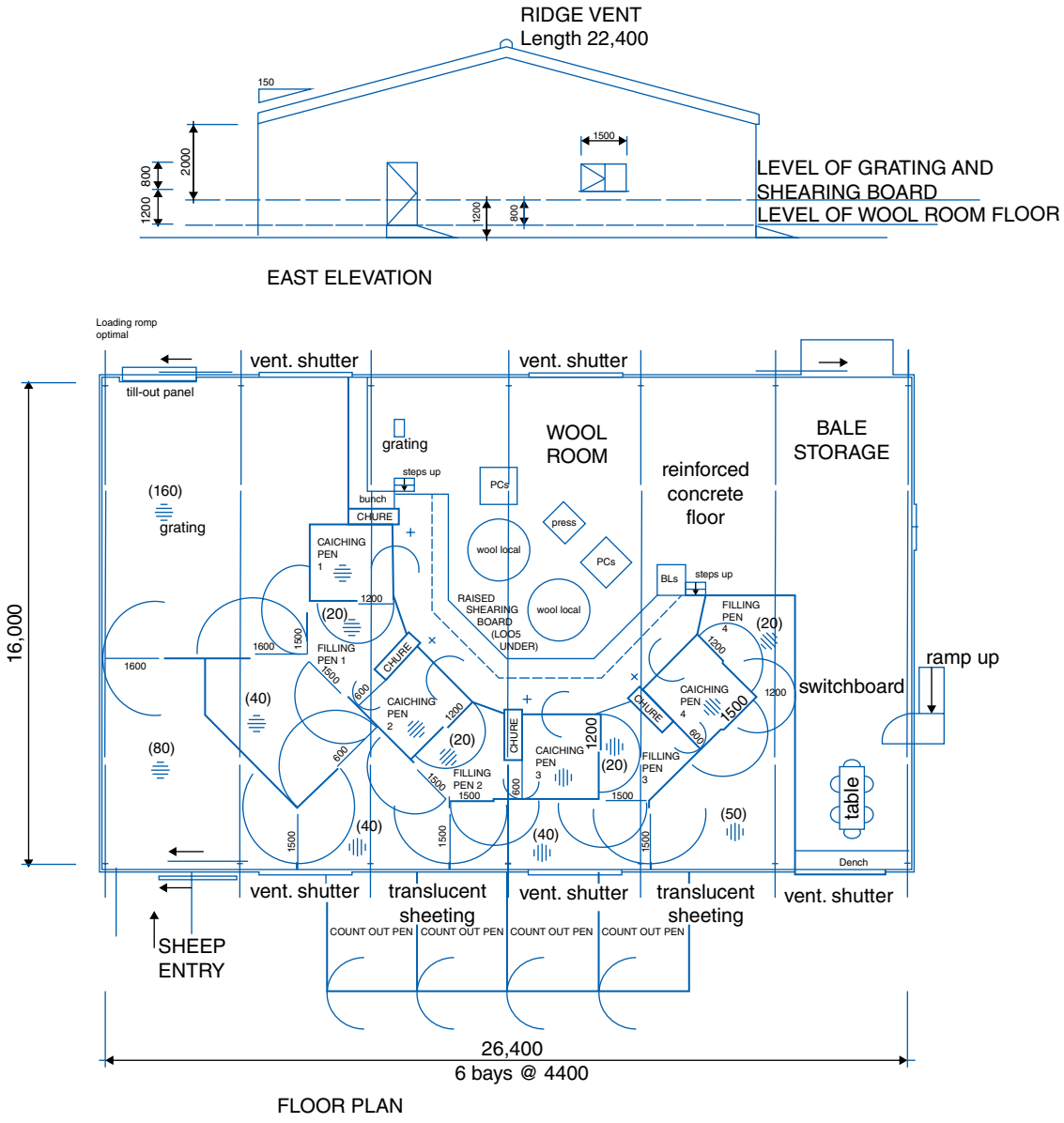


Fig. 12.9. Floor plan of three-stand (three shearers) curved-board shearing shed (dimensions in mm).

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Videos of Handling and Livestock

Due to licensing restrictions on YouTube, a number of these videos are not currently available outside the US. To access them from other countries, please search for the video title followed by the word 'video' using your preferred search engine.

Luke B, *Sheep yards in action* – aerial shots of new sheep yards with the classic Bugle design shown. Some video is sped up. https://www.youtube.com/watch?v=OzqVTNgndVE

Farmquip Argentina, *Corral completeo para ovinos FARMQUIP* – portable Bugle yard that can be easily set up. https://www.youtube.com/watch?v=LGTqsDLHs6K

Tomas Sanchez, *Apartando 4200 ovejas, Ea. Chali Aike-Santa Cruz, Patagonia Argentina* – shows sheep being handled in Bugle yard. https://www.youtube.com/watch?v=C2GOc9HpDbc

Patura, *Pare de contention mobile* – shows portable sheep yard with a straight race and a restraint device for hoof trimming. https://www.youtube.com/watch?v=C2GOc9HpDbc

David Duke, *Shearing Made Simple* – a demonstration of how to correctly shear sheep. https://www.youtube.com/watch?v=53KoRxxr1jc

Farmers Weekly Video, *Step-by-step Guide to Best Sheep Shearing Technique* – shows how to hold the sheep and remove the fleece correctly. https://www.youtube.com/watch?v=PpUTa1fyZ18

Prowaylivestockequp, *ProWay Cattleyards, Sheepyards Shearing Shed, Meander Lake, Tasmania* – sheep being handled in a large modern shearing shed. It also shows an automatic squeeze restrainer weighing individual sheep. https://www.youtube.com/watch?v=BzBuq3TEn9g

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13 Sheep Transport

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Introduction

Sheep are farmed throughout the world for meat, wool and also milk (Table 13.1). Sheep of various breeds, ages and sizes are transported to slaughter, to market or between farms for further fattening or breeding. The type of sheep transported, e.g. lambs (milk-fed and weaned), mature ewes, wethers (castrated males) and rams, and their physical and physiological state can affect their fitness for particular types of journeys. The journey from farm to slaughter might not be direct and can consist of transfer from one vehicle to another, multiple collections, unloading and reloading at assembly or staging points and auction markets/sale barns (Murray *et al*., 2000; el Dirani *et al*., 2009). The farmer's vehicle, e.g. a small trailer, may be used to transport small numbers of sheep within the farm, to a collection centre, market or local slaughterhouse. A commercial haulier is normally used to transport larger numbers of sheep. Long-distance journeys, especially within the EU, may be undertaken in specialized multi-deck vehicles that can contain feeding, watering, ventilation and vehicle tracking systems. In some countries, some sheep walk long distances to slaughter or market; others can be transported in open vehicles, by rail or boat, sometimes in less than optimal conditions (Jibat *et al*., 2008; el Dirani *et al*., 2009).

The main international trade is in meat from sheep slaughtered in the country of production. However, for religious and cultural reasons, some countries prefer not to import sheep meat, but import live sheep, which are subsequently killed at their destination (often after a further short period of fattening) (Table 13.1). There is public concern over the sea transport of sheep from Australia to the Middle East (Phillips and Santurtun, 2013) and the long-distance road transport of sheep within Europe (European Commission, 2016). The concern expressed is that during long journeys sheep suffer from stress, inadequate feed and water, injury, overcrowding, lack of rest and exposure to heat (Stevenson, 2008). When sheep are transported, they are potentially exposed to a number of factors that, either on their own or in combination, could affect their welfare. Whether this occurs will depend on the fitness of the sheep, the quality of the journey and the associated handling and management of the animals (Cockram and Mitchell, 1999).

Behaviour

During a 12-hour road journey, sheep spend most of the time standing relatively still but may need to brace themselves and make frequent foot movements to maintain balance in response to vehicular movements (Cockram *et al*., 1996). They stand with their head raised for about 80% of the time and lowered for about 10% of the time (Jones *et al*., 2002). Butting can sometimes occur (Cockram *et al*., 2004). If given sufficient space, sheep will lie down, but they lie down less and ruminate less than non-transported sheep (Cockram *et al*., 1996). The amount of lying and rumination is further reduced if the sheep are transported direct from pasture compared with those previously housed (Cockram *et al*., 2000). Almost all of the time that sheep spend lying down is with their head raised rather than with the neck relaxed and the head lowered (Cockram *et al*., 2004). Most rumination occurs when the sheep are lying down, but some rumination can occur while standing (Cockram *et al*., 1996, 2004). As a journey progresses, the amount of lying behaviour increases

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Table 13.1. Top ten countries in order of sheep population, and numbers of sheep slaughtered, exported and imported (millions). (From FAO, 2018)

Sheep population (2016)		No. slaughtered (2016)		No. exported (2013)		No. imported (2013)	
China	162.06	China	144.03	Sudan	3.71	Saudi Arabia	5.98
Australia	67.54	Australia	29.79	Somalia	2.19	Kuwait	1.40
India	63.02	New Zealand	24.78	Australia	1.97	Libya	1.28
Iran	42.50	Turkey	22.03	Romania	1.94	Italy	1.07
Nigeria	42.09	India	19.53	Spain	0.93	Jordan	0.67
Sudan	40.55	Nigeria	17.14	Ethiopia	0.70	Spain	0.54
United Kingdom	33.94	Algeria	16.06	Jordan	0.65	Qatar	0.41
Turkey	31.51	Sudan	15.51	France	0.60	Yemen	0.38
Ethiopia	30.70	United Kingdom	14.56	Hungary	0.58	France	0.37
Pakistan	29.80	Pakistan	11.26	Iran	0.52	Senegal	0.35

(Cockram *et al*., 1997, 2004) and towards the end of a 24-hour journey, lying is the main behaviour. When driven on minor or rough roads, fewer sheep lie down than when the vehicle is driven on smooth roads or motorways (Ruiz-de-la-Torre *et al*., 2001; Cockram *et al*., 2004). Driving events such as cornering or braking can disturb lying and rumination, and driving style can influence behaviour (Cockram *et al*., 2004). Sheep can appear more alert/anxious/nervous when driven erratically with repeated rapid acceleration and deceleration than when driven smoothly (Wickham *et al*., 2015). Road type and driving style can also affect the frequency of losses of balance. Cockram *et al*. (2004) showed that the frequency of loss of balance was greater on minor roads than on a motorway. Eight-two per cent of losses of balance were preceded by a driving event (acceleration, braking, stopping, cornering, gear changes and uneven surfaces) and about 22% of driving events were followed by a loss of balance. Journeys on unpaved roads are more stressful and require more muscular exertion than those on paved roads (Miranda-de la Lama *et al*., 2011).

Space Allowance

Sheep require a minimum amount of floor space to be able to stand in a normal position, adjust their posture and lie down. Increasing space allowance can also be beneficial in hot weather (Fisher *et al*., 2002). Teke *et al*. (2014) reported greater plasma cortisol concentration and greater plasma enzyme activities (indicative of tissue damage) after 29 kg sheep had been transported for 2.25 hours at 0.2 m^2/sheep compared with those transported at 0.27 m^2/sheep. However, most other studies have not found strong evidence that the range of space allowances used in Europe has a major effect on stress, dehydration, body temperature or injury (Jarvis and Cockram, 1994; Cockram *et al*., 1996; Knowles *et al*., 1998; De la Fuente *et al*., 2010; Cozar *et al*., 2016).

Floor space recommendations are related to the body size of the sheep and can be specified for various live weight ranges and for whether the sheep are shorn or have a full fleece, in terms of m^2/sheep or on the basis of live weight as m^2/kg. Petherick and Phillips (2009) considered that the floor space (m^2) required can be represented by an allometric equation:

$$\text{Area} = k(\text{live weight})^{0.66}$$

where live weight is in kg and k is ≥ 0.02 for short journeys; and to allow sheep to lie down during long journeys, k should be ≥ 0.027. The vertical or deck height is also an important consideration to enable sheep to stand in a normal posture and allow sufficient air space above the sheep so that air can flow into, across and out of the openings in the side of the vehicle. Jones *et al*. (2002) estimated that the minimum deck height for a 65 kg sheep should be 95.5 cm.

In general, providing plenty of floor space is beneficial. In young suckling lambs (12–14 kg) transported for up to 4.75 hours, provision of 0.25 m^2/sheep provided more opportunity to lie down than when 0.12 or 0.20 m^2/sheep were provided (de la Fuente *et al*., 2012). Cockram *et al*. (1996) showed that after the first 3 hours of a journey, a space allowance of 0.22 m^2/sheep for 35 kg sheep with a full fleece restricted the amount of lying behaviour compared with higher space allowances (0.27, 0.31 and 0.41 m^2/sheep) and these sheep showed more lying post-transport than those that

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were able to lie down during the journey. At this low space allowance, the sheep were so tightly packed that the frequency of losses of balance and slips was lower than at the higher space allowances, but there was no increase in their frequency as space allowance increased from 0.27 to 0.41 m^2/sheep. Jones *et al.* (2010) observed fewer losses of balance, slips and falls during a six-hour journey when sheep had plenty of space and could widen their stance or make slight leg movements to brace against the motion of the vehicle. For shorn lambs (33 kg), transported at a space allowance of 0.39 or 1.04 m^2/lamb, there were no falls, the frequencies of loss of balance, slips, riding and trampling were low and between 95% and 100% of the lambs could lie down. However, falls occurred at lower space allowances (0.23–0.3 m^2/sheep) and only 46% of the sheep could lie down at 0.23 m^2/sheep. For fleeced lambs (41 kg), the frequency of losses of balance was lower at 1.04 m^2/lamb than at 0.32–0.46 m^2/lamb. For shorn ewes (68 kg), transported at a space allowance of 1.56 m^2/sheep, there were no falls, the frequency of loss of balance and slips was low, and 31% of the sheep could lie down, but falls occurred at lower space allowances (0.3–0.44 m^2/sheep) and only 4–12% of the sheep could lie down. For fleeced ewes (65 kg), transported at a space allowance of 0.78–1.56 m^2/sheep, the frequencies of loss of balance and slips were lower than at a space allowance of 0.4 m^2/sheep.

Injury, Handling, Loading and Unloading

There is a risk that some sheep will sustain an injury during handling and transport. However, the frequency of sheep falling over during a journey in response to vehicular movement is normally low (Cockram *et al.*, 1996, 2004). During transport, plasma creatine kinase activity (indicative of muscle damage) increases with increased journey duration from 12 to 48 hours (Fisher *et al.*, 2010). Bruising can be observed on some carcasses (Jarvis and Cockram, 1994; Knowles *et al.*, 1994a). Factors that increase the risk of bruising are the presence of a fleece and transport via an auction market (compared with direct from a farm). Jarvis and Cockram (1994) found potential relationships between the occurrence of wool-pulls by handlers and riding behaviour between sheep and the occurrence of bruising, but no relationship between bruising and traumatic events during loading/unloading. Those who either transport or handle sheep during loading or unloading consider that the design and operation of the physical facilities, such as ramps and pens, have the greatest impact on ease of sheep handling followed by the naïvety of the sheep to handling and transport, and then breed of sheep (Burnard *et al.*, 2015). More problems, such as refusals to move and inappropriate handling, tend to occur during loading than during unloading (Gregory *et al.*, 2009). Hitchcock and Hutson (1979) showed that the time taken by sheep to either go up or down a ramp increased markedly when the angle of the ramp increased from 30 to 45°. After long journeys, Messori *et al.* (2015a) observed that sheep were more likely to fall during unloading when steeper ramps were used (range 10–70%) and if there was only partial or no coverage of straw on the ramp compared with complete straw coverage.



Fig. 13.1. Sheep in a vehicle with good ventilation openings and head height, but low space allowance.

Stress

When sheep are gathered from a paddock and then loaded into a vehicle, their plasma cortisol concentration can rise (Broom *et al.*, 1996). However, contrary to many statements, loading is not necessarily the most stressful part of the journey. If sheep are loaded carefully via a loading ramp onto a single-deck vehicle, they do not always show an increase in plasma cortisol concentration, whereas sheep that are loaded in this manner and subsequently transported show an increased plasma cortisol concentration (Cockram *et al.*, 1996). This finding was confirmed by Parrott *et al.* (1998) who found no significant differences in the heart rate and plasma cortisol responses of ewes loaded into a single-deck vehicle via a ramp, compared with those loaded using a mechanical lift. The plasma cortisol

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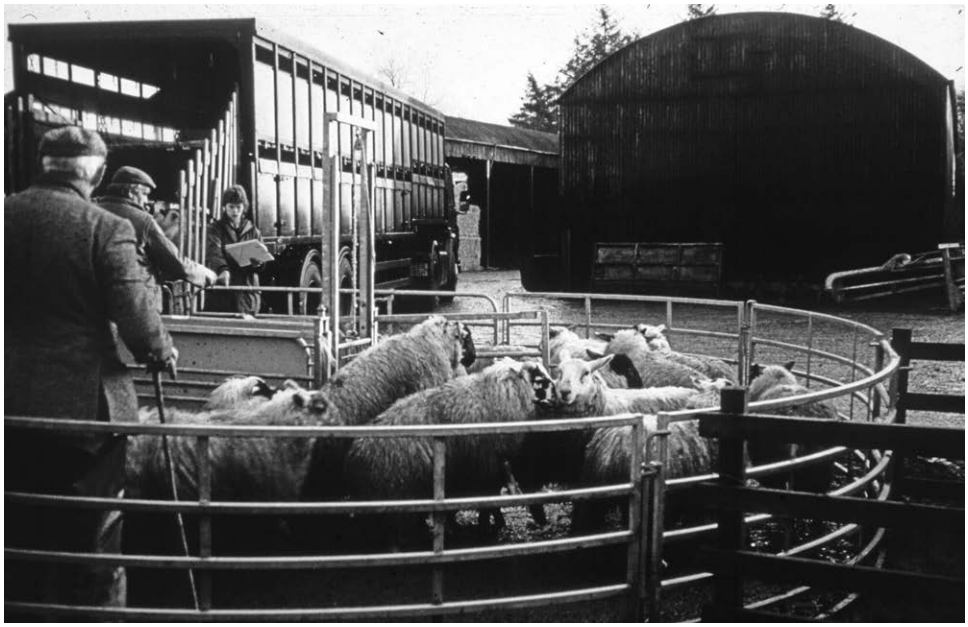


Fig. 13.2. Sheep in handling pen before loading.

response to loading into a trailer via a 20° ramp is less than that after loading by shouting, pushing and then manual lifting (Yardimci *et al*., 2013).

Transport causes a rise in the plasma cortisol concentration and heart rate during the first part of a journey (maximum after about 3 hours) and then these variables decline (Cockram *et al*., 1996, 1997). It is possible that sheep continue to perceive transport as an aversive stimulus, but this may no longer be reflected in the peripheral plasma cortisol concentration (Smith *et al*., 2003). Stress responses to transport (e.g. heart rate increases and behavioural appearance of alertness) can be greater in transport-naïve sheep than in those habituated to daily transportation (Wickham *et al*., 2012). In one study, the plasma cortisol responses to a 1.5-hour journey were lower if the sheep had restricted vision in a closed container compared with those in an open container (da Cunha Leme *et al*., 2012). Stress responses to transport can suppress oestrus behaviour and reduce ewe fertility by causing temporary disruption of endocrine events (Dobson *et al*., 2012).

Thermoregulation

If sheep have access to feed and water and protection from excessive air movement, solar radiation and precipitation, they have very efficient mechanisms for responding to changes in their thermal environment (Alexander, 1974). However, not only does transport not always provide these features, but high stocking density (Fisher *et al*., 2002), poor ventilation, exercise, stress (Parrott *et al*., 1999) and movement from their established environment could predispose sheep to thermal environments that exceed their capacity to maintain homeostasis. The thermoregulatory capacity of sheep to respond to the environmental conditions varies between breeds and their degree of adaptation to cold or heat (Slee and Forster, 1983; Srikandakumar *et al*., 2003). If metabolic heat is not removed by ventilation, the temperature within a vehicle transporting sheep will be higher than the external temperature. The humidity within the vehicle will be raised by respired air, excreta and wet fleece (Jarvis and Cockram, 1999). Mitchell *et al*. (2008) transported 600 lambs in a three-deck vehicle at a space allowance of 0.15 m^2/22 kg lamb for 8 hours at an ambient temperature of 31°C (relative humidity about 40%) and demonstrated that the lambs were able to maintain their body temperature at 39.3°C. In response to a hot and dry environment, many sheep can maintain body temperature at or below 40°C until the air temperature reaches a few degrees

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below normal body temperature. This is mainly achieved by an increased respiration rate to increase heat loss via respiratory evaporation of water (Blaxter *et al*., 1959). During transport, shorn sheep can maintain their body temperature in response to heat easier than sheep with a full fleece (Beatty *et al*., 2008). Short-term studies of non-transported sheep show that an increase in respiration rate occurs at about 20°C in sheep with a fleece (Fig. 13.3) and about 25–30°C in shorn sheep. These temperatures are only approximate and will be lowered by increased humidity, prolonged continuous exposure to heat, any solar radiation and the restricted ability of closely packed sheep at a high stocking density to lose heat by convection and radiation. Shorn sheep can increase their rate of sweating at high temperatures, but their capacity to sweat in response to heat is less than that of cattle and man, and sweating is unlikely to contribute greatly to heat loss in sheep with a full fleece (Brook and Short, 1960). If sheep have access to water, their intake is increased in hot conditions and this can assist cooling (Blaxter *et al*., 1959). When sheep are exposed to prolonged heat, those with severe water deprivation of sufficient severity to cause dehydration can have a higher body temperature than euhydrated sheep (Strauss *et al*., 2015). If water is restricted during a long journey, sheep will reduce water loss via respiration and this could reduce their ability to respond to hot conditions (McKinley *et al*., 2017). McKinley *et al*. (2009) showed that unshorn sheep (kept at 20°C) that had been dehydrated by two days without water, but with access to feed, lowered their respiration rate to reduce water loss. When offered drinking water, the sheep drank 3.5 litres to replace a bodyweight loss of 3.5 kg, their respiration rate increased and their body temperature and plasma osmolality returned to normal (McKinley *et al*., 2009). If sheep are exposed to high temperature and high humidity, their ability to lose heat by evaporative water loss is impaired compared with conditions of lower humidity, and this can result in hyperthermia (Bligh, 1963; Hales and Brown, 1974). Hyperthermia (rectal temperature >40.5°C) has been reported in conditions of high humidity, at an air temperature of 33°C in a sheep with a fleece and at 40°C in shorn sheep. When a sheep becomes hyperthermic, there is a change from rapid, shallow to slower, deeper, open-mouthed panting (Hales, 1969; Stockman *et al*., 2011). Sheep can lose consciousness and die when the rectal temperature reaches 43.8°C (Mustafa *et al*., 1988).

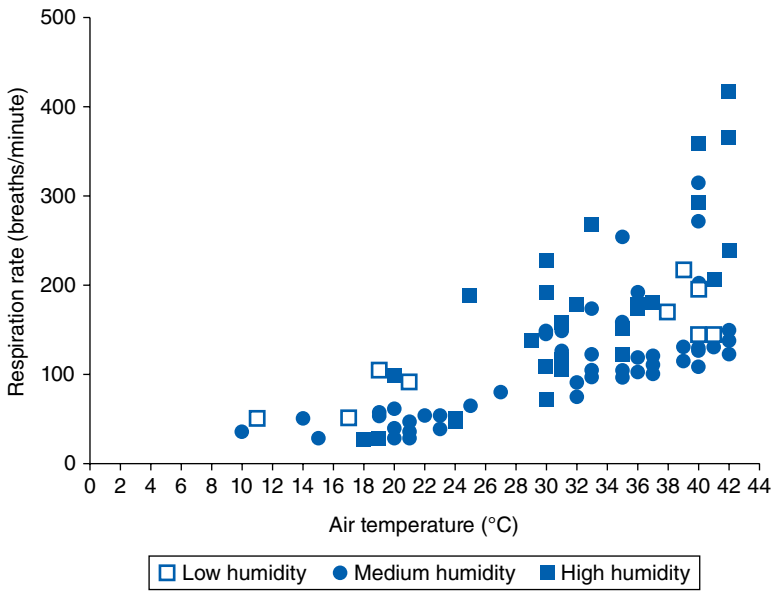


Fig. 13.3. Respiration rate of non-transported sheep with a fleece in relation to air temperature and humidity. (Compiled from reports in the literature)

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Most vehicles used to transport sheep are passively ventilated with air entering and leaving the vehicle or trailer through apertures spaced along each side of the livestock compartment. During movement, ventilation of the vehicle removes some of the metabolic heat and water produced by the sheep and it might also provide some direct convective cooling. However, airflow through the livestock compartment is not always uniform. Sheep transported in some compartments of a large multi-deck trailer, e.g. the 'belly' and the 'nose' of a 'pot-belly' trailer, can be at greater risk of heat stress than those in other locations (Miranda-de la Lama *et al.*, 2018). As airflow during a journey is, typically, from the back to the front, rear air inlets to each floor of the livestock compartment can provide additional ventilation (Gilkeson *et al.*, 2016). However, unless there is mechanical ventilation, when a vehicle is stationary air movement is dependent on the prevailing wind and thermal buoyancy.

Young lambs are very vulnerable to combinations of starvation, low temperature and air movement (Alexander, 1974) and great care should be taken if they are transported. A fit, healthy and recently fed sheep with a full fleece can withstand extremely low temperatures and might have a lower critical temperature of below –20°C, but a recently shorn sheep could have a lower critical temperature of only 28°C (Alexander, 1974). At temperatures below the lower critical temperature, a sheep would increase heat production and be able to maintain body temperature until it reached summit metabolism. Bennett (1972) estimated that the average summit metabolism in a sheep with a 7 mm dry fleece could occur at –56°C, but this would be higher after either fasting (–45°C) or exposure to air movement (–10°C) and would be –6°C if fasted and exposed to air movement. However, shorn sheep with a low-summit metabolism, exposed to air movement, might become hypothermic at 4°C, and, if wet, it might reach summit metabolism at 20°C. One case report showed that if during a 46-hour journey sheep are exposed to extreme cold conditions, e.g. external temperatures of –23 to –29°C, and an estimated wind chill of –58 °C (due to 50% of the air inlets on the vehicle remaining open), some of the sheep will die or become non-ambulatory (Canada Agricultural Review Tribunal, 2012). When a sheep is lying down, dry bedding, e.g. wood shavings or straw, can reduce conductive heat loss (Færevik *et al.*, 2005).

The advice provided by Richardson (2002) for transportation in extremely cold weather includes: increasing bedding, providing sufficient room to adjust posture, protection from water splashing from the road and balancing the need for ventilation with the risk of wind-chill. In hot weather, it is recommended that stocking density is reduced, the frequency and length of stops where sheep are not unloaded are kept to a minimum, parking in direct sunlight is avoided, the sheep should be handled carefully before loading to avoid raising body temperature, sufficient ventilation should be provided by opening inlets, and, whenever possible, journeys should be avoided when the temperature and humidity are high and transport is scheduled for the night or early morning.

Feed and Water Deprivation

When sheep are transported on long journeys, there is concern about the length of time that they are without feed, water and adequate rest. Some countries have introduced legislation to regulate maximum journey times, the maximum interval between staging points to provide rest, feed and water and for the provision of feed and/or water on the livestock vehicle. Although there is no consensus on specific maximum journey times (Cockram, 2007), sheep obviously require access to feed and water at intervals to maintain body functions and avoid excessive hunger and thirst. The ability of sheep to respond to periods of water deprivation, even in hot environments, is remarkable compared with that of humans, and this ability is greatest in breeds adapted to arid conditions (Meissner and Belonje, 1972). During the first two days of water restriction, water loss in the faeces and urine is reduced, and the rumen acts as a water reservoir. The plasma volume is maintained by drawing water into the circulation from the rumen to the extent that the water balance in the body (excluding the contents of the gastrointestinal tract) is kept virtually unaltered during the first two days of water deprivation (Hecker *et al.*, 1964; Silanikove, 1994; Jacob *et al.*, 2006). By the third day, the rate of absorption of water from the rumen slows (Hecker *et al.*, 1964), but plasma osmolality is maintained (Li *et al.*, 2000), and when offered the choice of drinking or eating, sheep choose to eat first rather than to drink (Shaheen, 2000). If after about four days sheep do not have access to drinking water, water will eventually be lost from the blood, osmolality increases

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and they will start to show signs of dehydration (Kataria and Kataria, 2007). These signs can include loss of bodyweight, increases in packed cell volume, total plasma protein concentration, plasma osmolality and blood urea concentration (MacFarlane *et al*., 1961). During dehydration, receptors detect the increased osmolality and decreased extracellular volume and stimulate activation of physiological homeostatic mechanisms to conserve body water and promote thirst to motivate the sheep to drink (McKinley and Johnson, 2004). Thirst is considered to be an unpleasant subjective experience in humans, but some sheep do not take the opportunity to drink even after prolonged periods without access to water (Jongman *et al*., 2008). When dehydrated sheep are offered water, they can rapidly restore their water deficit by drinking. However, severely dehydrated sheep should initially be given limited access to drinking water to avoid rapid ingestion of excessive volumes of water, which could, in some situations, cause cerebral swelling, nervous signs and death (Abdelrahim *et al*., 1985).

Several studies have assessed the combined effects of transportation and water restriction during long journeys by monitoring changes in the peripheral blood as potential indicators of dehydration, and comparing these effects with non-transported sheep either with or without feed and water. Increases in total plasma protein concentration have been reported after journeys in Europe of 24 hours (Knowles *et al*., 1996) and 29 hours (even with access to drinking water during the journey) (Messori *et al*. 2015b); in Saudi Arabia after a 30-hour journey (Al-Mufarrej *et al*., 2008); and in Australia after journeys of 30 hours and 48 hours (Fisher *et al*., 2010). In one study by Knowles *et al*. (1996), an increase in the plasma osmolality was reported, but in other studies in Europe, it was relatively stable after journeys of up to 24 hours (Cockram *et al*., 1996, 1997; Knowles *et al*., 1998). Fisher *et al*. (2010) did not find a significant increase in either plasma osmolality or urine specific gravity after sheep were transported in Australia on journeys of up to 48 hours.

In sheep, the immediate effects of fasting are not as apparent as they are in monogastric animals. Although the weight of rumen contents and the production of volatile fatty acids decrease within 12 hours of fasting, the continued fermentation of ingesta in the rumen provides dietary energy in the form of volatile fatty acids for at least three to four days after the last feed. However, heat production falls during the first two days without feed and then stabilizes at a lower rate (Blaxter, 1962; Karaca *et al*., 2016). Hypoglycaemia and hypothermia can occur after three days without feed (Heitmann *et al*., 1986; Piccione *et al*., 2002). In response to reduced dietary energy, a fasted sheep needs to mobilize carbohydrate reserves (in the form of glycogen from the liver, until this becomes exhausted after about 12–24 hours) and then body fat (as indicated by increased plasma concentrations of free fatty acids and increased transformation of fatty acids into ketone bodies, shown by an increased plasma concentration of β-hydroxybutyrate) (Warriss *et al*., 1989; Karaca *et al*., 2016). If fat reserves do not provide sufficient energy, protein in muscle is metabolized (Blaxter, 1962). Motivation to eat is high after journeys of 12 or 24 hours (Cockram *et al*., 1996, 1997), but Horton *et al*. (1996) found that after a three-day journey, feed and water intakes in the day after transportation were lower than in controls.

Lairage

After a 12-hour journey, sheep are likely to eat and lie down for longer, eat more hay and drink more water than before transport (Cockram *et al*., 1996). The priority of sheep after journeys for up to 24 hours is normally to eat, then drink, lie down and ruminate, rather than immediately lie down or drink. There is little evidence that sheep show signs of fatigue after long journeys. During the first six hours, after journeys of 30 hours and 48 hours, sheep did not lie down more than those that had been transported for 12 hours (Fisher *et al*., 2010). Some sheep will lie down after arrival at an auction market or slaughterhouse lairage, particularly if given adequate space (> 0.3 and preferably ≥1 m^2/sheep). However, the sheep can be disturbed by humans, noise and other activity (Kim *et al*., 1994; Jarvis and Cockram, 1995; Jongman *et al*., 2008; Lambton *et al*., 2017).

Legislation within the EU requires that sheep be offered water and, if necessary, feed during a long journey. Lambs transported continuously for 22 hours can show a reduction in the plasma glucose concentration and an increase in the blood urea nitrogen concentration that is not seen if they are provided with grain and water during six- and 24-hour mid-journey lairage periods (Krawczel *et al*., 2007, 2008). However, under certain transport conditions, a short mid-journey lairage period might not always be beneficial compared with completing the journey

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uninterrupted. Messori *et al*. (2015b) showed that after a 29-hour journey, unloading ewes into a pen for an 8-hour mid-journey lairage did not increase salivary cortisol concentration compared with keeping the sheep on a vehicle, but after a subsequent six-hour journey, those that had been unloaded had greater serum creatine kinase activity than those that remained on the vehicle. Cockram *et al*. (1997) compared the effects of transporting sheep for 24 hours continuously without feed, water or rest, with providing a mid-journey lairage period of either three hours or 12 hours. The sheep spent most of the three-hour lairage period and almost half of the 12-hour lairage period standing and eating hay, but not all sheep drank during the three-hour lairage period, and they only ruminated during the third hour. There was no difference in any of the biochemical measurements of dehydration between sheep transported for 24 hours and non-transported sheep with access to feed and water. However, in sheep that were provided with hay and water during the three-hour mid-journey lairage period, the plasma osmolality during the second part of the journey was greater than in non-transported sheep with access to feed and water. When sheep eat, they produce a large volume of saliva, and when feed enters the rumen, the increased osmolality can draw water into the rumen from the plasma. The net effect of this is a temporary decrease in plasma volume and increased plasma osmolality (Ternouth, 1967). If sheep do not have ready access to drinking water, they can become dehydrated after eating dry feed (Cockram *et al*., 1997) and they are more susceptible to heat stress (Ghassemi Nejad and Sung, 2017). If access to water is limited during a vehicle stop or lairage, it is advisable to restrict the availability of dry feed. However, provision of feed and water when sheep have reached their destination is beneficial. The plasma concentrations of free fatty acids and β-hydroxybutyrate that are raised during a long journey decrease during the first three hours after sheep are given access to feed. After 15–28 hours without water, Jongman *et al*. (2008) observed that 80% of sheep drank water during a 24-hour lairage.

Meat Quality, Weight Loss and Food Safety

Although the effects of transport on meat quality are less marked in sheep than in many other species (Young *et al*., 2005), meat quality can be affected in some consignments of lambs (Jacob *et al*., 2005a) and in young lambs in particular (Ruiz-de-la-Torre *et al*., 2001; De la Fuente *et al*., 2010). Mobile abattoirs have been investigated as a way of reducing stress and improving meat quality (Eriksen *et al*., 2013). Fasting of sheep for three to four days can, but does not always, reduce muscle glycogen concentration, but there is little effect upon the muscle pH_{24} (Warriss *et al*., 1987; Daly *et al*., 2006). Stressful journeys at high air temperatures, e.g. 42°C can increase muscle pH_{24} and reduce meat quality (Kadim *et al*., 2009) and exercise can reduce muscle glycogen concentration (Ferguson *et al*., 2008). However, McPhail *et al*. (2014) did not find an effect of journey distances of up to 3300 km on the ultimate muscle pH of sheep transported to slaughter.

During a 24-hour journey without access to feed, sheep lose live weight (5–8%) (Knowles, 1998). This decrease in live weight is due to a decrease in gut contents, with a significant decrease in carcass weight occurring after 24–48 hours (Warriss *et al*., 1987). Horton *et al*. (1996) showed that sheep transported over a 72-hour period for further fattening gained weight over the subsequent month, but the weight gain was less than in sheep kept without feed and water for the same duration and in control sheep that had continuous access to feed and water.

In some countries, it is standard practice to fast sheep for a prolonged period before and after transport to slaughter. However, no significant improvement in meat quality was found after lairage for one or two days without feed compared with slaughter on arrival at the slaughter plant (Jacob *et al*., 2005b). After an eight-hour journey, Liu *et al*. (2011) demonstrated that compared with periods of ≤24 hours, a 48-hour lairage period with access to water, but no feed, was detrimental to the sheep (plasma concentrations of cortisol and total protein, plasma creatine kinase activity, packed cell volume and blood urea nitrogen concentration were raised), the muscle pH_{24} was raised, and the carcass weight was lower. One reason for fasting sheep before slaughter is to reduce gut fill and faecal contamination of the fleece during transport, thereby reducing the risk of bacterial contamination of the carcass during dressing (Pointon *et al*., 2012). Guidelines on the presentation of clean and dry sheep for slaughter include provisions for transport such as adequate cleaning of vehicles between loads; provision of clean, dry bedding; withdrawal of feed before transport; avoiding transporting

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sheep directly from pasture; and keeping the sheep dry during loading (Food Standards Agency, 2007).

Biosecurity and Disease

The international trade in live sheep has the potential to transmit infectious diseases (Sherman, 2011). When animals are transported there is an increased risk of contact with infected animals or materials, e.g. an inadequately cleaned and disinfected vehicle (Hosie and Clark, 2007). Stressful situations, such as transportation, can reduce immunity (Krawczel *et al*., 2007) and it has been speculated that the stress, mixing and close confinement associated with transportation could increase the risk of respiratory disease (Brogden *et al*., 1998). Long journeys can cause transport tetany in feedlot lambs (Pierson and Jensen, 1975; Lucas *et al*. 1982) and periparturient hypocalcaemia in ewes (Simmons, 1975).

Knowles *et al*. (1994b) reported that the mortality rate of lambs transported directly from a farm to a slaughterhouse in the UK was 0.007% and in those that arrived via an auction market it was 0.031%. Death appeared to be associated with disease present before transport that was exacerbated by the transport, rather than as a direct consequence of transport. The highest mortality was associated with the times when the rate of carcass condemnations for conditions such as abscess, arthritis and pleurisy was highest. Messori *et al*. (2015a) recorded a mortality and non-ambulatory rate of 0.2% after sheep had arrived in Greece and Italy after journeys of 23 hours (range 14–101 hours).

Fitness for Transport

Although healthy lambs are physically fit and do not fatigue easily (Cockram *et al*., 2012), many sheep that are transported have some pathology that can affect their ability to cope with transportation. Examination of post-mortem statistics shows that a proportion of the lambs sent for slaughter have identifiable lesions, e.g. pneumonia, pleurisy, abscess, arthritis and peritonitis (Green *et al*., 1997). Clinical observations of sheep at some auction markets indicate that some sheep are transported with lameness, respiratory disease and in a thin body condition (Van Metre *et al*., 2009). Guidelines that include examples of the types of clinical conditions that would make a sheep unfit for transport (e.g. Canadian Sheep Federation and the National Farm Animal Care Council, 2013) are extremely useful. Locomotion scoring can be

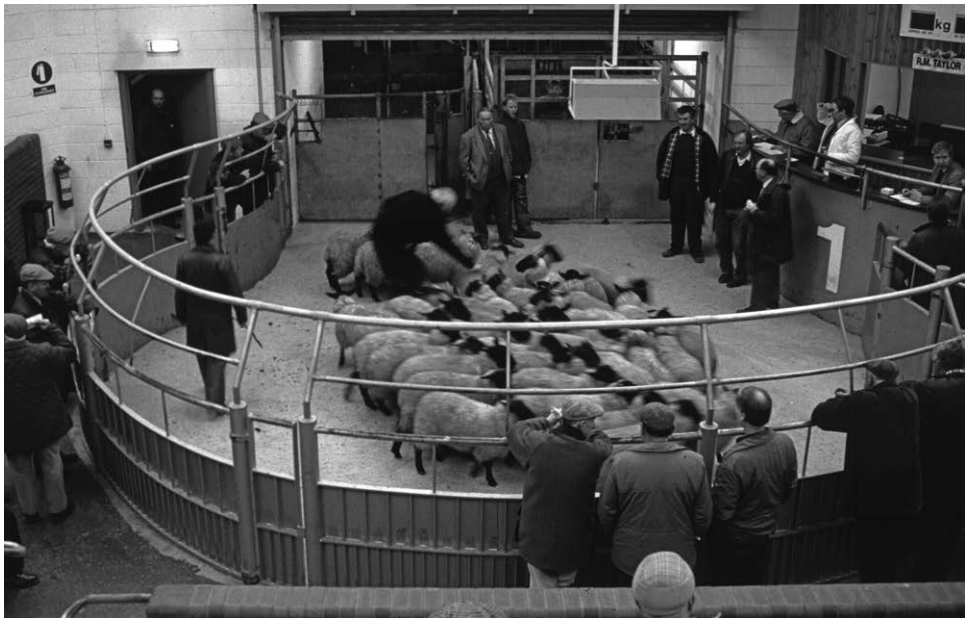


Fig. 13.4. Sheep in a ring at an auction market.

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conducted before loading (Angell *et al*., 2015) and severe lameness can be easily recognized (Kaler and Green, 2008). Sheep with lameness and clinical conditions involving inflammation are likely to experience various degrees of suffering that would be increased during transportation and handling by movement of sensitive tissues (Ley *et al*., 1989). Many other clinical conditions can be made worse by handling and transportation, and weak animals are more likely to fall and be unable to get back up again. A diseased animal may also feel ill (e.g. inappetence, thirst and fever) and be more susceptible to temperature extremes during transportation (Cockram and Hughes, 2018). Sheep in a poor body condition, e.g. some cull ewes (Herrtage *et al*., 1974), have limited fat reserves and are likely to be more susceptible to the combined effects of fasting and cold exposure (Verbeek *et al*. 2012).

Sea transport

For short journeys by ferry, sheep are normally kept in the vehicle used for road transport. For longer journeys – for example from Australia to the Middle East – the sheep are collected from pasture, transported to an assembly area/feedlot and offered pelleted feed and water before they are loaded onto a multi-deck ship where they are kept in pens on open or closed decks with mechanical ventilation (Phillips and Santurtun, 2013). Mortalities occur during and after the journey due to inappetence, heat stress, disease (salmonellosis) and trauma (Gardiner and Craig, 1970; Richards *et al*., 1991; Caulfield *et al*., 2014). Sheep that do not eat during the journey can have raised plasma concentrations of free fatty acids and β-hydroxybutyrate, and total protein and dehydration can occur (Richards *et al*., 1991). In sheep that become inappetent, those that had been gaining weight on pasture are less able to utilize their fat reserves and are at a greater risk of mortality than those transported in poorer condition at other times of the year from dry pasture (Higgs *et al*., 1991; Richards *et al*., 1991). Sheep on both open and closed decks can be exposed to combinations of high temperature and high humidity (Phillips, 2016; Zhang *et al*., 2017) and high concentrations of ammonia (Pines and Phillips, 2011). Ship movements can affect the behaviour of sheep and increase heart rate and heart rate variability (Santurtun *et al*., 2015; Santurtun and Phillips, 2018).

Conclusion

In some countries, many of the factors discussed above that can influence the effects of transport on the welfare of sheep are regulated by legislation, codes of practice or quality-assurance schemes. If the quality of the journey is good and care is taken only to select sheep that are fit, it can be possible to transport certain types of sheep over long distances without the sheep experiencing major welfare problems (Cockram, 2007).

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14 Dogs for Herding and Guarding Livestock

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Summary

Dogs that perform best for guarding and herding livestock have different behavioural profiles, as stated by the authors:

> Herding dogs are selected to show hunting behaviours, such as eye, stalk, grip or heel. Guarding dogs are selected to show more of the wild ancestor's puppy-like or juvenile behaviour, preferring to stay with the 'litter' of livestock to which they are bonded, and to react to novelty by barking an alarm.

In addition, the chase and bite behaviours are absent in guarding dogs. Ranchers in the western USA have reported that cattle located in areas of high wolf predation learn to react to Border Collie herding dogs by attacking them and so they are no longer useful for herding. The guarding dog that does not perform threatening movements towards cattle is tolerated. Ranchers have observed that the reintroduction of wolves has made mother cows more aggressive towards domestic dogs. Previously, the presence of smaller coyotes did not cause mother cows to be aggressive towards herding dogs. The protection of sheep against wolves will require two to five guard dogs.

Keywords: Border Collie, Great Pyrenean, guard dogs, herding dogs, Maremma, sheep predation

Foreword

The research conducted by Ray and Lorna Coppinger was groundbreaking and provided great insight into the behaviour of herding and guarding dogs. This classic chapter has received many citations. Ray Coppinger passed away in 2017 and this chapter is being reproduced in this fifth edition in its original form. However, to provide an update, I reviewed some of the recent research studies on herding and guarding dogs. Two recent papers bring up issues that are of concern from both a dog welfare and dog performance point of view. Taylor *et al.* (2016a) described Border Collie collapse disorder. Young adult two-year-old dogs would collapse and show neurological symptoms after strenuous activity. There is suspicion that the condition may be genetic (Taylor *et al.*, 2016b).

In the Kelpie breed, two divergent lines of Kelpies have emerged. They are pet lines and working lines (Arnott *et al.*, 2015). Stock people with herding dogs were surveyed and the trait of being fearless and bold was highly valued (Early *et al.*, 2014). It is important to have just the right amount of boldness. A bolder dog was needed in the yards (Early *et al.*, 2018). Andersson *et al.* (1988) found that calm dogs that were familiar to sheep resulted in less galloping and calmer sheep. A large survey of 812 herding dog owners showed that lack of working instinct was a major reason for failure (Early *et al.*, 2014). This applied to both Border Collies and Kelpies. Eighty-nine per cent of the dogs that failed to become good herding dogs failed due to non-health behavioural reasons (Early *et al.*, 2014).

Studies that reliably assess important behavioural traits in working dogs have had inconsistent results (Brady *et al.*, 2018). Having a good trainer is essential. McGreevy *et al.* (2017) stated that

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people who had good dogmanship were consistent, used positive reinforcement and knew how to catch the dog's attention.

Since the fourth edition of *Livestock Handling and Transport*, there have been new studies on the effectiveness of guard dogs for protecting cattle and sheep (Yilmaz *et al*., 2015). A study done in South Africa showed that farmers and shepherds were satisfied with Anatolian shepherd dogs (Binge, 2017). Several studies have shown that livestock guarding dogs are effective against the smaller canid predators such as coyotes, dingoes and jackals (Bommel and Johnson, 2015; Kinka and Young, 2018; Leijenaar *et al*., 2015). The dogs are much less effective against wolves (Kinka and Young, 2018; Scasta *et al*., 2017). There is some evidence that they are effective against puma (mountain lion), cheetahs and leopards (Leijenaar *et al*., 2015; Moral *et al*., 2016). There are many different breeds of livestock guarding dogs. Kinka and Young (2018) studied the behaviours of the different breeds and found that there were subtle behavioural differences.

There are two behavioural strategies that livestock guarding dogs can use to protect the flock or herd. They can stay close to the flock and defend it or move away and establish a territory around it (Bommel and Johnson, 2015). In Australia, Maremmas are used to protect sheep from dingoes. The dogs spent 90% of their time with the sheep, but sometimes they travelled at high speeds away from the flock and had large territories (Bommel and Johnson, 2014). In another situation, Maremmas dogs protected Australian sheep by staying close to them. An Italian study using GPS collars also showed that guarding dogs usually stayed with the sheep (Zingaro *et al*., 2017).

The reader must remember that the guarding dog's behaviour as an adult will be greatly influenced by how the puppies are raised. Puppies that become bonded to the livestock they will be protecting may stay closer. Some useful bulletins for shepherds and ranchers are in Redden *et al*. (2015) and Barth (2017). When a livestock guarding dog breed is chosen, another consideration is interactions with people. The Anatolian may be more likely to be aggressive and the Maremmas and Great Pyrenees would probably be more friendly. When purchasing either herding or livestock guarding dogs, they should come from dogs bred for working.

In two interesting videos by Dogmentary TV (2017) and Conservative Media (2013), sheep ranchers in Canada discuss the importance of having several different breeds of guarding dogs protecting their sheep. This takes advantage of the different behaviour patterns of either staying close to the sheep or running off to actively pursue predators. The Coppingers have always advised that guard dog puppies should live with the sheep and be handled very little by humans. The principle was to get the dog to bond with the sheep instead of people. There are some ranchers who disagree with this. There may be a need for management differences between very remote areas where dogs rarely see people and more populated areas. In many areas of the USA and Canada, there is more contact with hikers and other people. Dog bites and attacks on people are a real concern. A French study showed that guard dogs raised in isolation from people had significantly higher aggression towards people (Marion *et al*., 2018). Some ranchers on small properties are successfully training several breeds of guard dogs to live with the sheep and have friendly contact with people (Dogumentary TV, 2017). They may have been able to teach the dog to stay with the sheep at night and interact with people during the day.

Temple Grandin

Introduction

Two completely different types of sheepdog assist livestock producers all over the world. Herding dogs are specialists at moving stock from place to place. Guarding dogs protect domestic stock from wild predators. 'The sheepdog is such a willing and uncomplaining worker and without him the farmer could not even begin to look after his sheep', wrote Lt-Col. K.J. Price in his foreword to a popular book on the subject (Longton and Hart, 1976). Longton and Hart noted that, 'There are well over one thousand million sheep in the world, and one-third of this vast total is kept in countries where the Border collie is the chief work dog'.

Guarding dogs, well known among sheep and goat producers, particularly in the high pastures of countries all the way from Portugal to Tibet, also help to manage the world's ruminants. Although these large, placid protectors were all but unknown in the USA until the mid-1970s, they have since then been widely adopted throughout the USA and Canada. As a result, many flocks that had experienced a 10% or even greater loss to coyotes have enjoyed a marked reduction in predation.

Domesticated dogs and sheep appear together in archaeological excavations dating from 3685 BP

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(before present) (Olsen, 1985). They become part of written history in the Old Testament ('…with the dogs of my flock', *Job* 30:1) and in the writings of Cato the Elder and Marcus Terentius Varro in the two centuries before the Christian era. These treatises on Roman farm management, translated by 'a Virginia farmer' (Anon, 1913), are so full of good information that, if no other book had ever been written on flock dogs, today's farmers could learn just about all they need from Cato and Varro.

> Dogs…are of the greatest importance to us who feed the woolly flock, for the dog is the guardian of such cattle as lack the means to defend themselves, chiefly sheep and goats. For the wolf is wont to lie in wait for them and we oppose our dogs to him as defenders.
>
> (Anon, 1913, p. 247)

Modern stock producers still need that information on how to choose a pup, what an adult should look like, what to feed, the value of a dog, breeding, raising pups and number of dogs per flock. Much of this ancient 'manual' suggests that the first sheepdogs were primarily guardians rather than herders, although the difference is blurred.

The breeding and management of working farm dogs are not supported by an extensive academic farm dog-specific literature, but they are supported by a rich, knowledgeable and generally professional trade literature based on individual experience. In recent years, resources available via computer on the internet have greatly increased the accessibility of expert information. Herding dogs have received the most attention, with books and articles on their selection and training widely available. This popularity is driven in part by the success of organized competitions among the owners of herding dogs, especially of Border Collies.

Guarding dogs have been the subject of studies by biologists in the USA since the mid-1970s, and subsequently their use has greatly increased worldwide. Although the general principles of breeding, management and health care are common to all domestic dogs, working stock dogs (and their handlers) have specific needs that benefit from technical assistance. The scientific literature about farm dogs has yet to address genetic improvement at the level so prevalent for other domestic livestock or to study their behaviour at the level enjoyed by canine pets.

Willis (1992) emphasized the lack of support for research in this field: 'Bearing in mind the enormous funding given to research into sheep breeding it is surprising that so little has been expended on understanding herding ability in dogs, for without dogs most British and Australasian sheep farmers could not function'.

Taking the need for research on dogs even further, Hahn and Schanz (1996) and Hahn and Wright (1998) emphasized the lack of studies on the behavioural genetics of dogs, which limits the ability of professionals to provide useful techniques for breeders, trainers, veterinarians and end-users.

Today, scientists have sequenced the dog genome and this will help make it possible to determine how genetics and the environment interact to determine behaviour (Lindblad-Toh *et al.*, 2005; Ostrander *et al.*, 2005). Hopefully, these studies will provide useful tools for the selection of dogs.

The 10% loss to predators mentioned earlier is not uncommon in the USA, but businesses cannot sustain a 10% shrinkage for very many years. Research on guarding dogs needs to go beyond studies of breed differences and the effect of dogs on predation. Two projects that would help the industry immediately are: (i) behavioural analyses focused on improving the success rate of guarding dogs; and (ii) closely monitored field trials of dogs learning to work in locations critical for the reintroduction and survival of endangered predatory wildlife. Subsequent transfer of information back to users – and especially to potential users – also needs improvement. This is especially true in areas where wolves have been successfully reintroduced and predation is publicly scrutinized.

Better behavioural tests need to be developed to access the genetic component of specific herding and guarding traits. A review of the literature by Ruefenacht *et al.* (2002) indicated that fearfulness in dogs is highly heritable. Another study by Courreau and Langlois (2005) showed that attacking, biting and guarding behaviour is also highly heritable in Belgian Shepherd dogs. Tests for finer discrimination of behaviour need to be researched.

Differentiating the Sheepdogs

It appears, from the old literature, that early 'shepherd dogs' were used both for guarding and herding. Today, distinctions between the two types are made more clearly. Herding dogs are not 24-hour flock guardians, nor are guardians good at herding livestock. The reason becomes obvious when one considers the morphological and behavioural differences between the two types (Fig. 14.1; Table 14.1).

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Fig. 14.1. Border Collie (herding dog) and Maremma (guarding dog).

Table 14.1. Some differences between herding dogs and guarding dogs.

	Herding dogs	Guarding dogs
Examples	Australian Kelpie	Anatolian Shepherd
	Australian Shepherd	Great Pyrenean
	Border Collie	Maremma
	New Zealand Huntaway	Sarplaninac
Morphology	10–20 kg	30–55 kg
	Ears often pricked or 'tulip'; some breeds' ears hang down	Ears hang down
	Colour usually dark with white or brown markings; some are white/grey with darker spots	Colour usually white or grey, although some breeds are brown with darker markings
Behaviour	'Chase-and-bite'	Never chase or bite
	Active around stock	Passive, even lethargic, around stock
	Trained to respond to human commands	Seldom trained to respond to commands
	Have motor patterns specific to job: eye, clapping, heeling, heading or voicing, which are heritable	Have no job-specific motor patterns; form strong social bonds with stock through early, continuous association

Cato and Varro divided dogs into two kinds: hunting dogs ('used against wild beasts and game') and herd dogs ('used by the shepherd'). They described 'herd' dogs in terms of their guarding abilities. Other observers, as reported by Baur (1982), may have seen what they thought was a 'driving' dog when the dog was actually just 'following' the herd: 'These dogs take the entire care of the sheep, drive them out to pasture in the morning, keep them from straying during the day, and bring them home at night. These dogs have inherited a talent for keeping sheep, but the shepherds do not depend wholly on that' (Anon, 1873, reported in Baur, 1982).

Baur commented that shepherds reinforced the dogs' talents with 'the old Spanish custom of using a foster-mother ewe to train (suckle) a puppy'. Thomas (1983) distinguished between guarding and herding dogs, noting that the lack of wolves in England at the beginning of 'the early modern period' resulted in dogs that drove sheep, while in France or Italy, where wolves still survive, sheep follow a shepherd, and a 'mastiff or wolfhound, rather than a sheepdog, [goes] in front as their protector'. An early dog expert, Dr Johannes Caius (1576), wrote about 'The Shepherd's Dogge', describing a technique still used today by shepherds directing their herding dogs to move the stock: 'The dogge, either at the hearing of his master's voice, or at the wagging and whisteling of his fist, or at his shrill horse hissing, bringest the wandering weathers and

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straying sheepe into the self-same place where his masters will and wishes is to have them'.

Kupper (1945) described dogs in the 19th century American South West as movers of sheep, although she did wonder about 'the wonderful sheep dogs' that would die of starvation rather than leave the flock.

In France, herding dogs are known as a fairly recent development, supplanting the guardian when large carnivores (bear, wolf) disappeared from western Europe (de Planhol, 1969; Laurans, 1975; Lory, 1989; Schmitt, 1989). Laurans advanced an explanation for herding dogs becoming more useful, for as population increased, 'in countries with many small parcels of land…the shepherd needed herding dogs in order to keep his gardens safe from damage by sheep'.

The most comprehensive modern book on farm dogs is that of Hubbard (1947), whose historical overview of working dogs differentiates between herding and guarding dogs and includes a long section on herding dogs and the competitive trials that are so popular in the UK and the USA.

Hubbard described 58 working breeds, arranged in three categories: pastoral dogs (47), draught dogs (5) and utility dogs (6):

> For the most part the pastoral dogs are Sheepdogs proper, that is, those breeds used for herding and controlling sheep only. In this group we find the well-known Collie, German Shepherd Dog and Old English Sheepdog: breeds invariably used only with sheep. Apart from these there are also Cattle Dogs, drovers' dogs or cow-herds' dogs; breeds like the Welsh Corgi, the various Bouviers of Flanders, the Australian Heeler, the Hungarian Pumi, and the Portuguese Cattle Dog. Furthermore, there are other breeds which are used in the protection, droving and controlling of other animals, such as some Russian Laiki (which herd reindeer), other Russian herding dogs (which control the dromedaries of Central Asia), and the many varieties of native races of South Sea Islands dogs (which round up the indigenous pigs of the islands). There are, of course, some Sheepdogs which work as well with cattle as with sheep, and a few, indeed, that work with goats and pigs as well as with sheep.

Today, producers in the USA and Australia report that their guarding dogs have been bonded also with llamas, ostriches, emus, turkeys and other unusual or rare species.

Discovering how modern herding dogs could be developed to such precision – and how their morphology and behaviour could be so distinctly differentiated from the guardians – is based on ethology, or the study of their behaviour. An early analysis, cut short by the Second World War, was carried out by Dawson (1965) in 1935. His goal was to study the 'inheritance of intelligence and temperament in farm animals', with dogs the experimental animal and sheep herding one manifestation of intelligence, 'since it was of economic importance in agriculture'.

Various crossbreedings were made between Hungarian Pulis, German Shepherds, Border Collies, Chows and a pair of Turkish guarding dogs. Dawson reported wide variation in reactions of dogs in all tests, but could not detect differences due to sex or between the larger-breed groups. He noted 'marked indications that some of the behaviour traits were inherited'.

Development of different behaviour patterns

More recently, looking specifically at differences between the two types of sheepdog, Coppinger *et al.* (1987a) wrote:

> As with juvenile wolves or coyotes, adult livestock conducting dogs displayed the first-half segment of a functional predatory system of motor patterns and did not express play or social bonding toward sheep; whereas, like wolf or coyote pups, adult livestock protecting dogs displayed sequences of mixed social, submissive, play and investigatory motor patterns and rarely expressed during ontogeny (even when fully adult) predatory behaviours. The most parsimonious explanation of our findings is that behavioural differences in the two types of livestock dogs are a case of selected differential retardation (neoteny) of ancestral motor pattern development.

In other words, herding dogs are selected to show hunting behaviours, such as eye, stalk, grip or heel. Guarding dogs are selected to show more of the wild ancestor's puppy-like or juvenile behaviour, preferring to stay in the 'litter' of livestock to which they are bonded and to react to novelty by barking an alarm. Guarding dogs are not attack dogs: they are defence dogs, although they have been aptly described as 'unbribable…extremely loyal, distrustful of strangers, and capable of attacking both wolves and bears' (RuHil, 1988).

Further investigations into the differences in behaviour between guarding and herding dogs were

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undertaken by Coppinger and Schneider (1995). They juxtaposed the behaviour of herding dogs, guarding dogs and sledge dogs to hypothesize that it is the timing of events during canine development that intensifies differences in innate motor patterns, and which in turn differentiates learning abilities of breeds. Guarding dogs, as noted above, seem to have been selected to mature at an early ontogenetic stage, before predatory sequences emerge. Otherwise they would not be trustworthy and could not be left alone with the stock. Herding dogs, represented in both studies by Border Collies (see Fig. 14.2), were selected to show the predatory sequences of eye, stalk and chase, but to mature before the dangerous crush–bite–kill patterns of the true predator.

Detailed profiles of both types of dog, based on modern understanding of dog behaviour, appear in Coppinger and Coppinger (1998). In their book *Dogs*, Coppinger and Coppinger (2001) expand the analysis of breed differences, describing the genetic processes that can lead to the development of dogs specialized for herding, droving, guarding, racing and hunting.

Different breeds of herding dogs exhibit varying degrees of predatory behaviour. Gathering dogs such as the Border Collie circle the livestock with less direct contact than heeling dogs. Breeds such as the Queensland Blue Heeler, Kelpie and Huntaway exhibit a greater degree of predatory behaviour, and their natural tendency is to chase and bite livestock instead of circling them. Breeds with grab–bite or kill–bite behaviours can be stressful to livestock and their use should be limited to tasks such as mustering cattle in rough country.

Neurotransmitter differences

These variations in motor patterns appear to be genetically predisposed or inherited within each



Fig. 14.2. Border Collie circling and staring at sheep. The dog is on the edge of the collective flight zone of the sheep (see Chapter 5). Some sheep are facing the dog, but others have started to turn away because the dog is entering their flight zone.

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breed. Willis (1992) reported on the heritability of several traits, briefly mentioning the herding and guarding abilities of sheepdogs (N.B. 'heritability' does not equal 'inherited'; 'heritability' includes genes plus environment as factors affecting variation). He noted three instincts of Border Collies that are heritable: clapping (crouching), staring (at the sheep) and barking (not done when herding but done in other circumstances).

He also noted that studies of the effects of genetics plus environment (heritability) in guarding dogs would help breeders to improve their performance. Possible chemical reasons for these behavioural differences were studied by Arons and Shoemaker (1992). They reported livestock-guarding dogs to be different from both herding dogs and sledge dogs in both the distribution and amount of neurotransmitters in various sections of the brain. The guarding dogs (several breeds) had low levels of dopamine in the basal ganglia, whereas Border Collies and Siberian Huskies had higher quantities of this neural transmitter. Dopamine is related to rates of neural activity.

Herding Dogs

'There are expensively mechanised farms', wrote Longton and Hart (1976), 'where, to move bullocks from one field to another or bring sheep into the yards, involves turning out the entire farm staff. A good sheep dog could do the whole job more easily and economically'. Brown and Brown (1990) explain that the instinct of a gathering and herding dog such as a Border Collie is to circle around the livestock. The dog will instinctively position itself opposite the handler on the other side of the livestock (see Fig. 14.3). If the handler moves to the right the dog will tend to move to the left, and vice versa.

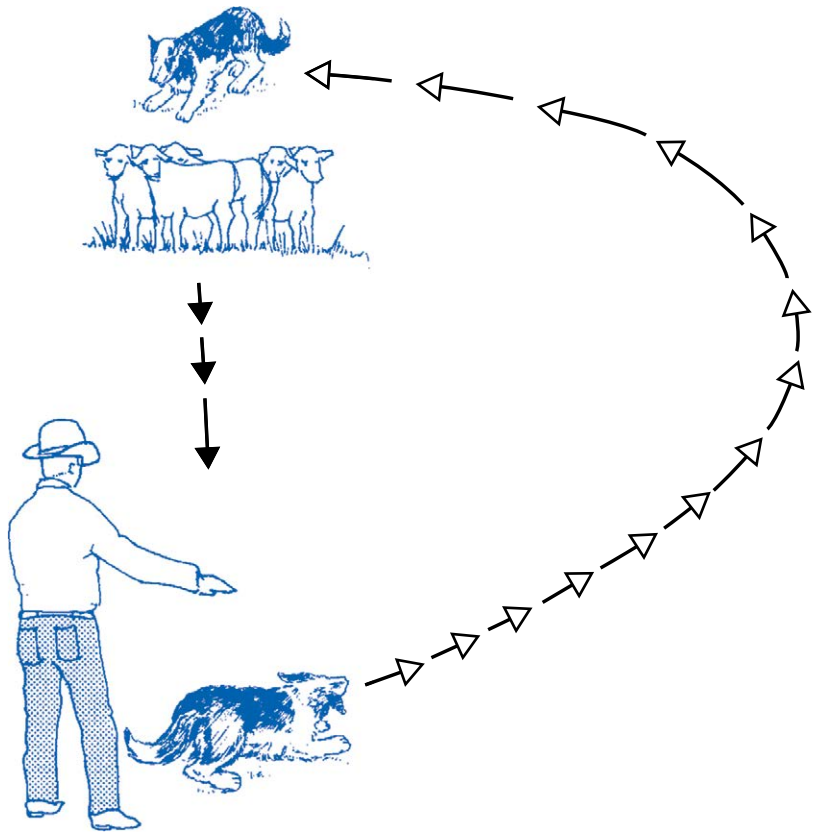


Fig. 14.3. Teaching a young Border Collie to circle around the livestock and bring them to the handler. (From Brown and Brown, 1990)

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A good dog can be ruined if the handler tries to position him/herself on the same side of the livestock as the dog. The gathering instinct is part of canine predatory behaviour. This behaviour can be modified by training to enable the handler to send the dog out and have it bring the livestock to him/herself.

Training information

Modern technology has greatly enriched the methods by which livestock producers can acquire needed information about training stock dogs. The training methods may vary, but details are quickly visible when shown on videotapes or explored on the internet. Several 'standard' books, however, should never be replaced on the shelves of dog trainers. The techniques of Jones and Collins (1987) and Jones (1991) are slightly different from those of Longton and Hart (1976), but the results are similar.

The classic 'old, reliable' book on training a sheepdog is *The Farmer's Dog* by John Holmes (1976). His descriptions of training and using dogs in daily shepherding are based on a broad understanding of dog behaviour, which he applies effectively to explain the process. For example, he describes herding behaviour as inhibited (by the handler, usually) predatory behaviour by the dog.

Iley's (1978) *Sheepdogs at Work* includes chapters on the history of the working dog, the pup and its early training, trials and breeding. A right-to-the-point book is by Means (1970), who trains Border Collies to work with cattle. The text includes basic training and use of a stock dog, and also what can go wrong and how to prevent or cure it, rather than assuming everything goes right the first time.

Other books include *Working Sheepdogs: Management and Training* by John Templeton and Matt Mundell (1992) and *Border Collies: Everything about Purchase, Care, Nutrition, Breeding, Behavior, and Training*, by Michael DeVine and David Wenzel (1997). The former is excellent, and written by two of the best working dog trainers in the UK. The second appeals more to owners of the Border Collie as a pet. *Ranch and Farm Dogs: Herders and Guards*, by Elizabeth Ring (1994), is geared for younger (age 4–8) readers, and provides for youngsters a much-needed connection with these important tools. It has colour photographs of most of the breeds.

The above-mentioned books concentrate on Border Collies, mostly with sheep, whereas Taggart (1991) discusses 21 herding breeds, including the Australian Cattle Dog and others bred to work more with cattle than with sheep. Training methods for all are similar, but Taggart's descriptions allow for the different styles of the different breeds. She, too, discusses common problems and suggests solutions. Diagrams and photographs of the different breeds and of dogs in action help emphasize the finer points.

The training of cattle dogs is also addressed by Little (1975), whose positive view of her job as dog trainer is evident from the title, *Happy Herding Handbook*. Little describes how to train for the various commands, and what to do about problems such as biting, grabbing or harassing stock, not obeying commands, not outrunning well, and so on. Charoy's (1989) descriptions of standard selection and training methods are enhanced by the inclusion of techniques relevant to the daily needs of European shepherds, such as training a dog to conduct sheep along a road with cars or crossroads.

Among the cattle dog books is *The Complete Australian Cattle Dog* (2002) by John Holmes and Mary Holmes, long-term cattle dog trainers. Narelle Robertson's *Australian Cattle Dogs* (1996) is good for novice owners, providing a history of the breed and a discussion of the dogs' behaviour.

For people desiring to learn how to train a dog, step by step, Vergil S. Holland's *Herding Dogs: Progressive Training* (1994) is the most detailed. He writes mostly about dogs working with sheep, but his depiction of problems and solutions, and the way different dogs approach stock, plus the amusing drawings and photographs, broaden the scope of this book to make it useful to trainers of any stock dogs.

The traits that allow herding dogs to be trained so well to their tasks are the essence of an article by Vines (1981). Fiennes and Fiennes (1968) also noted reasons for sheepdogs being so well suited for studies of how dogs process information and what they do with it. For a range of techniques and advice, the internet provides immediate access. Websites run by experts and other practitioners contain articles, breeder lists, membership applications and links to other dedicated sites, as well as to news groups, whose participants discuss issues and give advice at all levels. On the internet, search engines lead to scores of resources. Performing a search for 'stock dog' or 'herding dog' is the best way to start. One main website is http://www.stockdog.com.

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Acoustic signals

One of few scientific studies on herding dogs (McConnell and Baylis, 1985) discusses: (i) locomotion and postural behaviour of Border Collies when working around sheep (visual communication from dog to sheep); and (ii) acoustic signal systems used by shepherds to control their dogs. Analysis of data on 'mature trained and immature untrained Border collies shows that the [stalking] posture [of a hunting mammalian predator] was innate, but was refined by training and experience'. The signals (whistling) that stimulated the dog into activity (e.g. go fetch, go closer to the sheep, go faster) were short, rapidly repeated notes, tending to rise in frequency. Those that inhibited activity (e.g. slow down, stop) were continuous, long and descending.

McConnell (1990) subsequently looked more closely at the acoustic structure and response, and confirmed these observations. A more recent study showed that dogs respond to commands more efficiently when they came from a person instead of from a tape recorder. Dogs are highly responsive to eye and body language cues, which a recording does not provide (Fukuzawa *et al*., 2005).

The original question asked by McConnell and Baylis (1985), 'How do individuals of two different species effectively communicate to manoeuver a third (and usually unwilling) species?', might well be asked also within the interspecific triangle of guarding dog, livestock and predator. McConnell and Baylis mention that shepherds exploit the interactions between predator and prey species (in order to move their stock), and that ethologists can exploit the shepherds' systems by studying the results of the shepherd-generated interspecific behaviour. Researchers into the behaviour of guarding dogs have begun to explore these interactions.

Guarding Dogs

The following quotes illustrate the value of guarding dogs to the stockholder:

> In the two and one half years that we had Ike we didn't have a single incidence of livestock being harmed by dogs or coyotes. Ike literally made it possible for us to continue having sheep and to begin purebred breeding with feelings of security regarding the safety of our animals.
>
> (S. Sorensen, 1990, personal communication)

> Estimates indicate coyotes … kill an average of 1–2.5% of the domestic adult sheep and 4–9% of the lambs in the 17 western states … Livestock producers reduce losses [mortality] by using various livestock management practices, frightening devices, trapping, snaring, calling and shooting, sodium cyanide guns, denning, aerial gunning, and livestock guarding dogs.
>
> (Andelt, 1992)

> Only the dogs stopped coyote predation (O'Gara *et al*., 1983); but they also harassed sheep'.
>
> (Linhart *et al*., 1979)

The ancient Romans, generations of Old World shepherds and a few 19th-century New World ranchers knew how to protect their livestock from predators with guarding dogs. But, in late 20th-century USA, guarding dogs were essentially unknown. In spite of an array of 'sophisticated' poisons and various high-tech devices, sheep and cattle producers were still losing 8–10% of their animals to predators.

In the mid-1970s, a three-month, on-the-road survey of producers in the USA using guarding dogs with sheep and/or goats showed 7 dogs out of the 12 located to be successful (Coppinger and Coppinger, 1978). Yet few producers had even heard about guarding dogs, and many were highly sceptical that a carnivore could protect a prey species from other carnivores. 'Why should I pay for my predators when I can get them for free?', one of them asked.

Research began in 1976 at Hampshire College in Amherst, Massachusetts, and at the Denver Wildlife Research Center (US Fish and Wildlife Service) in Colorado. At the Denver project and its successors at the US Sheep Experiment Station in Idaho, researchers studied dog/coyote interactions under controlled conditions and ran field trials with dogs placed on western ranches.

At Hampshire, biologists and their students focused on the basic, instinctive behaviour that results in good guardians, and hypothesized that guarding dogs achieve protection by being attentive to the livestock and trustworthy with them. Both projects placed dogs on farms and ranches for on-site trials, and almost immediately reports came back of lower predation levels.

By the end of the 1980s, the data looked good: predation on dog-guarded flocks was reduced by 64–100% (Coppinger *et al*., 1988), dogs were an economic asset for 82% of the people surveyed (Green and Woodruff, 1988) and dogs in a Colorado survey saved an average of US$3216 worth of sheep annually per dog (Andelt, 1992). Green *et al*.

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(1984) reported that 37 ranchers spent about nine hours per month feeding and maintaining their adult guardians, corroborated by Andelt's (1992) ten hours. These authors agreed on the costs of a guarding dog: first-year dollar amounts, including purchase, were US$700–900 and subsequent annual costs were US$250–290.

Use of guarding dogs may have died out among Spanish and Anglo-American ranchers in the American South West during the late 19th century, but at least one native American group either learned from the immigrants or reinvented the system. Black (1981) and Black and Green (1985) found Navajos in Arizona using mixed-breed guarding dogs in a practice very like those still seen in Europe and Asia:

> Navajos call their dogs 'sheep dogs' but, unlike sheep dogs used by other ranchers to assist in herding and moving the flocks, Navajo dogs function primarily as guardians of sheep and goats to whom they have developed social bonds. This attraction is a result of raising dogs essentially from birth in visual, olfactory, auditory and tactile association with sheep and goats. A minimum of handling of pups reduced the likelihood that they would bond strongly to humans. Mixed-breed dogs of the Navajo appear to exhibit all behavioural traits believed to be important in protecting flocks from predators, especially coyotes: they are attentive, defensive and trustworthy.
> If ranchers choose to employ dogs, the rather simple Navajo recipe for training may serve them well. Mixed-breed dogs could be quickly deployed in a variety of ranching situations to help reduce predation on livestock.

Training of guarding dogs

From the following recipe, reported in the Black and Green (1985) paper, it is obvious that guarding dogs need a different kind of training from herding dogs:

> Raise or place mixed-breed pups in corrals with sheep, lambs, goats, and kids at 4–5 weeks of age. Feed the pups dog food and table scraps. Provide no particular shelters such as dugouts or doghouses (the pups will sleep among the sheep and will dig their own dirt beds). Minimize handling and petting. Show no overt affection. Return pups that stray to the corral (chase them, scold them, toss objects at them). Allow pups to accompany the herds onto the rangeland as age permits. Punish bad behaviour such as biting or chasing the sheep or goats, and pulling wool by scolding and spanking. Dispose of dogs that persist in chasing, biting, or killing sheep.

Within this straightforward approach is the basis of the attentive, trustworthy and protective behaviour identified as characteristic of a good guarding dog (Coppinger *et al*., 1988). It also contains the wisdom behind the dog's critical socialization periods identified under laboratory conditions by Scott and his colleagues (Scott and Marston, 1950; Scott, 1958). Applying the findings of Scott and other modern ethologists to the training of a livestock guarding dog results in a more formal recipe for what the Navajos (and the ancient Romans) knew all along (see Table 14.2).

Making a case against the importation and use of large, Old World guardians, Black and Green (1985) wrote that the small, mongrel-type dogs used by Navajos were cheaper, easier to get and keep, of lower liability and easier to dispose of if they showed unacceptable behaviour.

Coppinger *et al*. (1985) agreed that mongrels could be an efficient dog for wider use in the USA, and better than most pure, non-guarding breeds. However, they reiterated that dogs selected specifically for the task of stock guarding, and bred true, were likely to be more successful than non-guarding breeds. Green and Woodruff (1990) also found purebreds to be more successful than 'others'.

This is not to imply, however, that the crossbreeding of guarding breeds is not a great idea, for many producers increase their benefits by doing so. It must be remembered that the pure breeds were selected for specific habitats and might have inappropriate conformations in a different habitat. For example, big, powerful, aggressive dogs might be suitable in remote habitats with wolves, bears and mountain lions, while such dogs might be a liability in habitats with hikers, joggers or customers picking up farm products. Small predators can be deterred by a smaller dog than can big predators. Thus, in the long term, producers should develop their own dogs, adapted to their own special needs. This is best accomplished by crossbreeding and experimenting with colour, coat or size.

The success of research in the USA has attracted the attention of wildlife managers and sheep producers in many areas of the world. A comprehensive summary of these efforts was published by Rigg (2001). In those European countries where guarding dogs were rarely, if ever, used, recent population recoveries of wolves, bears or cats have caused wildlife and agriculture agents to look at the potential for these dogs as stock protectors in their regions. A series of reports in the journal *Carnivore*

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Table 14.2. First stages of development of livestock-guarding dogs.

Stage 1 Attentive behaviour	Stage 2 Attentive behaviour	Stage 3 Attentive behaviour	Stage 4 Trustworthy behaviour	Stage 5 Protective behaviour
Puppy, 0–8 weeks; consists of 3 phases	Early juvenile, 8–16 weeks	Late juvenile, 4–6+ months (ends at puberty)	Sub-adult, 6+–12+ months	Adult, over 12 months
Neonatal, 0–2 weeks Pup is insulated from the environment outside the litter. Reflex care-soliciting behaviour: cries, sucks, roots towards warmth, crawls *Transitional, 2–3 weeks* Eyes open, teeth appear, walks; non-reflexive learning behaviours appear; mother stops responding to pups' cries *Primary socialization, 3–8 weeks* Ears and eyes begin to function; notices other animals at a distance; begins to form primary social relationships that determine later attachments; can eat solid food; food dish dominance begins and wrestling with littermates	Secondary socialization begins; attachments made to other animals and even species. Non-reflexive care-soliciting behaviour, such as dominance–submission and food begging, appear. These become the basis for the complex social behaviours of the adult. The target of these behaviours is determined to some degree by primary socialization. However, in guarding dogs, this is the period for bonding pups with livestock. By 16 weeks the 'critical period' – or window during which social attachments are made – is closed	Emerging social behaviours of Stage 2 must be reinforced. Pup must be kept with livestock all the time and not be allowed to play or interact extensively with other dogs or people. Exception would be if the pup is put in a pasture with another guardian dog, presumably older, which is acting as a 'teacher' dog. Any wandering or other inattentive behaviour should be stopped immediately	Onset of predatory behaviour patterns and of 'play', which includes the predatory movements of chase, grab–bite, wool pull, ear chew. If this behaviour is allowed to be expressed, which to the pup is a reinforcement of the behaviour, it will become common and be almost impossible to correct. If the behaviours are not reinforced, they will disappear from the pups' repertoire of behaviours. Heat cycles begin in females, sometimes resulting in unexpected behaviour such as wandering or gnawing on sheep. Males may stray if attracted by a female in heat	Caregiving and mature sexual behaviours emerge. A dog that has been properly bonded with livestock and not allowed to disrupt them should be an effective guardian at this point. First experience with serious predators must not be overwhelming; dog needs to gain confidence in its ability as it matures

Damage Prevention News has highlighted field research in Switzerland and Germany (Klaffke, 1999; Landry *et al*., 2005; Lüthi and Mettler, 2005; Mettler, 2005), and in Norway and Sweden (Hansen and Bakken, 1999; Smith *et al*., 2000; Hansen, 2005; Levin, 2005).

Other areas in Europe have traditionally used guarding dogs and have developed their own breeds. Shepherds in many of these countries had stopped using dogs when wolf or bear populations had been eradicated. The indigenous breeds existed mainly with breeders. But with depredatory carnivore populations recovering under protection of the law, there is renewed interest in restoring the guarding breeds to help protect the livestock. Shepherds are being urged to acquire dogs and relearn techniques their great-grandfathers knew.

Other studies in Europe of interest to producers in the USA are those of Rigg (2005) in Slovakia, and Ribeiro and Petrucci-Fonseca (2005) in Portugal. In addition to these studies, *Carnivore Damage Prevention News*, in 2005 (issues 8 and 9), included observations in Bulgaria, Poland, Romania and Spain (now *KORA News* and available by e-mail from: http://www.kora.ch).

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Further south, across the equator, in the south-western African country of Namibia, guarding dogs were imported from the USA in 1994 to help protect sheep, goats and cattle from cheetah predation. These cats have been an easy target for ranchers, who have reduced the populations of cheetahs to the point where conservation experts are worried about their survival as a species (Marker *et al*., 2005). Interestingly enough, subsequent reports noted that the dogs were effective in deterring several other predators, such as leopards and baboons. Our own interviews with the Herrero people in Namibia and Masai in Kenya, who regularly use guarding dogs, suggest that dogs are aids against all predators including lions – at least in their ability to sound an alarm (Coppinger and Coppinger, 2001).

Are guarding dogs 100% successful at protecting livestock? Of course not, but they would not have survived as flock guardians had they not been cost-effective. Old World herders are well aware that a dog can be vulnerable to a wolf attack, and manage the dogs to minimize overt conflict. A report by Bangs *et al*. (2005) documents fatal attacks by wolves (usually a pack) on guardian dogs. Eighteen dogs were killed over a span of ten years in three western states. No data are given on how many dogs were working during the same period. The report also makes recommendations for increasing the effectiveness of dogs to protect against wolves.

As with herding dogs, guarding dogs are well served by the internet. One main web page is at: http://www.lgd.org. One of its links is to the livestock-guarding dog newsgroup (LGD-L), an active, highly informative source of advice – some of which is conflicting, but all of which is of great interest to owners of livestock-guarding dogs.

Guarding dog behaviour

To try to understand the underlying behaviours that characterize the guarding breeds, Coppinger and his colleagues at Hampshire College studied three basic guardian behavioural traits: attentive, trustworthy and protective. The attentiveness to sheep of dogs that had been used in the USA for several years was found to be similar to that of their parent and grandparent generations still working in Italy (Coppinger *et al*., 1983a).

Looking at trustworthy and untrustworthy dogs, Coppinger *et al*. (1987a) quantified differences in motor patterns and found that untrustworthy guarding dogs shared some behaviours with herding dogs. Their protective abilities were severely tested in wild, forested wolf territory in northern Minnesota, where several guardians showed that dogs, if managed correctly, could protect stock against North American wolves (Coppinger and Coppingerer, 1995).

McGrew and Blakesley (1982) found that interspecific adjustments to the dog were made by both sheep and coyotes: 'The sheep learned to run to or to stand with the dogs when attacked, and usually bedded with the dog. The coyotes learned to attack the flock when the dog was not present'. Anderson *et al*. (1988) used a trained Border Collie as a mock predator in an experiment to discover the advantage of interspecific behaviour in providing protection from predators. The collie's 'aggressive, threatening' approach did result in a closer association between sheep and cows that had been bonded with each other, but non-bonded animals moved in distinctly intraspecific groups when threatened. McGrew and Blakesley (1982) reported that early exposure of pups to sheep (i.e. bonding) was important, and that a dog's value was determined by what breed it was and by its own personality.

Guard dogs on the open range

Early doubts that dogs could protect sheep on the huge, unfenced ranges of western USA were diminished by reports by Coppinger *et al*. (1983b) and Green and Woodruff (1983). Methods of increasing the dogs' effectiveness were studied by looking at causes of presenescent mortality (Lorenz *et al*., 1986) and by transferring inattentive or untrustworthy dogs to new ranches (Coppinger *et al*., 1987b). That guarding dogs are a positive presence in managing livestock is evident in reports from other researchers. Pfeifer and Goos (1982) found them to be effective in North Dakota, and Hagstad *et al*. (1987) noted that the presence of a dog with dairy goats reduced predation in Louisiana.

Conclusions

Sheepdogs – both herding and guarding types – are highly efficient for moving or protecting livestock. Within the herding types, different breeds tend to specialize in moving different stock, although most breeds are versatile and adaptable to sheep, cattle, llamas – whatever needs moving. Livestock are safer when moved by herding dogs than by people, for dogs are fast at heading off a stampede and deft

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at aiming reluctant beasts into the pen or changing a maverick's mind.

Sheep are safer, too, when protected by guarding dogs, whose senses match those of most predators and which live with the stock day and night. Sheepdogs extend a herder's control over the stock, saving time, energy and animals. Many livestock growers who use dogs – both herding and guarding dogs – confirm, in chorus, 'Without our dogs, we would be out of business'.

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Useful websites

Bud Williams Stockmanship: http://www.stockmanship.com
Stock Dog Server (information on stock dogs and herding): http://www.stockdog.com
Stockdog Journal is now on the Bvd Williams site. It can be accessed by typing stockdog journal into a search engine. workingdogweb.com

Videos

Conservation Media (2013) *Livestock Guardian Dogs: Working on Common Ground*. Discusses the use of different breeds of guard dogs on the same ranch. https://www.youtube.com/watch?v=obmBXCzTp2Q
Dogumentary TV (2017) *Livestock Guardian Dogs: The Way of the Pack*. Brenda Negri – a rancher with sheep that lives in close proximity to her home discusses that guard dogs of different breeds can have bonds with both sheep and people. https://www.youtube.com/watch?v=Tgph9fMlcXQ

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15 Goat Handling and Transport

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Summary

Goat production is linked to our social, cultural, economic and ecological heritage. Although mainly oriented towards agri-food production, goats are also farmed for textile fibre production, and play an important role in the preservation of rural livelihoods, land fertilization and grazing as a means of wildfire prevention. However, all of the current goat production systems expose the animals to various stress thresholds that can reduce their ability to adapt to the production environment, affecting their health and compromising their welfare. This chapter examines aspects that can affect goat welfare in farm handling and husbandry practices and transportation, paying special attention to factors that can be directly influenced to improve goat welfare. In addition, it presents scientific and technical elements to taken into account in decision-making with the aim of preventing, mitigating or controlling risk factors that cause suffering to goats during handling and transportation, and can affect the well-being of people involved in the activity.

Keywords: goats, behaviour, husbandry, handling, transport

Introduction

Goats are probably one of the domestic species best adapted to a wide variety of geographical and environmental conditions, particularly to arid and difficult agricultural regions characterized by poor climatic and soil conditions, scarcity of food and water, extreme temperatures and complex orography (Carolino *et al*., 2017). These biological abilities make goats highly adaptable to diverse production conditions that include feral, transhumant, extensive, intensive and total confinement systems. It is thought that goats might have been domesticated from two wild Capris species (*Capra aegagrus* and *Capra falconeri*) in a process that started at least 10,000 years ago during the Neolithic period in the Fertile Crescent of south-west Asia, beginning with the selective harvesting of subadult males and the transition from hunting to herding, and then spreading rapidly following human migration and their trade patterns (Daly *et al*., 2018). Traits selected during domestication include tameness, dairy, meat, skins, pelage colour, mohair, cashmere, horns, pathogen resistance and the ability to survive better in hot and arid environments (Hess *et al*., 2018). In this context, goats were a reliable source of a high protein food (milk and meat), clothing, blankets and shelter (skins and mohair), fuel and fertilizers (manure), and have also fulfilled social, economic, cultural and even religious functions (Dong *et al*., 2013).

Today, there are more than 1000 breeds of goats and a total population of one billion, distributed worldwide in the following percentages: 58.5% in Asia, 34.5% in Africa, 4.3% in the Americas, 2.2% in Europe and 0.4% in Oceania (FAOSTAT, 2018). Goats play a vital role in the livelihood of small-scale farms in developing countries (Polycarp *et al*., 2016), contributing to food security by alleviating seasonal food variability and availability, either directly through milk and meat production, or indirectly through cash earned from selling their products (Homann *et al*. 2007). Farmers tend to mix sheep and goats as a strategy to maximize the use of pastoral resources (Fig. 15.1). Many emerging and developing countries have developed a highly

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Fig. 15.1. The mixed flock of sheep and goats is very frequent around the world (i.e. French-Spanish Pyrenees).

specialized value chain focused especially on dairy production (Dubeuf *et al*., 2004). In these countries, a wealthy dairy goat industry has been developed, not only with the support of big dairy companies but also feedstuffs distributors, drug labs, equipment and facilities companies or private research into nutrition, reproduction and genetics (Dubeuf *et al*., 2018). However, migration, growing incomes, urbanization and globalization are leading factors in the changing behaviour of consumers towards meat and dairy goat products in many developed and developing countries. Thus the world's goat production has shown remarkable growth and specialization over the last 30 years. This is due largely to the good reputation of milk as a healthy food and the growing consumer demand for goat meat in countries with an increase in ethnic diversity among its consumers. Regardless of whether goats are produced in modern production systems or self-subsistence systems, it is clear that they are exposed to a series of handling and transportation practices that may represent a risk to their welfare. The objective of this chapter is to review current knowledge of goat behaviour and look at husbandry practices that may compromise animal welfare during handling and transportation operations.

Principles of Goat Behaviour

To assist predator avoidance, goats have prominent eyes, wide-angle (320–340°), monocular and binocular vision of 20–60°, and vision has dominance over hearing (Blackshaw *et al*., 2003). Goats are dichromats, having two types of cones, sensitive to short wavelengths, which enable them to see bright purple, or long wavelengths, which enables them to see yellow-green colours. However, the goat's brain is able to combine the signals from the eye, thereby enabling it to distinguish between orange, yellow, green, blue and violet (Adamczyk *et al*., 2015). Goats usually avoid crossing shadows and changes in textures or colours on the ground, probably due to their lack of in-depth vision (Grandin, 1980). Goats have hearing ranges of 78–37 kHz with a well-defined point of best sensitivity at 2 kHz (Van der Staay *et al*., 2011). However, sound localization acuity in goats is relatively poor, and therefore they tend to have their most acute vision concentrated in a broad horizontal streak so that their best vision encompasses a wide angle, sometimes including nearly the entire horizon (Heffner and Heffner, 1992). Olfaction is less important to goats in handling situations, although they have a strong olfactory apparatus (main olfactory epithelium and the vomeronasal organ) and are able to make keen olfactory discriminations (i.e. mother–young bonds). The vomeronasal organ plays an essential role in mediating responses to many social and sexual pheromone sensations and to determining the flavour of food in the mouth (Moawad *et al*., 2017).

Feeding behaviour

Goats can distinguish bitter, acid, sour, sweet and salty flavours, although they have a better perception of sweet and bitter flavours. However, goat responses to salt (sodium chloride), sour (acetic acid) and bitter flavours changed very rapidly with

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changes in concentration. Goats are less affected by the flavour of food than sheep are, and this facilitates their more diverse dietary response (Robertson *et al*., 2006). Goats differ in their grazing behaviour from sheep as they are not typical grazers; rather, they are considered selective browsers/grazers with flexible, broad-scale and opportunistic feeding behaviour, although some grazing patterns may be altered by the prior experiences of individual animals (Mellado, 2016a). Small body dimensions and mobile upper lip and tongue are some of the anatomical characteristics that enable them to be highly selective (Decandia *et al*., 2008). It has also been reported that goats are able to adopt a bipedal stance and consume leaves from the upper vegetation layer, and sometimes they even climb trees if the branch structure so permits (Manousidis *et al*., 2016). Nowadays, goats are even used frequently to actively modify vegetation cover by clearing thick areas of bushes, shrubs and thorny vegetation to reduce or avoid the risk of forest fires (Boyazoglu *et al*., 2005). Compared to sheep, goats have a greater preference for/tolerance of tannins (Min and Solaiman, 2018). Amit *et al*. (2013) found that the periodic and selective consumption of plants rich in tannins corresponds to self-medication behaviour. It is likely that this knowledge is transmitted from mothers to their offspring.

Maternal behaviour

One of the main behavioural differences between sheep and goats is their anti-predator strategy. While lambs follow their mother within hours of birth, and therefore are classified as 'followers', goat kids remain temporarily hidden from their mother while she forages (Gonzalez-Mariscal *et al*., 2017). Goats give birth to well-developed offspring, which stand and walk as early as 30 minutes after birth and start to suckle within one hour (Hernandez *et al*., 2002). Goats' recognition of their own offspring depends on the perception of the olfactory signature of the newborn at parturition and its consolidation as an olfactory memory (Lévy *et al*., 2004). At greater distances, this recognition may depend on visual and acoustic cues (Terrazas *et al*., 2009). The mother leaves her kid for periods of up to 8 hours before returning to the precise location where the kid is lying. During this stage, mother–young separation does not trigger any distress response (Gonzalez-Mariscal *et al*., 2017). Gradually, kids tend to associate and form bonds with other kids of the same age rather than with their mothers. Under natural conditions, the weaning process in kids normally occurs between four and six months and involves a gradual reduction in milk intake accompanied by increasing social independence from the dam and an increasing intake of solid food. Weaned kids tend to form groups with kids of different ages, of both sexes and, eventually, old goats or grandmothers. These groups, called crèches, are the first sign of a weakening in the mother–young bond (Miranda-de la Lama and Mattiello, 2010).

Repeated stress during pregnancy can have consequences for the ability of goats to adapt to husbandry practices. In this sense, Baxter *et al*. (2016) found that handling pregnant dairy goats in an unpredictable and aggressive manner for only 20 minutes per day, over a five-week period in mid-gestation, significantly affects placental development, foetal loss and aspects of maternal care. These authors also demonstrated that prenatal handling stress can delay the expression of play behaviour in kids, which may reflect a cognitive deficit that could impact upon neonatal survival. Another example of the stress effect was demonstrated by Roussel *et al*. (2005). These authors found that repeated transportation associated with isolation stress during the last third of pregnancy affects the sympatho-adrenomedullary system and the emotional reactivity of offspring in a gender-specific manner. In the presence of novelty, prenatally stressed female kids were more active than control females. They also showed more signs of arousal and tended to explore more of their environment in reaction to a startling stimulus. On the contrary, prenatally stressed male kids tended to be less active than control male kids but showed more signs of distress in the presence of novelty. Thus, in the context of animal welfare, precautions should be taken to avoid stress in pregnant goats.

Social behaviour

In the wild, goats live in gender-segregated flocks, except in geographical areas where breeding occurs year-round. The females typically live in small, stable groups and the males in satellite groups; however, during the breeding season, males join the female groups and compete for access to the females. A largely stable relationship of dominance exists between group members, maintained through affiliative and aggressive interactions (Miranda-de

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la Lama and Mattiello, 2010). Furthermore, goat physiology may be affected by social cognitive challenges, social proximity while feeding, dominance, confrontation with unfamiliar individuals, introduction to new social groups, and emotions (Briefer *et al*., 2015a). Goats also express consistent individual differences in terms of social personality (aggressive, affiliative, passive and avoiders), which are associated with physiological differences (cortisol, glucose and non-esterified fatty acid (NEFA) (Pascual-Alonso *et al*., 2013), thorax circumference and length of beards (Miranda-de la Lama *et al*., 2011). Social competition between animals is often thought to be regulated primarily through dominance relationships. In this context, social dominance can be defined as 'a priority of access to an approach situation or to leaving an avoidance situation that one animal has over another'. In goats it is clearly established and quite stable, and there is a nearly linear hierarchical order in a herd (Miranda-de la Lama *et al*., 2011). Thus, social stability is conditioned by the size of the herd and the cognitive ability of the goats to recognize all of the members of the group.

Order of dominance is influenced by the presence of horns, horn length, aggressiveness, age, size and bodyweight, sex, parentage, experience and individual differences. Nevertheless, under intensive dairy or meat production systems the social behaviour of goats differs substantially from that displayed in their natural habitat with respect to gender segregation, taking into account the limitation of natural substrate, space and resources, such as resting or feeding places, as well as the composition and size of the group. These conditions can exacerbate social relationships and increase the aggressiveness of a group and even affect human–animal relationships. For example, Miranda-de la Lama *et al*. (2013) observed that high-dominance goats are usually more reactive to handling and physical restraint compared to low-dominance goats. Another example of the influence of dominance is the reluctance of high-dominance animals to enter the first positions for milking. It is probable that dominant goats may be fearful of the milking parlour because of the risk of injury during access to the parlour or during the milking process itself (Polikarpus *et al*., 2015). Another management practice that affects the usual social dominance in these systems is the mixing of unfamiliar animals, which may disturb the social structure of the group and increase agonistic interactions in establishing a dominance order.

At a social level, contact vocalizations (closed-mouth or open-mouth) are used to maintain contact at relatively close distances. Contact calls contain information about individuality, age, sex and body size, kinship and even group membership (Briefer *et al*., 2015a). However, there is evidence that goats have other sophisticated social skills, including a great capacity to recognize conspecifics, through olfactive cues and facial traits (Keil *et al*., 2012). They can also recognize positive and negative emotional states in other goats (Bellegarde *et al*., 2017) and even humans (Nawroth *et al*., 2018). An interesting aspect is that the position of the ears is a form of visual communication between goats. Bellegarde *et al*. (2017) found that goats displayed more ears forward when the image of a negative face was shown compared to a positive one. These cognitive abilities are part of behavioural strategies giving the herd social cohesion. The ability to recognize emotional states in other goats allows goats to establish alliances to access valuable resources (i.e. shade, feed and partners), mediate in conflicts and even induce post-conflict reconciliation (Miranda-de la Lama *et al*., 2011). There are other group strategies that help reduce the rate of predation of the herd. An example of this is social-surveillance strategies during grazing, which consist of alternating surveillance among the individuals in a herd. While most of the goats in the herd are grazing, a few are watching. The alert position of a goat is to raise its head in the direction of the source of the new stimulus, while moving its ears and lifting the tail. If the stimulus is a real threat to the herd, the sentinel goats emit an alarm vocalization that consists of high-pitched sneezes. If a sentinel animal flees, the flock flees too. In large herds, it is possible that more than one goat assumes the leadership and vigilance in turn. According Escós *et al*. (1993), leadership is strongly influenced by experience, and not necessarily by dominance rank.

On-farm Handling and Husbandry Practices

Keeping goats inevitably involves periodical husbandry practices and routine handling (Kruger *et al*., 2016). Husbandry practices that damage tissues, also causing pain, are often conducted within a few hours or days of birth, and include ear tagging, castration, disbudding and hoof trimming. Other practices induce anxiety and frustration leading to negative human–goat relationships, artificial

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weaning and social isolation. Routine handling includes moving the herd between pastures, yards, races and sheds, and, in the case of dairy goats, milking. There is a lack of formal studies on goat handling practices. Books and extension bulletins on goats outline some of the differences between goats and other livestock such as sheep or cattle (Dalton, n.d; Sayer, 2010; Belanger and Bredesen, 2018). Goats flow less easily through a handling system and they are more likely to sulk and lie down when scared. If packed too tightly in a pen, they may become aggressive towards each other. To prevent injuries due to horns becoming caught, it is recommended to have high, smooth, solid walls on handling races. Exercise during herd movement increases cortisol concentration in goats without modifying the levels of the other stress indicators (Zimerman *et al*., 2011). Woolsoncroft *et al*. (2018) suggest that moderate routine exercise conducted in a calm manner could improve feed-conversion efficiency in ruminants. Furthermore, routine handling is usually less stressful than sporadic handling, although abrupt changes in routine or handlers can also cause marked stress in animals and increase costs in terms of reduced productivity, health, welfare, and handler safety. In this respect, goats become familiar with handling routines and can be trained for certain manipulations such as shearing, milking and trimming of hooves. Although they are usually very reactive to physical restriction, and especially to the taking of blood samples, a calm, trained handler can reduce the goat's levels of reactivity (escape, hide and defence behaviours). Environmental enrichment has also proven to be a useful tool to reduce fear and stress responses to routine handling in dairy goats (Miranda-de la Lama *et al*., 2013).

Human–goat bonds

Human–animal relationships seem to be better on small farms due to there being more frequent contacts between goats and farmers (Mattiello *et al*., 2010). Regular, calm handling of animals during daily activities seems to decrease the animals' fear responses towards humans (Can *et al*., 2016). Jackson and Hackett (2007) and Nawroth (2017) demonstrated that goats approached people more quickly if they had already experienced positive contact with humans. Some empirical evidence indicates that goats are very receptive to herding and guiding at pen level by children. The most important indicators to assess a goat's habituation to humans are flight or approach speed, and distance to handler. The quality of human–animal relationships is a key element in reducing the fear of people in weaned kids. In this sense, the clear, durable signs of appeasement shown by kids in the presence of their caregiver suggests that humans can be perceived as an affective substitute in artificially reared animals. In contrast, kids raised by their mothers are more reluctant to establish relationships with humans, in particular displaying less motivation to interact with handlers (Boivin and Braastad, 1996). Recently, Nawroth *et al*. (2018) reported that goats can discriminate human facial expressions and prefer happy faces, regardless of the human gender. This finding indicates that goats could possibly predict certain aversive handling events depending on the facial expressions of their handlers.

According to Muri *et al*. (2012), training handlers for the purpose of improving goat welfare during handling involves more than just conveying knowledge and skills, as one also needs to alter existing habits as well as deep-rooted attitudes and beliefs. The degree of empathy towards animal welfare is a key element in developing intervention strategies for the prevention of risks for animal welfare and the occupational well-being of livestock hauliers (Pulido *et al*., 2018). Interventions should also include multiple components that target several risk factors (not just one factor) to better understand which risk factors should be modified to obtain a better welfare outcome and also cost savings. For example, a change in behaviour with regard to one risk factor can improve the outcome of another. Training in animal welfare and ethological handling, for instance, can lead to greater empathy towards animals and better handling practices, thus reducing the risk of accidents (Valadez-Noriega *et al*., 2018).

Ear tagging

There is a hierarchy of pain associated with periodical management methods, rubber-ring castration being the most painful and ear tagging the least painful intervention (Windsor *et al*., 2016). Ear tagging, a husbandry procedure performed on kids for identification and management purposes, involves piercing the ear to allow the attachment of an identification tag and, in some cases, to comply with regulatory requirements (Lomax *et al*., 2017). This procedure is typically performed without the

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use of local anaesthetic or analgesia and there is little information on its effect on welfare and health in small ruminants. Some evidence is available from the study in lambs carried out by Karakuş and Karakuş (2017), who used infrared thermography to assess the effects of three ear-tag types (metal-tipped, plastic-tipped and electronic) on inflammatory response on day 1, 4, 10 and 30 after ear tag application. They found that plastic-tipped ear tags caused fewer problems and are preferred to traditional ear tags with metal tips, and that electronic ear tags caused more inflammatory reactions compared to metal- or plastic-tipped ear tags. A possible alternative, to reduce pain during ear tagging, is cryo-anaesthesia using vapocoolant sprays. These sprays induced local anaesthesia and significantly reduced the pain response to ear tagging and ear notching in livestock neonates (Lomax *et al*., 2018).

Castration

Castration is usually performed to avoid undesirable odours associated with male goats, to reduce aggressive behaviour, to prevent accidental breeding by a buck of inferior quality, and to reduce undesirable flavours of meat (Dawson, 2010). Castration of male goats or kids is usually done during the first 7–14 days of their life. Castration has been shown to elicit inflammatory reactions, physiological stress, suppression of immune function, pain-associated behaviour, and a reduction in performance (Karademir *et al*., 2016). The main techniques used to castrate goats include surgical or non-surgical/ischaemic (rubber ring, burdizzo or emasculatome) methods. Castration in lambs has been extensively studied, in the case of kids the information is limited. It seems that the results of lambs are not directly comparable with the kids. For example, Mellor *et al*. (1991) found that, according to the stress response (cortisol and behaviour), it can be concluded that castration with rubber rings is less painful and stressful for kids compared to lambs. Restlessness, lateral recumbency and recumbent immobility are considered to be useful indices of pain and stress for castration with rubber rings in kids. Ahmed and Ahmed (2011) studied the effects of castration by burdizzo and rubber ring methods in kids of 7, 21 and 42 days of age. They found that the rubber ring method causes more pain and reduces the lactation times of the kids. The authors concluded that castration with the burdizzo produces less pain at any age. In the case of surgical castration in unweaned kids, mothers tend to reject them after the procedure. This may be due to the smell of the fresh wound and the antiseptic solution. In these cases, the mother interrupts lactation and other maternal care that causes stress and immunosuppression in the kid.

Disbudding

Dehorned goats are considered to be safer to handle, require less feeding and trough space, cause less damage to other animals and have less negative impact on their housing environment (Alvarez *et al*., 2015). Disbudding of goat kids is a widespread management practice on most dairy farms (Fig. 15.2). Nevertheless, it is a practice that causes pain, discomfort and distress, and occasionally compromises the health of the kids (i.e. tetanus, meningoencephalitis and brain abscesses). Disbudding is recommended before two months of age, although it is better to perform it during the first three weeks of the kid's life (Smith and Sherman, 2009). The most common method is heat cautery, although there are other alternatives such as caustic paste, cryosurgery and clove oil injection. The behavioural indicators of pain during cautery disbudding are leg-shaking and intense sharp vocalizations (Alvarez and Gutierrez, 2010). After the procedure, the animals perform head and body shakes and head-scratching episodes. At a physiological level there is an increase in plasma β-endorphin and cortisol concentrations (Hempstead *et al*., 2017). Although the use of local anaesthetics such as lidocaine (with or without cornual nerve block) is recommended for disbudding, several studies show that it does not prevent the increase in cortisol secretion or the behavioural effects that indicate stress (Alvarez *et al*., 2015). Only sedation (with or without local anaesthesia) has shown to be effective (Nfor *et al*., 2016). Also, general anaesthesia with gases such as isoflurane (with or without meloxicam) is effective (Hempstead *et al*., 2018a). A study by Hempstead *et al*. (2018b) indicated that caustic paste and cryosurgical disbudding appeared to cause more pain compared to cautery disbudding; thus, these methods may not provide good alternatives to cautery disbudding. Clove oil appeared to cause a similar pain response as that of cautery disbudding and smaller wounds with earlier tissue repair; this method could be considered a good alternative to cautery disbudding.

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Fig. 15.2. It is advisable to disbud all the animals of the herd, to avoid having animals with and without horns together. Poorly performed dehorning can cause the asymmetric growth of one or both horns.

Artificial weaning

Commercially reared animals are generally separated from their mother before the age at which they would naturally be weaned in free-living conditions (Veissier *et al*., 2013). This is mainly due to the fact that milk-feeding kids are very expensive for farmers and it is more cost-effective to wean kids as early as possible (Panzuti *et al*., 2018). Farmers wean animals and form artificial groups according to age, sex or weight. When kids are classified, they often have to cope with the stress of weaning, a novel environment, mixing with unfamiliar animals, different feeding regimes and increased susceptibility to multi-factorial diseases, all of which affect their behaviour and physiology (Miranda-de la Lama *et al*., 2012). In terms of behaviour, weaning can cause changes in feeding patterns, increasing aggressiveness between kids and oral stereotypies. Weaning can be carried out gradually although it would appear to be much more stressful for kids and can affect adaptation to fattening. In contrast, abrupt separation is much more stressful for mothers than for kids (Iyasere *et al*., 2018). Abrupt weaning is therefore the most common and recommended method, taking place in dairy kids between 50 and 60 days of age and early weaning between 30 and 40 days of age.

Early weaning in kids should be no sooner than 30 days of age, as before this age it is highly related to weight loss, diarrhoea and a marked mortality (Memisi *et al*., 2009). In a study comparing weaning and early weaning in dairy kids, Ugur *et al*. (2004) found that the average daily live weight gains of the kids in both of the treatment groups were similar between weaning and four months of age, however oral stereotypies and aggression levels were higher in the animals in the 60-day group than in the 45-day group. These results suggest problems related to weaning occur more often when the bodyweight of kids is lower, the milk replacer level is higher, non-liquid feed is not used, and when they have been affected by diseases (Malher and Noordhuizen, 2008). Artificial rearing of kids implies that the handler knows that all the animals have taken colostrum and that they know how to suck from the rubber bottles; and, if necessary, they need to be able to train them how to use automatic feeding equipment. Kids are susceptible to hypothermia, which can be solved with a good bed of straw and the use of heating lamps (Gonzalez-Mariscal *et al*., 2017). Environmental enrichment can be an alternative to reduce the effect of post-weaning stress on kids, as demonstrated by Rosas-Trigueros *et al*. (2017).

Social isolation

Goats are characterized by their highly gregarious behaviour; they react very strongly to social isolation with high-pitched vocalizations and increased locomotion (Price and Thos, 1980). According Siebert *et al*. (2011), social isolation of different degrees induces differential behavioural and vocalization responses in goats. In partially isolated goats, permanent sensory feedback from their adjacent pen mates (acoustic and olfactory contact) facilitates an active response pattern, increases behavioural arousal and supports socially motivated efforts to restore social contact. In contrast, complete isolation appears to lead to a loss of control, probably due to a higher level of emotional distress, fear and frustration. Given that social isolation clearly affects animal welfare, this treatment should be avoided or only applied in exceptional cases (i.e. clinical treatments), and conspecifics should be allowed to provide some social support (Siebert *et al*., 2011). Patt *et al*. (2013) showed that the separation of goats from a group and their reintroduction into the group, and the introduction of goats into established groups, is stressful. Consequently,

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if an individual goat has to be separated from its group, it would seem that allowing visual, acoustic and tactile contact with members of the group mitigates the adverse effects of separation on the goat's welfare.

Hoof trimming

Lameness, a painful condition that impedes a normal walking gait, is one of the most serious welfare issues faced by dairy goats (Deeming *et al*., 2018). Common causes of lameness include overgrown hooves, foot rot, arthritis, incorrect hoof trimming, injury, or caprine arthritis encephalitis (Mellado, 2016b). There are few published studies of dairy goat lameness, for example Anzuino *et al*. (2010) report a prevalence of severe lameness of 3.2% at 24 dairy farms in the UK; Battini *et al*. (2016) found a prevalence of 3% at 30 intensive farms in Italy, and Can *et al*. (2016) reported a prevalence of 2.1% at 30 Portuguese farms. Evaluation of lameness should be done during milking or when the animals walk on cement floors, as it is easier to detect lameness in these situations rather than in pens with earthen floors and/or straw (Anzuino *et al*., 2010). Overgrown hooves often trap particles of sand, twigs, manure and other detritus and this can lead to lameness (Vincent, 2018). This welfare problem is particularly a problem in intensively managed goats, where normal wearing of the hoof associated with exercise is limited (Smith and Sherman, 2009). Claw trimming is useful for reducing maximum pressure, enlarging the floor contact area of the claw, improving balance between the medial and lateral claws, and preventing the development of claw, joint and tendon disorders, facilitating access to food and enhancing the ability to exercise (Ibrahim *et al*., 2018). The basic steps of foot trimming include removal of hoof wall that has overgrown the sole, shortening of the toe, and levelling of the sole and heel (Smith and Sherman, 2009). Good restraint of the goat is necessary for proper trimming. A milk stand, a small ruminant restraint chute, a person holding the goat, tying the goat to a fence, are all ways of restraining a goat to do an effective job of trimming the feet (Dawson, 2010). This procedure should be carried out at least twice a year due to the fact that on intensive farms, the limited movement of goats may alter the normal growth of the hoof, leading to claw overgrowth (Battini *et al*., 2014).

Transport and Logistics

During transport, even in favourable conditions, goats are exposed to a range of potential stressors, which may compromise their welfare, health and performance, including increased handling and human contact, loading and lairage, different or unfamiliar environments, food and water deprivation, alterations in weather conditions and also changes in social structure through separation, mixing and crowding, vibration, noise and environmental pollutants (Miranda-de la Lama *et al*., 2014). Consequently, animal welfare during transport depends greatly on the attitudes and training of hauliers and on appropriate goat facilities (Pulido *et al*., 2018). Incorrect handling and transportation are also responsible for stress-induced meat quality problems, such as shrinkage of the carcass, higher pH, dark meat and damage to the carcass through bruising (Romero *et al*., 2013). However, according to Maria (2008), stress during transport would have to be quite considerable to have a visible effect on meat quality (Table 15.1). When there are even small effects on the meat, it is clear that the animals have suffered, and other welfare criteria such as behavioural changes, physiological constants or plasmatic indicators are normally greatly affected. However, an absence of an effect on meat quality is not a clear sign of absence of suffering due to poor welfare (Maria, 2008).

Compared to other ruminants, the points of origin in goat transportation are much more diverse: journeys between farms, from farm to market, feedlot, slaughterhouse or even for export, and according to Alarcon *et al*. (2017), in some developing countries goats are driven in herds over several days to reach local markets, slaughterhouses or for export. There is also a varied range of vehicles used to transport goats, from ordinary cars or pick-ups (Qekwana *et al*., 2017), small trailers to specialized three-tier trailers (Fig. 15.3). Frequently, goats are transported in the same truck with other species such as sheep (Miranda-de la Lama *et al*., 2010). Smallholders usually transport small groups of animals for replacement or sale at market or directly to the slaughterhouse, although there is a trend towards co-operatives that, among other advantages, can offer a transportation service (Miranda-de la Lama *et al*., 2010). Commercially speaking, the categories usually transported are: kids (especially males for fattening or immediate slaughter), adult castrated males and cull-goats for slaughter.

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Table 15.1. Summary of the consequences of transport in goats under stressful conditions. (Modified from Miranda-de la Lama, 2018)

Productivity	Physiology	Weight losses
↓ Live weight	Dehydration	Age (↓ age, ↑ losses)
↓Carcass performance[1]	Loss of electrolyte balance	Weight (↑ weight, ↓ losses)
↓ Carcass quality[2]	Negative energy balance[5]	Breed (↑ temperament, ↑ losses)
↑ Low quality meat[3]	Muscle glycogen reduction	Feedlot goats (↓ losses)
↓ Marbling[4]	Protein catabolism	Grazing goats (↑ losses)
↓ Final price	Fat catabolism	Drink (↓ water, ↑ losses)
	Emaciation (↑ mortality)	Weather (↑ extreme, ↑ losses)
		Infrastructure (↑ quality, ↓ losses)
		Stocking density (↑ extreme, ↑ losses)
		Handlers (↑ empathy and training, ↓ losses)
		Loading/unloading (↑ time, ↑ losses)
		Social mixing (↑ mixing, ↑ losses)
		Transport (↑ time, ↑ losses)
		Lairage (↑ time, ↑ losses)

[1](Carcass weight/live weight) × 100
[2]Carcass bruises
[3]Dark meat
[4]Degree of infiltration of intramuscular fat
[5]Energy intake is less than energy output



Fig. 15.3. Examples of transportation in goats: (a) car towing a small trailer with kids (Courtesy of Juan Manuel Micheo Puig); (b) specialized three-tier trailer to transport kids; (c) gooseneck trailer transporting cull-goats; and (d) pot-belly trailer with cull-goats.

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Transportation of kids

There are two phenomena that help explain human attraction to young animals, anthropomorphism (the tendency to attribute human characteristics to animals) and neoteny (those features considered 'cute' by humans such as round facial features and big eyes) (Keaveney, 2008). Decreased meat consumption is associated with an increased recognition of human features in animals and an increased empathy towards animals (Niemyjska *et al*., 2018). The transportation, lairage and slaughter of kids is a problem for the public image of the livestock industry as public opinion often considers these practices to be cruel and unethical (López and Venegas, 2018). This is one of the reasons why some countries send kids to others to be slaughtered. For farmers and hauliers, transporting kids requires specialized transportation, precise handling, preventative medicine and logistics management. These conditions are necessary to avoid high mortality rates because kids are very sensitive to diseases, changes in temperature and dehydration. Naïve immune systems and lack of exposure to new environments make them more vulnerable than adult goats (Miranda-de la Lama *et al*., 2014).

According to Malher and Noordhuizen (2008), the most common microbiological risks for kids that can pose problems before, during and after transportation are respiratory diseases (*Pasteurella* and *Mycoplasma* spp. after weaning), and digestive disorders such as *E. coli* diarrhoea (first week of life), *Cryptosporidium* diarrhoea (second and third weeks of life), ecthyma (up to two months old) and coccidiosis (from one to five months old). Before and after transportation, kids need more water than adults due to their body structure; they are growing faster, and their metabolism is also faster than that of older animals; consequently, young animals are more prone to dehydration than older ones. In general, pre-ruminants such as suckling kids are more susceptible than weaning kids to periods of food and water deprivation during transportation, because the rumen acts as a reservoir of potential nutrients and water (De la Fuente *et al*., 2010).

Female kids are usually transported less than male goats that are a by-product of goat milk production systems. In Mediterranean countries, suckling kids are fed on just milk for four to six weeks before being slaughtered (Alcalde *et al*., 2017). In other countries, kids are weaned and fattened to different weights according to regional consumer preferences (Greenwood *et al*., 2010; Matos *et al*., 2018). In all cases male kid transportation is a constant, whether they are subjected to short-, medium- or long-distance journeys. Short transportation times (1–2.5 h) are widely recognized as being stressful for weaned kids, although the stress response to this type of transportation was shown to decline within one hour and it did not affect the quality of the meat (Greenwood and Shutt, 1992). Conversely, the combination of transportation and prolonged fasting (12 h) in kids subjected to short journeys produces high pH^{24} (>6) and darker meat (Greenwood *et al*., 2010). In suckling kids, regardless of the journey duration (2 h vs. 6 h), Alcalde *et al*. (2017) observed that transportation affected some blood parameters indicative of stress, such as cortisol, glucose or creatine kinase and that the kids had dark meat (higher values of pH^{24} and colour traits). Furthermore, the kids that underwent a six-hour journey had a greater loss of fat carcass coverage compared to the animals transported for two hours, which might be attributed to lipolysis and the release of fatty acids from adipose tissue due to the longer journey duration.

The limited slaughter capacity or social concerns that certain countries have to slaughter suckling kids has motivated the need to transport them to other countries to be slaughtered upon arrival. This is the case of the transportation of thousands of kids from the Netherlands to Spain and France, or Spain to Portugal or France to Italy (Corson and Anderson, 2008). Stocking density, journey time and postural comfort are the main concerns of the livestock industry for these types of journeys. For example, in France, kids are transported in containers or crates similar to those used to transport turkeys. These containers do not allow the animals to stand up; they also hinder ventilation during the journey and lack the enforcement of the EU regulation on the protection of animals during transport (Council Regulation EC 1/2005; EC, 2005). In a study of suckling kids in France that compared three sizes of transport container heights (37cm, 42 cm and 65 cm), Deiss *et al*. (2015) found that kids transported for three hours in containers of an intermediate height had better thermal comfort, were able to maintain their balance, change position and stand up, compared with kids transported in containers with lower and higher heights. Although these results are promising, this type of transport in France may have to be replaced by multi-deck vehicles, similar to those used for

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piglets, as is the case in Spain, Italy, Austria and the Netherlands.

In the context of long-distance transport, Hindle *et al.* (2013) studied the effects of suckling kid loading densities in a three-tier trailer (5, 7.5 or 10 animals per m^2) in transport from the Netherlands to Spain (1400-km journey). They reported that there were no significant differences in the behaviour and physiological parameters of kids, although they found that kids (8–10 kg) lost between 2.4% and 5.9% (0.2–0.5 kg) of bodyweight. In weaned kids undergoing a long-distance ship and truck journey from Australia to Malaysia, Shahrom and Zamri-Saad (2012) found a post-arrival mortality pattern that revealed a gradual increase as early as at week 1, with an average of 5% mortality reaching a peak at week 3 with 35% mortality, before it gradually decreased to 6% at week 6 and 3% at week 7. Shipping fever was the major cause of mortality reported in this study. Shipping fever is a multifactorial disease characterized by a bacterial infection of the respiratory tract, typically involving predisposing factors such as viral co-infection and transport stress stimuli that can negatively impact the immune system (McMullen *et al.*, 2018). More research will be required to assess whether routes, loading densities, transport systems and post-arrival management in kids are more or less favourable for welfare and meat quality than the recommended values.

Adult transport

Among farmers and hauliers there is a deep-rooted idea concerning the high tolerance of goats to transport, resulting in adult goats being transported in conditions of a lower quality, compared to those provided for other domestic species. Adult animals usually have more behavioural and physiological resources to cope with stress during transport. However, health, body condition and previous experiences can be decisive factors for handling transport with some success. Also, it is known that females are more susceptible to stress during transport than males, as well as presenting a marked post-transport inappetence. Testicular androgen is the major cause of these gender differences in stress response, related to cortisol secretion from the adrenal cortex (Aoyama *et al.*, 2003). In this context, special consideration should be given to discarded goats because they are more vulnerable than the other commercial categories transported. According to Malher *et al.* (2001), goats are discarded by farms for health reasons (i.e. respiratory diseases, udder disorders, locomotor and digestive disorders, abortions) and animals that are nervous, emaciated, old, infertile or low producers. A discarded goat will be more vulnerable to falling during the trip or to being stepped on by other animals. In addition, these animals find the journey physically demanding, and may show signs of post-transport fatigue.

Orientation is important for animals to maintain their balance during a journey. If an animal is able to maintain postural control, stability and adapt to vibration, it does not fall during the journey (Santurtun and Phillips, 2015). Das *et al.* (2001) observed that goats transported 50 minutes by road spent most of the time parallel to the direction of vehicle travel, but with frequent diagonal and perpendicular changes in orientation to maintain balance. However, Minka and Ayo (2014) found that after the first hour of the journey goats changed their positions from parallel to perpendicular. It also seems that animals prefer a standing position during the transportation period and only lie down when fatigued or exhausted, which occurred after seven to eight hours of transportation. These authors also reported that goats that adopted the standing or lying-down positions that were perpendicular and in the opposite direction during transportation had predominantly lower values of creatine phosphate kinase, alanine aminotransferase, aspartate aminotransferase, glucose and urea, which suggested less muscular damage and the best journey position.

Goats are considered to be more tolerant to heat stress than dairy cows because of their greater sweat rate and lower bodyweight. It has been established that the limit of tolerance to heat in goats is between 35 and 40ºC (Salama *et al.*, 2014). However, transportation in hot climates causes stress responses in goats (increased plasma concentrations of cortisol, glucose and NEFA), even on short-distance journeys. This effect has been described in goats subjected to two-hour trips in hot dry climates (28 and 30°C) by Kannan *et al.* (2000, 2003). Also, Kadim *et al.* (2006) found that transported goats in hot dry climates (35°C) had significantly higher plasma cortisol, adrenalin, nor-adrenalin and dopamine levels, besides this affecting bodyweight, carcass quality and meat quality (higher pH and darker meat). In goats transported for three hours under hot, humid tropical conditions (31–32°C and 85–88% of humidity), Zulkifli *et al.* (2010)

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reported an increase in rectal temperature, leucocyte counts and circulating levels of cortisol. In the same climatic conditions, Nikbin *et al.* (2016) found that goats transported 3.5 hours at high densities (0.4 m^2 per animal) had dark meat and a high pH, compared to goats transported at low density (0.2 m^2 per animal). Finally, sometimes dairy goats have to be transported and relocated to another farm, Canaes *et al.* (2009) demonstrated that a one-hour journey in hot and humid climates on unpaved roads had effects on milk one day after the trip. The production of milk decreased, and there was an increase in the milk-fat percentage and somatic cell count, although on subsequent days the effect of stress on milk disappears.

In goats subjected to journeys of six hours in temperate climates, plasma cortisol and glucose levels decreased rapidly and returned to base values six hours after the end of transportation. These results show that at the start of transportation stress the sympathetic nervous system is activated and then the adrenal medulla and cortex are simultaneously activated, followed by immediate physiological changes. It seems that the starting phase is the most important, and hence controlling the reaction of animals at the start of transportation may reduce their stress response (Nwe *et al.*, 1996). From the point of view of oxidative stress, goats subjected to seven hours of transportation in hot, humid tropical conditions experience haematological derangements and oxidative stress, which they take an average of 3–16 days to recover from (Polycarp *et al.*, 2016). Erythrocyte osmotic fragility (EOF), in particular, is a good indicator of transportation stress and represents an important index for quantifying oxidative stress in goats, which tends to decrease after 24 hours from the end of transportation (Fazio *et al.*, 2016).

The high demand for goat meat in some countries, for cultural and religious reasons, has stimulated an international trade involving the transport of live goats. Animals from all over the world tend to be subjected to long-distance travel by road, ship and plane. These journeys are usually emotionally, physiologically and physically demanding. After long transportation, goats may become extremely susceptible to respiratory diseases upon arrival. The immuno-suppressive effect of transportation is primarily due to increased glucocorticoid secretion when animals are exposed to stressful situations (Kannan *et al.*, 2007). Upon arrival, it is common to observe animals with inappetence, dehydration, fatigue, emaciation, respiratory disorders, lameness, bruises, fractures of horns and gores. An increase in the prevalence of these clinical signs usually occurs in developing countries with poor infrastructure and logistic conditions such as: non-specialized trucks, poor loading/unloading facilities, frequents stopovers, negligent handling and holding pens in secondary and terminal markets as the animals await sale or slaughter (which sometimes takes days, without adequate food or water) (Menczer, 2008; Regassa *et al.*, 2013).

Sea and air transport

The increasing trend towards international trade flows and the great quantity of means of transport currently available has generated complex routes, with truck-ship-truck trajectories (Miranda-de la Lama *et al.*, 2013). In some cases, the truck is transported by a ferry (i.e. England to France), and in others, animals are unloaded from the truck and loaded onto other ships (i.e. Australian exports to the Middle East). However, the export of live goats by ship from Australia gradually decreased from 2003, and by 2017 it had practically disappeared, being replaced by air transportation. According to Norman (2017), in 2016, 53,959 goats were exported by plane, mainly to Malaysia and the United Arab Emirates, of which 89.6% were for slaughter and 10.4% for reproduction. Since air transportation was implemented in Australia as a common practice in 2008, mortality has been reported to be very low compared to that occurring in maritime transportation. For example, in 2007 (the last year of ship-only transportation) the reported mortality of goats transported by ship was 0.69% (179 animals out of a total of 25,000), in 2016 when goats were only transported by plane, the reported mortality was 0.041% (22 animals of a total of 54,000). Goats from grazing systems usually suffer inanition during the trip due to their refusal to consume pelleted food. In these conditions, inappetence and stress during the journey can lead to a decrease in metabolic rate, weight loss, weakness, kidney damage, liver damage and death (Phillips and Santurtun, 2013). There are several strategies to reduce mortality due to inappetence, including straw supplementation, inclusion of more cereals in the pellets, lower densities and lower levels of environmental ammonia (Phillips and Santurtun, 2013), although the most effective method seems to be to keep the animals in the assembly centre for 7–14 days and

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feed them with straw and hay, gradually replacing it with pellets (Gherardi and Johnson, 1994).

Pharmacological methods to mitigate goat stress response

In the specific case of meat goats, there are serious limitations to the use of pharmacological methods to reduce stress response for three fundamental reasons. First, some drugs may decrease sensory and motor abilities (especially central nervous system depressants), compromising the ability of animals to cope with transport. The second reason is the high cost of administering drugs, particularly if they are central nervous system depressants, and the third reason is the minimum time required to eliminate residues of drugs or their metabolites in dairy or meat animals (Miranda-de la Lama, 2018). Ali *et al*. (2006) demonstrated the effectiveness of xylazine in significantly improving the effects of short-distance transportation stress in goats. It is not practical to use this treatment in commercial conditions, although in high-value breeding animals that are very sensitive to transportation it could be an option.

Transport-associated alterations of oxidative balance may induce oxidative stress, resulting in cell damage and an increased susceptibility to disease if not adequately mitigated by anti-oxidant responses (Padalino *et al*., 2017). This is of relevance in goats that are not for slaughter and that are replaced or fattened. In this case the goat industry has shown interest in the administration of antioxidants in the pre-transport diet. Kannan *et al*. (2007) studied the effect of a feed supplement containing brown seaweed (*Ascophyllum nodosum*) extract in adult goats for a period of three weeks before transportation lasting six hours. The result showed that the seaweed extract did not affect the physiological stress response of goats and that stress increased due to transportation but then decreased after overnight holding. Probably the anti-oxidant activities of the extract increased coinciding with the simultaneous decrease in oxidative stress-induced lipid damage after the start of transportation. In adult goats, Minka and Ayo (2013) found that 12 hours of road transportation were stressful and post-transportation holding in lairage further increased the level of stress, whereas post-transportation grazing facilitated the recovery of the goats. These authors concluded that the administration of ascorbic acid as anti-oxidant before transportation improved the adverse effects of transportation stress in goats. Similar results have been reported by Biobaku *et al*. (2016) in adult animals also transported for 12 hours and recently by Ahmad-Mir *et al*. (2019), in adult goats transported for 10 hours during the hot, humid season. The results of these studies suggest that the use of antioxidants works better in adult animals and long-distance journeys.

However, antioxidant administration does not always have the expected effect. For example, a study with lambs and kids that underwent a journey of three hours found that the administration of ascorbic acid to lambs before transportation could partly reduce the adverse effects of road transportation stress, whereas its effects on kids were found to be insignificant (Saribey and Karaca, 2019). It is likely that administration only of ascorbic acid is not effective enough to help animals overcome stress during transport. In this sense, in a recent study, Gupta *et al*. (2018) studied the comparative ameliorative effect of ascorbic acid, electrolyte and jaggery on transportation of eight hours at different flocking densities in hot, humid and winter seasons on adult goats. They found that supplementation of ascorbic acid, electrolyte and jaggery aided in reducing transportation stress individually, but ascorbic acid + electrolyte combination proved more beneficial in alleviating transportation stress in both seasons. Instead of blocking the effects of stress through the administration of antioxidants, it is clear that the best solution to reduce the stress response during transportation is to avoid violent handling, make loading/unloading more efficient, reduce journey time, improve transport conditions (i.e. temperature/humidity index, stock density, good bedding, vibration, overcrowding), and especially the fitness of goats for transport (i.e. age, body condition, lameness). Anti-stressors such as antioxidants and other constituents should only be used when there are several of these factors that cannot be controlled.

Conclusions

At present, goat welfare during handling and transportation is a controversial, complex and dynamic phenomenon involving scientific, ethical, economic, cultural, social, religious and political aspects. The problems that occur during routine handling and husbandry procedures are essentially due to lack of handling expertise; there is the need to train

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handlers in ethological practices to ensure that they have a positive, empathetic attitude towards the goats. More research into alternatives that mitigate goat pain at ear tagging, castration, disbudding and hoof trimming is required. It is also essential to look for alternatives to practices that induce anxiety and frustration, such as negative human–goat relationships, artificial weaning and social isolation. Maintaining an acceptable level of welfare during transportation requires the animal loaded onto the vehicle to be fit. Some examples of animals not apt for transportation are goats that are close to parturition and are at risk of giving birth during transport; emaciated goats that would be too weak to remain standing during the journey; downed goats that are not able to walk; blind in both eyes; goats with unhealed wounds from recent surgeries and severely lame goats that have difficulty walking. Many of the problems associated with stress during handling and transportation can be solved by controlling the risk factors that affect the ability or aptitude of the animals to cope with the production environment. This objective could be achieved through a programme of operational quality that, regardless of the conflict between goat welfare and production efficiency, would become a strategic factor for the agri-food sector. The incorporation of goat welfare at the core of an operational quality programme has effects that go beyond the reduction of reactivity and suffering of animals during handling and transportation, it also indirectly impacts on other important aspects that influence the quality of products and the competitiveness of the agri-food sector, such as traceability, safety, loss reduction, operational efficiency, risk prevention and the public image of the goat industry.

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16 Behavioural Principles of Pig Handling

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Summary

Fear is a motivational state aroused by certain specific stimuli that give rise to avoidance, immobility, threat, defence and attack, depending on the species and the intensity of the fear-provoking stimulus. Pigs that are fearful of people normally show avoidance of people and are more difficult to handle. Fearful pigs will also have lower productivity on a variety of production parameters, such as weight gain and piglet production, and lower pig welfare. Many studies have shown that pigs develop conditioned avoidance or approach responses depending on how they are treated by stock people. Examples of aversive negative treatments are slaps, kicks or shocks with electric prodders; examples of positive interactions are pats, strokes or resting a hand on the back of the animal. Pigs that are handled in a negative manner often fear all humans, but there are some situations in which they can discriminate between aversive and positive handlers. The attitude of the stockperson is very important and it is highly recommended that stock people are trained about pig behaviour and handling to ensure positive attitudes towards handling and care of pigs in these stock people. Other subjects covered in this chapter are exploratory behaviour, learning, the effects of environmental enrichment on pig handling and the behavioural principles of pig handling.

Keywords: fear, exploration, handling, pigs, stockmanship, training, welfare

Introduction

The ability of farm animals to be handled easily is affected by fear and exploratory and social behaviour, with fear particularly affecting the animals' contact with humans, as well as the animals' sensory characteristics and physical environment. Learning, including experiences during rearing, can have long-term effects on fear and exploratory and social behaviour (Dewsbury, 1992; Price, 2002; Lyons *et al*., 2009). Pigs remember their previous handling: young piglets handled positively, neutrally or negatively still remember the experience for at least five weeks (Brajon *et al*., 2015). Thus, understanding the behavioural and sensory characteristics of animals is important in handling them efficiently, as well as for ensuring high animal welfare and productivity.

Fear-provoking stimuli are likely to elicit behavioural responses by the animal that may be inconsistent with ease of handling. Furthermore, research, particularly in the intensive livestock industries, has shown that the interactions between stock people and their animals can limit animal welfare and productivity (see Hemsworth and Coleman, 2011). While many of these interactions are routinely and, at times, habitually used by stock people, and may appear harmless to the animals, this research has shown that the frequent use of some of these routine behaviours by stock people can result in farm animals becoming highly fearful of humans.

It is these high fear levels, through stress, that appear to limit animal welfare and productivity. For instance, fear-provoking stimuli, leading to stress, may interfere with animal productivity. One key function of the stress response is to divert food and substrates, including glucose, amino acids and fatty acids, away from normal day-to-day functions such as growth and reproduction (Sapolsky, 2000).

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Fear is an undesirable emotional state of suffering (Jones and Waddington, 1992), and the implications of fear of humans for the welfare of livestock are highlighted by the substantial between-farm variation in the avoidance response of commercial dairy cows, pigs and poultry towards humans (see Hemsworth and Coleman, 2011).

Researchers have gained a greater understanding of the underlying biological systems of both positive and negative affective states in pigs; for example, the brain regions and neurotransmitters involved in the control of fear and exploratory behaviour in pigs (Boissy *et al*., 2007; Carreras *et al*., 2016; Arroyo *et al*., 2016). Recent research emphasizes the importance of promotion of positive affective (emotional) states when managing sentient animals (Hemsworth *et al*., 2015).

Exploratory and social behaviour can also affect ease of handling, by both facilitating and exacerbating movement. The stockperson's frustration with difficulties in handling animals can lead to increased negative interaction with the animals, which, in turn, may increase the animals' fear responses. Figure 16.1 depicts some of the handling interactions that affect the farm animal's responses to handling, with particular reference to the pig.

Exploratory and social behaviour can affect ease of handling. Thus, understanding the animal's behavioural and sensory characteristics is important in the efficient handling of animals as well as for ensuring high welfare and productivity in these animals. This chapter will review some of the main principles of pig handling based on current knowledge of fear, exploratory and social behaviour, learning capability and sensory characteristics of domestic pigs. The second part of the chapter briefly considers opportunities for improving the handling of pigs and offers recommendations.

Principles of Pig Handling

Fear and anxiety are two closely related emotions (Forkman *et al*., 2007), with fear generally defined as a reaction to an explicit threatening stimulus, and anxiety generally defined as a more general state of distress, more long-lasting, prompted by less explicit or more generalized cues. Fear-related responses are characterized by physiological and behavioural responses that assist the animal in its attempts to cope with the danger. Fear can be expressed in a number of ways such as avoidance, immobility, threat, defence and attack, depending on the species and the intensity of the fear-provoking stimulus. Similarly, the physiological stress responses to fear-provoking stimuli can be varied and complex, but the responses generally include activation of the sympatho-adrenal medullary system and the hypothalamo-pituitary adrenal axis, with the consequent increased synthesis of catecholamines and glucocorticoids, respectively (Hemsworth and Coleman, 2011; Turner *et al*., 2012). It is these behavioural and physiological stress responses that highlight the ease of handling, welfare and productivity implications of fear.

Gray (1987) recognizes that fear may be triggered by environmental stimuli that are novel, have high intensity (such as loud and large stimuli), have special evolutionary dangers (such as heights, isolation

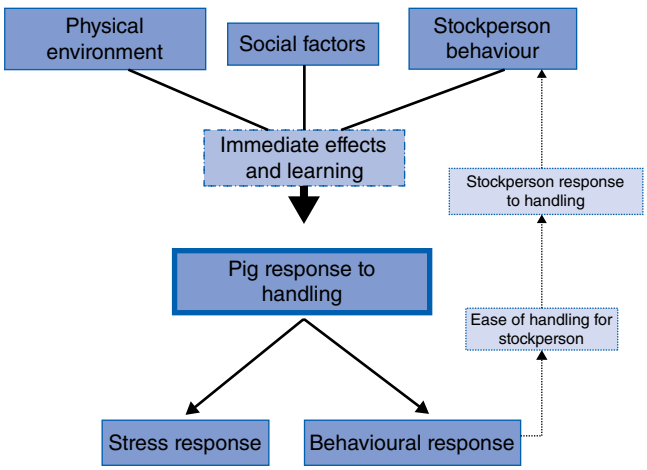


Fig. 16.1. Pig response to handling: diagram showing relationships between various handling factors influencing animal behaviour.

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and darkness), arise from social interaction (such as contagious learning) or have been paired with aversive experiences. Indeed, in considering principles of pig handling, fear of novelty and stimuli that have been paired with aversive experiences, such as humans and locations, fear arising from social learning and fear of evolutionary dangers, clearly are likely to affect ease of handling pigs. While fear appears to be activated almost exclusively by external stimuli (Hogan, 2008), intrinsic factors are also important. For example, experiential, social, gender, breed and strain effects on fear responses have been shown in both laboratory and farm animal species.

Two forms of exploration are often recognized: inquisitive exploration in which the animal is looking for a change, and inspective exploration in which the animal responds to a change (Berlyne, 1960). Some authors have proposed that information gathering, such as exploration, is a self-reinforcing behaviour that is only interrupted when other, more immediate, needs are present, and thus the behaviour can be regarded as a pleasurable activity in itself (Berlyne, 1960; Inglis *et al*., 2001; Boissy *et al*., 2007; Špinka and Wemelsfelder, 2011). The amount of exploration of an object will depend on the characteristics of the object (i.e. its stimulus properties), such as its novelty (e.g. the time since it was last encountered or its degree of resemblance to other encountered situations), its complexity, its intensity and contrast, and the poverty of the preceding environment (Berlyne, 1960).

A sudden environmental change will usually elicit the movement of turning towards the source, a response called the orientation response, which may be followed by startling responses and immobility, threat, defensive, attack or flight responses by the animal (Hemsworth and Barnett, 1987). As fear responses wane, the animal will also approach and examine the stimulus (Hinde, 1970). Exploration will be terminated once the animal is somewhat acquainted with the stimulus. Therefore, the responses of animals to novel stimuli can be considered to contain elements of both fear and exploratory responses. What is more, in response to a novel stimulus or a stimulus perceived as aversive (with or without previous experience), the initial avoidance and subsequent exploration can be viewed as a consequence of the conflicting motivations of fear and exploration (Toates, 1980) and the waning of fear responses. Hence, fear and exploration are important states of motivation that affect ease of handling animals.

The next section will consider the impact of these two motivations – fear and exploration – on the handling of pigs. Furthermore, as the sensory and cognitive (learning) capacities of pigs, as well as their social behaviour, will also affect their movement in both familiar and unfamiliar environments, an understanding of these characteristics of pigs can be effectively utilized both in their handling and in the design of their handling facilities, and so these aspects will also be considered in the next section.

Fear of humans

Fear and ease of handling

Most of the limited research on fear of humans and ease of handling pigs and other farm animals indicates that animals that are highly fearful of humans are generally the most difficult to handle. As shown in the results presented in Table 16.1, the behavioural response of pigs to humans showed moderate to large correlations with their ease of handling (Fig. 16.2). These correlations indicate that pigs with high levels of fear of humans, based on their avoidance behaviour of, or lack of approach to, an experimenter in a standard approach test were the most difficult pigs to move along an unfamiliar route: fearful pigs took longer to move, displayed

Table 16.1. Correlations between the behavioural response of pigs to an experimenter in a standard approach test to assess fear of humans and the ease of movement of 24 pigs along an unfamiliar route by an unfamiliar handler. (From Hemsworth *et al*., 1994a)

Variables recorded in test to assess fear of humans	Variables recorded in ease-of-movement test[a]		
	Time to move	Balks	Score[b]
Time to approach experimenter	0.34	0.44*	–0.63**
Number of interactions with experimenter	–0.42**	–0.42*	0.51*

[a]Correlation coefficients with * = $P < 0.05$ and with ** = $P < 0.01$.

[b]Score based on ease of movement, with 0 reflecting substantial difficulty and 4 reflecting little or no difficulty in moving the pig.

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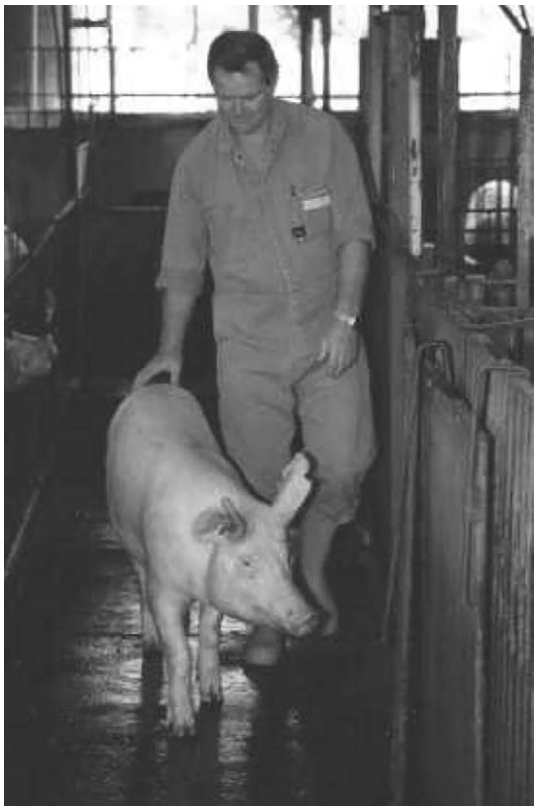


Fig. 16.2. A pig showing low fear responses to humans is generally easier to handle.

more balks and were subjectively scored as the most difficult to move by the handler.

While it may intuitively appear that fearful animals are easy to move, animals that are fearful of humans are generally the most difficult to handle in unfamiliar locations for several reasons. When alarmed and stressed, pigs will often vocalize and may pack together, making sorting and handling difficult. Vocalizations may make other pigs difficult to handle and, as discussed later (in the section 'Sensory characteristics'), stressed pigs may release pheromones in their urine and saliva that communicate to other pigs that they have encountered a fear-provoking situation. Other pigs following will respond fearfully to these auditory and olfactory signals, making these pigs also difficult to handle. Moreover, pigs are generally wary of moving towards an unfamiliar or unpredictable situation, and if they are fearful of both this environment and the handler, they may show exaggerated behavioural responses to handling, such as balking or fleeing back past the handler.

Other authors have also reported that high levels of fear of humans will decrease the ease of handling of pigs (Gonyou *et al*., 1986; Grandin *et al*., 1987). In contrast, Hill *et al*. (1998) found no effect of fear of humans on the time taken to regularly move pigs to and from a weighing area. With a routine handling task of moving pigs to a familiar location, fear of humans may actually facilitate ease of handling because the predominant response of pigs that are highly fearful of humans may in these situations be avoidance of the human rather than avoidance of the location. However (and as suggested above), if pigs are *both* fearful of humans *and* they are being moved to an unfamiliar location, the conflicting responses to the handler and the location may lead to exaggerated behavioural responses (e.g. balking or fleeing).

Several studies have reported that pigs regularly moved out of their pens prior to slaughter were quicker to move during the early stages of transport, such as moving out of their home pen and into a transport crate or box (Abbott *et al*., 1997; Geverink *et al*., 1998). While increased familiarity with locations early in the transport process may be responsible for these effects, increased human contact may be implicated as well. For example, Eldridge and Knowles (1994) reported that commercial grower pigs that were regularly handled and moved out of their pens to a range of locations were easier to move in an unfamiliar environment.

Handling effects on subsequent ease of handling have been found in other livestock too. Studies on cattle, sheep and horses have shown that positive handling, generally involving speaking and touching the animals, particularly during infancy, improved their subsequent ease of handling (e.g. Waring, 1983; Boissy and Bouissou, 1988; Lyons, 1989; Hargreaves and Hutson, 1990; Mateo *et al*., 1991; Boivin *et al*., 1992; Hemsworth *et al*., 1996a).

A number of authors have commented that genetics may affect the ease of handling pigs (Grandin, 1991). Hill *et al*. (1998) found differences between two genotypes in speed of movement to a weighing scale, and Yoder *et al*. (2011), who assessed the ease of moving pure-bred pigs from a nucleus herd into a weighing scale, found that Landrace pigs resisted moving to and into the scale more than Duroc and Yorkshire, while Chester White resisted moving more than Duroc and Yorkshire, and Yorkshire resisted moving more than Duroc.

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As reviewed by Price (2002), although there is little evidence that domestication has resulted in the loss of behaviours from the species repertoire, or that the basic structure of the motor patterns for such behaviours has been changed, in nearly all cases, behavioural differences between wild and domestic stocks are quantitative in character and best explained by differences in response thresholds. An excellent example of this is fear of unfamiliar stimuli (i.e. fear of novelty or neophobia) with studies on wild and domestic Norway rats indicating that the former are more reactive or fearful of novelty (see Price, 2002). The genotype differences that may affect ease of handling of pigs reported by Hill *et al*. (1998) (see above) could act through effects on fear of novelty.

Factors affecting the pig's fear of humans

In modern intensive management of pigs, human contact is becoming progressively more stressful as the number of animals managed by each stockperson increases, with many of the stockperson interactions biased towards negative ones, given that opportunities for positive human contact are probably minimal, and many routine husbandry tasks undertaken by stock people may contain negative elements, such as restraint, vaccinations and surgical interventions (Boissy *et al*., 2005; Hemsworth and Coleman, 2011).

A commercial pig's response to a stockperson may be affected by both stimulus-specific fear and fear of novelty. While the initial response of a naïve pig to humans may involve a response to novelty or unfamiliarity, with subsequent experience, and as a consequence of learning, a specific and learned response to humans develops (Hemsworth and Coleman, 2011). The initial response of a naïve farm animal to humans may be similar to the animal's response to an unfamiliar object or to unfamiliar animals of another species. Furthermore, Suarez and Gallup (1982) have suggested that the predominant response of naïve farm animals to humans may be a response to a predator.

As a consequence of interactions with humans, particularly the amount and nature or quality (i.e. positive, neutral or negative in nature for the animal) of the human contact, pigs in commercial settings will develop a stimulus-specific response to humans. Therefore, even though there will be some components of novelty in the response of experienced animals to humans, which will occur with changes in the stimulus property of humans (e.g. changes in behaviour, clothing, location of interaction, etc.), a major component of this response will be experientially determined. There is some evidence that the behavioural response of relatively naïve pigs to humans, which may be predominantly a result of fear of novelty, may be moderately heritable (Hemsworth *et al*., 1990). However, experience with humans affects the pigs' subsequent fear of humans (Hemsworth *et al*., 1990) in that the behavioural response of young and relatively inexperienced pigs to humans is only moderately correlated with their behavioural response to humans in adulthood.

There is considerable support for this view of the development of a stimulus-specific response of farm animals to humans. For example, numerous handling studies have shown that handling treatments varying in the nature of human contact, but not in the amount of human contact, resulted in rapid changes in the level of fear of humans shown by pigs (Hemsworth *et al*., 1981a, 1986a, 1987; Gonyou *et al*., 1986; Hemsworth and Barnett, 1991).

Over the past four decades, considerable research has been conducted in the livestock industries on the sequential relationships between stockperson attitudes, stockperson behaviour and animal fear (see Hemsworth and Coleman, 2011). These human–animal relationships were studied in the pig industry by measuring stockperson beliefs about handling and working with pigs (attitudes), conducting direct behavioural observations on stock people and assessing the pigs' fear of humans by measuring the time taken by pigs to approach and interact with a stationary experimenter in a standard approach test. These studies have shown significant sequential relationships between the stockperson's attitudes and behaviour towards animals and the fear of humans exhibited by pigs (Hemsworth *et al*., 1989, 1994b; Coleman *et al*., 1998; Hemsworth and Coleman, 2011). In addition to these studies on human–animal relationships in commercial farms, handling studies on pigs, involving brief human contact, indicate that conditioned approach–avoidance responses develop in pigs as a consequence of associations between the handler and aversive and rewarding elements of the handling bouts (Hemsworth *et al*., 1981a, 1986a, 1987; Gonyou *et al*., 1986; Paterson and Pearce, 1989; Pearce *et al*., 1989; Hemsworth and Barnett, 1991; Tanida *et al*., 1995; Day *et al*., 2003; Pedersen *et al*., 2003).

A practical way for stock people to gauge the fear responses of pigs to humans is to observe the avoidance of pigs to their approach (Hemsworth *et al*., 1981b; Scott *et al*., 2009; Powell *et al*., 2016).

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Group-housed sows on farms with good stockmanship will allow people to walk up to them and do an ultrasound pregnancy test (T. Grandin, personal communication, 2018).

These field and handling studies show that the main aversive properties of humans for pigs include hits, slaps, kicks and shocks with a battery-operated prodder by the handler; rewarding properties include pats, strokes and the hand of the handler resting on the back of the animal. Moreover, it is the percentage of the negative tactile interactions to the total tactile interactions that appear to determine the commercial pig's fear of humans. Research has shown that auditory interactions by stock people may not be highly important in regulating these fear responses in pigs (Hemsworth *et al*., 1986b), but in some livestock species, such as cattle and sheep, talking to the animals may reduce their fear responses to humans. For instance, Pajor *et al*. (2000) showed that shouting by humans is aversive to dairy cows, and Mateo *et al*. (1991) found that regular positive handling of ewes in the form of talking and stroking resulted in reduced fear responses to humans. However, as in other farm animal species, visual interactions by the stockperson, such as fast and unexpected movements may also affect the pig's fear of humans (Gonyou *et al*., 1986). Habituation is also likely to occur over time as the animal's fear of humans is gradually reduced by repeated exposure to humans in a neutral context (Fig. 16.3).

Evidence from a number of handling studies on pigs supports the view that the animal's response to a single human might extend to include all humans through the process of stimulus generalization (Hemsworth and Coleman, 2011). For example, pigs that were previously briefly but regularly handled either by one handler in a predominantly negative manner, or by two handlers who differed markedly in the nature of their behaviour towards pigs, showed similar behavioural responses to familiar and unfamiliar handlers (Hemsworth *et al*., 1994b). Similar evidence is also available from studies with poultry and sheep (Barnett *et al*., 1993; Jones, 1993; Bouissou and Vandenheede, 1995).



Fig. 16.3. Fear of humans can be reduced in pigs through regular exposure to humans in a neutral context, such as a human standing stationary and near the animals, followed by the opportunity for positive behaviours, such as talking and patting, as the animal approaches. (Photo: Wageningen UR Communication Services)

Such results suggest that in commercial situations, the behavioural response of pigs to one handler may extend to other humans. However, it is possible that there are handling situations in which pigs may discriminate between particular people. In situations in which there is intense handling or distinct physical differences between handlers, animals may learn to discriminate between one handler and other handlers to which the animals may be subsequently exposed. Following an extensive period of intense human contact, Tanida *et al*. (1995) found that young pigs showed greater approach to the familiar handler than to an unfamiliar handler, even though both handlers wore similar clothing. Additionally, in situations in which the physical characteristics of the handlers may differ markedly, farm animals may learn to discriminate between them.

An example of this is given by a series of experiments conducted by de Passillé *et al*. (1996) and Rushen and de Passillé (2010), who found that dairy calves exhibited clear avoidance of a handler that had previously handled them in a negative manner compared with handlers wearing different-coloured clothing who were either unfamiliar to the calves or had previously handled them in a positive manner. Initially, there was a generalization of the aversive handling, with calves showing increasing avoidance of all handlers, but with repeated treatment, calves discriminated between handlers, and, in particular, between the 'negative' and 'positive' handlers. It is of interest that discrimination was greatest when tested in the area in which handling had previously occurred rather than in a novel location. Young piglets were able to discriminate between an aversive handler who wore a white shirt and blue trousers and a neutral handler who wore all blue clothing (Sommavilla *et al*., 2011). These data indicate that discrimination between people by farm animals will be easier if the animals have some distinct cues on which they can discriminate, such as colour of clothing or location of handling.

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Although several species of farm animals, including pigs, are capable of discriminating between stock people, there is little evidence that they appear to do so under normal commercial circumstances. Nevertheless, even when farm animals learn to discriminate between humans, fear responses to humans in general are likely to increase in response to the most aversive handler (Hemsworth *et al*., 1994b; de Passillé *et al*., 1996). This finding has important implications in situations in which several stock people may interact with pigs.

In conclusion, tactile and visual contact with humans are important determinants of the fear responses of pigs to humans. Research has shown that human interactions, such as slaps, hits and shocks with a battery-operated prodder, are likely to increase fear responses in pigs, while contact such as slow speed of movement and stroking are likely to reduce fear. Limited interaction also appears to be influential in determining fear responses to humans, indicating the sensitivity of farm animals to brief human contact that at times may appear to be innocuous and inoffensive. So previous handling clearly affects the ease of handling pigs. Thus, in situations where pigs are fearful because of previous handling at the farm or during transport, or where the handling facilities are poor, the behaviour of the stockperson is even more critical in determining the ease of handling, stress and welfare of pigs.

It should be recognized that in situations in which contact may be markedly reduced, such as in the grower and finisher sections of pig units, the importance of regular contact and the nature of this contact is particularly important for subsequent ease of handling. For example, studies by Eldridge and Knowles (1994), Abbott *et al*. (1997) and Geverink *et al*. (1998) suggest that regular handling and moving may facilitate subsequent ease of handling from farm to slaughter. This bias towards negative interactions, together with the sensitivity of pigs to even moderate negative interactions, highlights the challenge confronting stock people in improving their interactions with pigs. This aspect will be considered in more detail later in this chapter (see section on 'Achieving desirable human contact').

Fear of novelty (neophobia) and exploration

Pigs, like other animals, are initially fearful of strange objects and locations and will generally balk in response to them. Therefore, structural features such as floor surfaces, floor levels and wall types should be as consistent as possible throughout a race or corridor to reduce balking. It is probably particularly important to minimize such changes at critical points in the route, such as pen exits, corners and entrances to corridors or races, where these challenging situations, combined with unfamiliarity, are likely to have a greater effect on ease of handling. Novel objects in the race, or moving and flapping objects, will also cause balking.

If pigs refuse to move forward in an unfamiliar situation, allow them a few seconds to familiarize themselves with the environment rather than initially trying to force them and, thereby, stressing both them and other animals. Trying to move pigs quickly in this situation may also be costly in terms of time and effort, as well as risking injury to both pigs and the handler. Habituation to novel stimuli of moderate intensity will occur over time as the animal's fear is gradually reduced by continuous exposure in a neutral context.

Grandin (1982) reported that a smooth concrete floor with a wet slippery surface inhibits pig movement. Furthermore, Grandin (1988) observed that fattening pigs reared on metal-mesh floors were difficult to move on concrete floors. The novelty of an unfamiliar floor for these fattening pigs may also have adversely affected their movement.

Indoor pig production systems, particularly those with fully slatted or partially slatted concrete floors, are considered by some to provide barren environments for pigs (Barnett *et al*., 2001). Environmental enrichment is often defined as an increase in the biological relevance of captive environments by appropriate modifications (Newberry, 1995) and it is commonly recommended to offer pigs permanent access to a sufficient quantity of material to enable investigation and manipulation, such as straw, hay, wood, sawdust, mushroom compost or a mixture (e.g. The European Union Commission Directive 2001/93/EC, p. 37). However, some have questioned the extent to which this provides effective enrichment (Marchant-Forde 2009; Van de Weerd and Day 2009). Grandin *et al*. (1987) found that giving fattening pigs novel objects to manipulate, such as rubber hoses, made them easier to handle, and Pearce *et al*. (1989) found that young pigs housed in pens with novel objects, such as chains and tyres, showed less avoidance of humans than those reared in barren pens. In contrast, Hill *et al*. (1998) found no effect of the provision of such novel objects

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either on the behavioural response of pigs to humans in their pens or in the ease of moving them. In an example of the effects of environmental deprivation, it has been reported that pigs are subsequently more easily startled and more difficult to handle when reared in darkness (Grandin, 1991). As discussed earlier, several studies have reported that pigs regularly moved out of their pens during rearing were quicker to move during the early stages of transport (Abbott *et al*., 1997; Geverink *et al*., 1998). In a study that examined the effects of environmental enrichment through the provision of toys, Moore *et al*. (1994) found that toy provision for early weaned piglets reduced their fear of humans. It is possible that these effects observed on neophobia and ease of handling may have been a consequence of increased environmental stimulation. Previous handling may also result in habituation to handling *per se*.

Learning ability

As reviewed by Kilgour (1987) and Houpt (2011), pigs easily learn a variety of tasks. For example, they readily learn multiple-choice spatial tasks. Pigs are generally considered easy to condition in the classic sense: they are capable of quickly learning to show a range of conditioned or associative responses such as salivation or increased heart rate in response to auditory stimuli (Houpt, 2011). Pigs can be trained, quite easily, to perform operant responses and will respond, for example, by pushing or manipulating levers with their snouts to receive sensory rewards such as lighting or temperature (Houpt, 2011), or jumping across an obstacle to avoid the punishment of an electric shock (Craig, 1981). They perform well in maze learning tests, but often perform poorly in visual discrimination tests (Kilgour, 1987). The ability of pigs to learn from experience is particularly obvious for food-related and social tasks (Spinka, 2009).

Pigs have good short-term and long-term memories (Houpt, 2011), and this can be used to develop handling routines. With breeding pigs, there is an excellent opportunity for pigs to learn to move to and from commonly used locations by regular exposure. By allowing the pigs to initially move at their own pace, and thus by minimizing their aversive experiences, pigs are likely to move more easily on subsequent introductions.

Rewards for pigs can be used to mask or minimize aversive husbandry experiences or even to train them to those experiences. Positive rewards, such as patting and talking by handlers, opportunities to explore novel settings (as mild novelty is rewarding) or palatable feed rewards, can be used to alleviate moderately aversive husbandry procedures such as restraint and vaccination. For example, Hemsworth *et al*. (1996a), in examining the aversiveness of daily injections, surprisingly found that daily intramuscular injections, using a low-penetration gas injection gun, were not highly aversive to pigs. The authors suggested that there may have been some rewarding elements for the pigs in these handling bouts, such as the presence of, and opportunity to closely approach and interact with, the handler before and after the injection. Indeed, Jones (1993) has suggested that as animals find increased complexity attractive, human contact may be rewarding for farm animals in environments that lack complexity. Positive rewards could also be used to promote movement to and from a familiar location, as shown by Hutson (1985) with sheep.

Sensory characteristics

Pigs use olfactory and auditory stimuli extensively in a range of activities, including gathering social information and mutual communication (Spinka, 2009). Dominant boars mark their environment with odours more than subordinate animals do (Mayer and Brisbin, 1986), and pheromones in the saliva and urine of boars affect both the onset of puberty in gilts, the onset of ovulation in weaned sows and the stimulation of sexual receptivity in oestrous gilts and sows (Hughes *et al*., 1990; Hemsworth and Tilbrook, 2007). Pigs will avoid places containing urine from stressed pigs (Vielle-Thomas and Signoret, 1992). Livestock in general have sensitive hearing, and so they may avoid excessive and unfamiliar noise (Grandin, 1990; Waynert *et al*., 1999). Pigs have a rich repertoire of vocal signals (Spinka, 2009) and use auditory stimuli as a means of communication. For example, vocalizations are used to maintain within-group contact, such as between littermates and the sow (Gonyou, 2001), while the duration and frequency of the vocalization is indicative of the degree of distress (Weary and Fraser, 1995). Pigs vocalize during an aversive event with high-pitched vocalizations (screams, squeals or grunt-squeals) and during a rewarding event with barks (a low tone that sounds like 'woof') (Reimart *et al*., 2013). Therefore, the handling of fearful pigs, or handling that creates stress in pigs, may cause other pigs that are following to respond fearfully to both olfactory

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and auditory signals from the preceding pigs, so making them also difficult to handle.

Pigs have relatively good vision. They have poorer visual acuity than cattle, dogs, horses and humans (Houpt, 2011), but a wider field of view than humans (but narrower than that of cattle), with a blind angle of 50–100° to the rear (Spinka, 2009). Their wide angle of vision (310°; Prince, 1977) allows pigs to detect stimuli on either side of them, and so the walls of corridors, pen fronts and gates should be solid (at least up to pig height) to prevent the pigs that are being moved becoming distracted by what they see, such as other people or pigs (Grandin, 1980). Stock people should also follow behind, and slightly to one side, and use a solid board to prevent the pigs from turning back. Most diurnal animals probably have some form of colour vision, and though it has been difficult to demonstrate colour vision in pigs from the few studies that have been conducted, they may be red–green colour blind, but can distinguish blue from grey (Lomas *et al*., 1998). Pigs may, therefore, respond to the novelty of a change in some colours of the routine clothing of handlers or of other features in their environment.

Livestock appear to move more easily on a level surface, but excessively steep ramps were avoided by pigs in a preference test in which 20–24° ramps were preferred to 28–32° ramps (Grandin, 1990). Berry *et al*. (2012) found that pigs moved more easily during loading onto an improved loading ramp in which one of its major design features was a slope of less than 20°. One large company in the USA has switched to using portable loading ramps that have a slope within 15° (T. Grandin, 2012, personal communication). Figure 16.4 shows a loading ramp design to promote following by livestock. The optimum-size group for moving pigs onto a transport vehicle is five or six animals (Lewis and McGlone, 2007).

Pigs, like other animals, have a tendency to move towards a more brightly lit area (van Putten and Elshof, 1978). Tanida *et al*. (1996) found that piglets preferred to move from dark to lighter areas and were encouraged to move to darker areas by the provision of lighting in them. Experiments indicate that the light should be even and diffuse (Grandin, 1980). Thus, lights can be used to encourage movement into poorly illuminated areas, such as races and dark corridors. Although Grandin (1987) suggests that shadows will cause balking, Tanida *et al*. (1996) found no effect on the movement of piglets with either shadows or lines on the floor. While the light intensity of a flashlight (160 lx) did not affect pig movement (Tanida *et al*., 1996), excessive light (1200 lx) caused avoidance (see Grandin, 1990). Furthermore, pigs avoid black-and-white patterns on the floor (Tanida *et al*., 1996), and as they are only moderate judges of distance (Grandin, 1980), they are reluctant to cross changing light patterns, drain grates, steps, puddles of water, gutters and other high-contrast objects. Batching gates and pig boards should be solid to block the vision of pigs, to encourage their movement away from the gates or boards to the desired direction or location.

Social behaviour

Domestic pigs are often mixed when grouped in nursery, grower or finisher accommodation, or in breeding groups, which generally results in intense aggression for the first few hours, but shows a steady decline to low levels by 24–48 hours (Barnett *et al*., 2001; Gonyou, 2001). The frequency of this initial post-mixing aggression will depend on a number of factors, such as familiarity, floor space allowance, age/parity, feed intake and diet (see Arey and Edwards, 1998; Barnett *et al*., 2001; Gonyou, 2001; Verdon *et al*., 2015) but not group size or presence of straw and other substrates (see Arey and Edwards, 1998; Verdon *et al*., 2015). Odour appears to be the main means by which pigs identify familiar and unfamiliar pigs (Gonyou, 2001).

A prominent characteristic in farm animals, including pigs, when they are given the opportunity to range freely, is the active way in which individuals associate in groups and form various types of

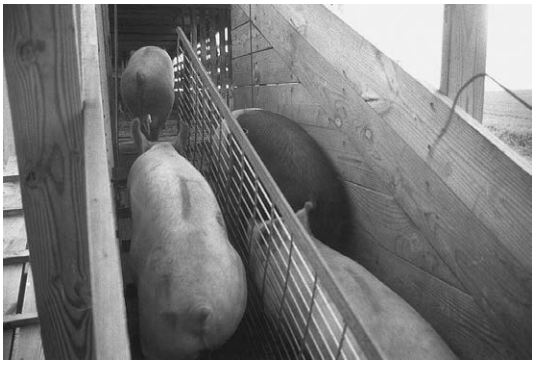


Fig. 16.4. A 'see-through' partition promotes following in this loading ramp. The outer fences are solid.

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social organizations. In domestic pigs, in both free-range settings and when confined in groups, one of the main types of social organizations is the dominance hierarchy (Gonyou, 2001), and, once established, one of the main results of the hierarchy is to avoid the need for aggressive and injurious interactions (Lindberg, 2001). Living in groups provides the opportunity for synchronization and the social facilitation of behaviour such as walking, running, feeding and lying (van Putten and Elshof, 1978; Broom and Fraser, 2007; Spinka, 2009).

This synchronization and social facilitation of behaviour such as walking and running obviously can, and should, be utilized in moving pigs. For example, the walls of corridors, pen fronts and gates should be solid (at least up to pig height) to prevent the pigs that are being moved from becoming distracted by adjacent pigs. However, the design of barn alleys should utilize the attraction of pigs to the sight of others moving ahead. Thus, corridors or alleys should be wide enough to provide the animals with a clear view ahead and of other animals moving ahead. Grandin (1990) suggests that alleys for pigs should be one metre wide to enable two market-weight pigs to be able to easily walk side-by-side. Moreover, if one animal needs to be isolated from the group, it may be preferable to move it within a small group to a location where the animal can easily be drafted from the rest, or to use a large pig board in the pen to direct the pig out of the pen or away from the group.

Main Recommendations on Handling Pigs

Achieving desirable human contact

Modern pig production involves several levels of interaction between stock people and their animals. Many interactions are associated with regular observation of the animals and their conditions. This type of interaction often involves only visual contact between the stockperson and the pigs, perhaps without the stockperson entering the animals' pen, but the pigs in most production systems have to be moved by the stockperson as well, and this often also involves tactile and auditory interaction with the animals. Growing pigs are occasionally moved from pen to pen in order to provide accommodation suitable to their stage of growth, and breeding pigs are regularly moved according to the stage of the breeding cycle that they are in. It is during these situations that human–animal interactions have considerable potential to influence animal behaviour.

Considerable between-farm variation exists in the pig industry in both the behaviour of stock people and the fear response of pigs to humans (Hemsworth and Coleman, 2011). This highlights the opportunities for reducing fear responses in pigs and for improving their ease of handling, welfare and productivity. Studies conducted in the pig industry have also shown sequential relationships between the stockperson's attitudes and behaviour towards their animals, and the pigs' fear of humans and productivity (Hemsworth *et al*., 1994b; Coleman *et al*., 1998; Kauppinen *et al*., 2012) (Fig. 16.5).

This research indicates that the best way to influence how a stockperson will interact with their animals is by explicitly targeting this attitude. Two recent studies show that stock people with positive attitudes are generally more motivated to care for their pigs, and piglet mortality was lower (Hemsworth, 2018; Jaaskelainen *et al*., 2014). Stock people's attitudes towards their animals and working with them, their beliefs about other people's expectations of them, and their beliefs about the extent to which they have control over their ability to interact appropriately with the animals determine the nature and extent of their interactions with these animals (Hemsworth and Coleman 2011; Coleman and Hemsworth 2014). Studies in the livestock industries (including the pig industry) using cognitive behavioural training of stock people have successfully reduced fear of humans in commercial farm animals. This approach in improving the attitudes and behaviour of stock people has been described in detail by Hemsworth and Coleman (2011) and Coleman and Hemsworth (2014). Basically, cognitive-behavioural training techniques involve retraining people in terms of their behaviour by first targeting both the beliefs that underlie the behaviour (attitude) and the behaviour in question, and secondly, maintaining these changed beliefs and behaviour. This process of inducing behavioural change is really a comprehensive procedure in which all of the personal and external factors that are relevant to the behavioural situation are explicitly targeted.

Hemsworth *et al*. (1994b) found that targeting the key stockperson's attitudes and behaviour, which are correlated with the level of fear of humans in pigs, resulted in stock people having a

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Fig. 16.5. Irrespective of the production system, the attitudes and behaviour of stock people towards their animals have profound effects on these animals.

more positive attitude towards their pigs, with subsequent reductions in the proportion of negative interactions with their animals and reductions in the animals' fear of humans (Table 16.2). Furthermore, there was a marked tendency for an improvement in the reproductive performance of the pigs at the farms in which this training programme was introduced. There are several studies that have, to a greater or lesser extent, shown similar results of training that targets key stockperson attitudes and behaviour in the pig industry (Coleman *et al*., 2000) and the dairy industry (Hemsworth *et al*., 2002; Windschnurer *et al*., 2009). Thus, there is a strong case for utilizing stockperson training courses in the livestock industries that target the attitudes and behaviour of the stockperson.

The training or intervention procedure used as an experimental tool in the research just described in the pig industry has been commercialized for the pig industry as ProHand, an original concept developed by Australian Pork Limited and the Animal Welfare Science Centre (ProHand® 1996). The ProHand approach has been extended into a package for dairy stock people as well, and, following recent research at abattoirs, into packages for pig and red-meat abattoir stock people in Australia. Training

Table 16.2. Summary of the effects of a cognitive-behavioural intervention procedure, applied at training farms, targeting the attitudes and behaviour of stock people in the pig industry.

Variables	Change following training (relative to control)
Stockperson attitudes[a]	
Positive beliefs about 'petting'	15% increase
Stockperson behaviour[b]	
Negative behaviour (%)	31% decrease
Sow fear of humans[c]	
Time near experimenter (s)	40% increase
Sow productivity	
Piglets/sow/year	7% increase

[a]High score indicates positive beliefs.
[b]Percentage of tactile interactions displayed by the stockperson that were negative in nature (e.g., slap, hit or kick).
[c]Fear of humans was assessed by the time pigs spent near a stationary experimenter in a standard test.

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packages based on the ProHand principles have been developed in Europe by the authors and European colleagues as part of the EU's Sixth Framework for Stock People in the Pig, Poultry and Cattle Industries. Details of these training programmes are described by Hemsworth and Coleman (2011).

There has been a number of other training approaches that are designed to either reduce stress in farm animals or improve the way that stock people handle animals. Typical of these is 'low-stress handling methods', which appears to incorporate the principles of livestock handling developed by Bud Williams in the USA (Cote, 2004). It is claimed that these methods lower animal stress and increase ease of animal handling (http://www.stockmanship.com). Although there is little reference in the scientific literature supporting these training approaches, they utilize some sound behavioural principles that have implication for animal stress and ease of handling, such as a consideration of the animal's fear, and exploratory and social behaviour, as well as the animals' sensory and cognitive abilities, as discussed in the present chapter. A survey of Canadian pork producers indicated that they placed a major emphasis on patient, low-stress handling (Spooner *et al*., 2014). Low-stress training programmes are used in Canada and may be having some beneficial effect. Grandin (2007) contends that calm cattle are easier to handle and sort than agitated, fearful cattle, and that the secret to low-stress cattle handling is to keep them calm. However, at present there are no controlled studies that have evaluated the effectiveness of these programmes or similar programmes in improving welfare or productivity outcomes for the animals. Also, apart from the studies by Hemsworth *et al*. (1994b, 2002), Coleman *et al*. (2000) and Windschnurer *et al*. (2009), none of the stockperson training programmes designed to either reduce farm animal stress or modify stockperson handling are based on theoretical, research-validated approaches that target both human and animal factors (Hemsworth and Coleman, 2011; Coleman and Hemsworth, 2014).

In order to achieve change, a training programme that incorporates the relevant skills and knowledge, as well as targeting the attitudes and beliefs that underpin good observational and handling practices, is required (Hemsworth and Coleman, 2011). Consequently, such a programme needs to address not only the specific skills, knowledge and beliefs that are relevant, but also to deal with organizational influences, peer pressure, resistance to change and the difficulty in altering and maintaining changes to well-established habits (Coleman, 2004). Thus, in this process, it is essential to address the possibility that stock people or farmers may become defensive or offended, because they may see the content of the programme as criticizing their beliefs and behaviour. For this reason, it is essential to present the material as the outcome of scientific research and the programme as one of information transfer, in much the same sense as any technology transfer, such as new knowledge of nutrition of a new vaccine. The emphasis should be on the training as developing a competency that is important for professional stock people (Coleman, 2004).

Finally, the programme needs to target all stock people and supervisors in a facility to ensure that there is minimal peer pressure to revert to the old practices and, at the same time, increased pressure to adopt and maintain the new practices. This approach has been proven to be effective on farms and in abattoirs in the pig and dairy industries (Hemsworth *et al*., 1994b, 2002; Coleman *et al*., 2000; Windschnurer *et al*., 2009).

The conclusion is, therefore, that the stockperson requires a basic knowledge of both the behaviour and requirements of farm animals together with a range of well-developed husbandry and management skills to care for and manage farm animals effectively. These are skilled tasks, and stock people are required to be competent in many of them. Clearly, the conventional training of stock people to develop such competencies should be a systematically and soundly implemented process in which the requirements of both the stockperson and the industry are addressed.

Utilization of the characteristics of pigs to handle and control them

An understanding of the learning and sensory abilities, and the fear, exploratory and social behaviour of pigs, can be utilized effectively in handling pigs and in designing the features of their handling facilities. The scientific and popular literature on livestock handling describes many of the features of livestock and their environment that are relevant to livestock handling, and the main factors to be considered in the handling and control of pigs are presented in Table 16.3. For detailed information on the design of races and loading and unloading facilities for livestock, including pigs, readers are referred to the review by Grandin (1990).

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Table 16.3. Main considerations in handling and controlling pigs.

Facility design

- Familiarity with direction of flow and route will promote pig movement.
- Covering race walls adjacent to distractions, such as other pigs, will promote movement.
- Use of covered and open panels can direct pig movement and vision.
- Wide, clear, well-lit areas will promote pig movement.
- Darkening the area in which the pigs are held, and brightening the area to which they are to move, will promote movement.
- Races with clear unobstructed view towards the exit, or where the pigs are meant to move to, will promote movement.
- The sight of other pigs moving ahead will promote movement.
- Changes in race construction material or changes in floor type (e.g. slats to concrete) will inhibit pig movement.
- Walls painted one colour to avoid contrasts will promote pig flow.
- Covered sides of ramps, so that pigs cannot see the height, will promote flow.
- When requiring to separate individual pigs, they will move easier as a small group, rather than individually, to a holding facility where individual animals can be separated and treated.
- Direction of movement should be across the direction of the gratings or slats to improve footing and to reduce the possibility of pigs seeing through the floor or perceiving heights.
- Reducing excessive noise, such as banging gates, shouting and engines, will facilitate pig movement.

Handling

- Stock people should undertake pig handling training.
- Negative behaviours (e.g. slaps, pushes, kicks, hits and shocks with a battery-operated goad or prodder) should only be used when absolutely necessary.
- Positive behaviours (e.g. talking, slow movement, pats, strokes, rubs, and a hand on the back) should be used when the opportunity arises.
- Each pig should be handled on the basis of its behaviour in each individual situation.
- If a pig refuses to move forward, it should be allowed a few seconds to familiarize itself with the environment rather than forcing it, thus stressing both it and other pigs.
- Less speed/haste will often assist in reducing stress in pigs.
- In situations where pigs are fearful as a result of previous handling at the farm or during transport, or where the abattoir handling facilities are poor, the type of handling becomes even more critical in determining pig stress, welfare and meat quality.

Reduce aversive experiences and provide rewards

- To promote return to a location, minimize or reduce the duration of restraint and severity of handling and treatment and provide rewards after any treatment (e.g. opportunity for exploration, feed, interaction with handler etc.) in the location.
- Allow habituation to the location and handling through repeated exposure, if possible.
- Apply all aversive husbandry treatments in a location other than those in which pigs are routinely introduced or handled.

Conclusion

Human–animal interactions are a key feature of modern pig production. Research has shown that the quality of the relationship that is developed between stock people and their animals can have surprising effects on both the animals and the stock people. Handling studies on pigs and observations in the pig industry show that human–animal interactions may markedly affect the behaviour, productivity and welfare of pigs. Furthermore, by influencing the behavioural response of the pigs to humans, these interactions can affect the ease with which pigs can be observed, handled and managed by the stockperson. In addition to human contact, physical features of the environment will also influence animal movement, and thus animal handling. Therefore, an understanding of the behavioural and sensory characteristics of pigs is also important in their effective handling and control.

There is a clear ongoing need for the pig industry both to train their personnel to effectively handle and move their stock and to ensure that current knowledge on the characteristics of pigs is utilized in the design of handling facilities. The role and

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impact of the stockperson should not be underestimated; to do so will seriously risk the welfare and productivity of pigs. Indeed, it is possible that the stockperson may be the most influential factor affecting pig handling and animal welfare (Hemsworth and Coleman, 2011). Moreover, it is likely that in the near future, both the livestock industries and the general community will place an increasing emphasis on ensuring the competency of stock people to manage the welfare of livestock.

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17 Transport of Pigs

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Summary

Transport stress is both an animal welfare issue, resulting in animal losses and fatigued animals at slaughter, and a meat quality issue, resulting in carcass depreciation and meat quality defects. Both issues may result in significant economic losses for the industry. The welfare of pigs during transport depends on many interacting factors, such as the condition of the animal, temperature, loading density, time in transit and other factors. Death losses during transport of pigs can vary from a low of 0.06% under good conditions to a high of 6.8% under very hot conditions. The results arising from transportation studies run over the last years have shown that very short journeys may be more stressful than longer journeys and poor vehicle design reduces ease of loading/unloading and thermal comfort of pigs during transport, sometimes resulting in meat quality defects. These effects can be exacerbated by the use of stress-susceptible pigs and insufficient space allowed for pigs to lie down and rest during transport.

Keywords: behaviour, handling, meat, mortality, physiology, pigs, stress, transport, welfare

Introduction

Based on the proportion of dead-on-arrival (DOA) and non-ambulatory pigs, and the animal behavioural and physiological response (heart rate, body temperature and blood parameters), transportation to slaughter, including loading at the farm and unloading at the abattoir, can be considered as one of the most stressful events pre-slaughter for pigs (Ritter *et al*., 2009a,b; Edwards *et al*., 2010a; Correa *et al*., 2013, 2014; Torrey *et al*., 2013a,b). Actually, transport stress is the result of several factors, such as close interaction with humans, handling through ramps, steps and tight spaces, unfamiliar noises and smells, vibrations, extreme variation of ambient temperatures and social stress (mixing with unfamiliar pigs and lower individual space; Bench *et al*., 2008). When the effects of these factors on animal welfare during transport are severe, they can even affect the physical condition of pigs at slaughter resulting in meat quality defects (Schwartzkopf-Genswein *et al*., 2012).

Over the years, transport research has mainly focused on market pigs (Rioja-Lang *et al*., 2019) and has been, above all, addressed to meet animal welfare, regulatory and pork industry economic concerns related to the loss of animals during transport or related carcass condemnations ($4–46 million annually; Ritter *et al*., 2009b; Schwartzkopf-Genswein *et al*., 2012; Peterson *et al*., 2017) and maintain public trust towards meat production practices (Faucitano *et al*., 2017; Muringai *et al*., 2017). In response to these concerns, transport regulations and guidelines have been developed or revised based on the latest science, or are in development. Examples are the Transportation Codes of Practice, which are presently under revision in Canada, the Transport Quality Assurance (TQA) in the USA (National Pork Board, 2017), the EU Practical Guides for Transport (www.animal-transportguides.eu), the new Code of Welfare developed by the New Zealand government (Minister for Primary Industries, 2016), the Australian Animal Welfare Standards and Guidelines (Australian Government, 2012) and the Farm Animal Requirements set up by the China Association for

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Standardization (Standards of China Association for Standardization, 2014).

The objective of this chapter is to provide an overview of some of the latest outputs of swine transport research related to the effects of vehicle design and travel conditions (i.e. travel time, loading density, ambient control and reception at the abattoir) on pigs' behavioural and physiological response, and carcass and meat quality.

Welfare

Transport stress

Coping

The term 'stress' is used when an animal's coping strategy is unable to deal with a change in circumstances, such as transport. Stress activates hormones via the pituitary-adrenal system (glucocorticoids) and the sympathetic-adrenal medullary system (catecholamines), resulting in clinical and behavioural deviations from normal functioning, followed by exhaustion (Fig. 17.1). The animal's control system becomes overloaded and its biological fitness starts to fall (Broom and Johnson, 1993). The feelings of stress have an impact on the animal's energy reserves and on its body temperature causing its breathing and heart rate to accelerate and its evaporation level to increase. The animals also defecate more frequently (Broom and Johnson, 1993). Excretion, evaporation and respiratory exchange finally result in loss of live and carcass weight (Dantzer, 1982), which is a normal physiological reaction. However, when food and water are withdrawn for a longer time, dehydration and mobilization of fat and muscle glycogen may occur (Tarrant, 1989; Warriss *et al*., 1989).

A well-known disease related to transport is Porcine Stress Syndrome (PSS) (Tarrant, 1989). This syndrome is the acute reaction to stress, mediated by the sympathetic nervous system, which can cause severe distress and even death. The affected animal shows severe signs of dispnoea, cyanosis and hyperthermia and may develop rigor in the muscles before death occurs. Fábrega *et al*. (2002) determined the halothane (HAL) genotype of pigs that died during transport. They assumed that elimination of the halothane gene, which is associated with the PSS, would substantially reduce pre-slaughter mortality. Barton-Gade *et al*. (2007) emphasized that total pre-slaughter mortality was reduced eight-fold in Danish slaughter pigs during the period of halothane gene removal from the pig population. However, genetics can have complex effects on transport stress. For example, pig crossbreds with increasing proportion (25–50%) of Pietrain genetics were more responsive to transport stress as shown by their greater body temperature and blood lactate and CK levels at slaughter, regardless of the presence of the HAL gene (Weschenfelder *et al*., 2012, 2013a).

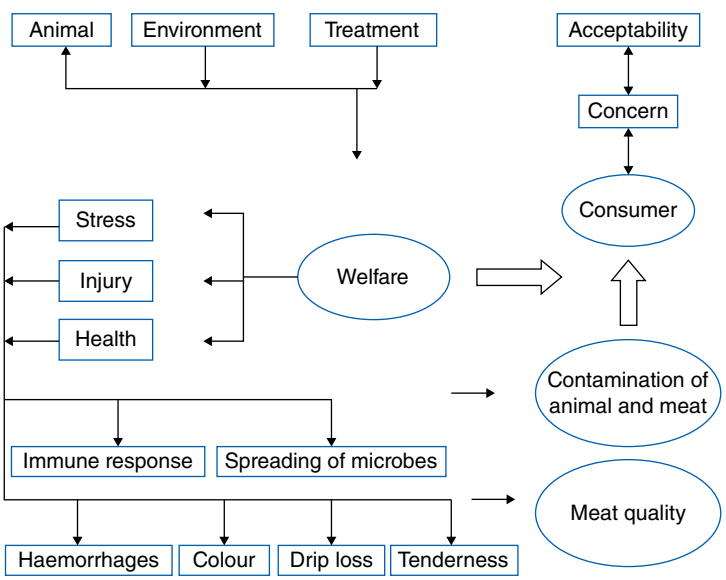


Fig. 17.1. Factors that affect stress, meat quality and contamination.

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Stress indicators

Animal-based measures that are most frequently used as tools to assess transport stress response (acute or chronic) are heart rate, body temperature, blood stress metabolites, skin lesions and meat quality.

Heart rate

The relatively small heart mass with bradycardia (low heart rate) may contribute to the pigs' susceptibility to stress. The heart mass of present crossbreds is, in fact, smaller compared with the wild pig (approx. 0.003 versus 0.007% of the bodyweight) (Yang and Lin, 1997). Furthermore, a lower heart rate and ST-deviation in the QRS complex is especially observed in the ECG of heavyweight pigs (Geers *et al*., 1990). The small heart size combined with the rapid growth of modern pigs, heart abnormalities and acute stress during transport can result in tachycardia and death due to heart failure (Zurbrigg *et al*., 2017).

Heart rate variability can be described as tachycardia, in terms of acceleration of heart beats induced by the release of adrenalin from the sympathetic nervous system in response to an acute disturbing situation or physical activity (Mills *et al*., 2010). Overall, in pigs, heart rate has been largely used as an indicator of a response to a physical stressor, such as being handled using an electric prod or at a fast pace at loading (Correa *et al*., 2010), or climbing or descending a ramp slope (Correa *et al*., 2013, 2014; Goumon *et al*., 2013a), being exposed to a novel environment (Lewis *et al*., 2008), being in thermal discomfort (Correa *et al*., 2013; Goumon *et al*., 2013b) or being moved in larger groups (> 5 pigs/group) (Lewis and McGlone, 2007).

Body temperature

The stimulation of the autonomic nervous system during the stress response induces changes in the peripheral vascular tone and blood flow on the animals' body, resulting in increased body temperature (Blessing, 2003; Mitchell, 2013).

Core body temperature is an index of the thermal balance of the body (Hanneman *et al*., 2004), while measuring skin temperature provides information on the dynamics of body surface temperature distribution, which is regulated by convection through the blood flow in the surface layer and from deeper blood vessels (Ludwig, 2013).

The variation in core body temperature in response to stress has been quite extensively assessed using the I-button technology in recent transport studies (Weschenfelder *et al*., 2012, 2013a; Goumon *et al*., 2013b; Fox *et al*., 2014; Conte *et al*., 2015; Pereira *et al*., 2018). This technique has the advantage to provide a direct measure of body temperature variation in response to thermal and exercise stress, without inducing stress during the measurement (Dallmann *et al*., 2006). After being orally administered to the pig, the data logger is installed in the gastrointestinal tract from which it records the variation of body temperature, real time, at every minute. It is later recovered from the viscera on the processing line for data downloading (Fig. 17.2).

For skin surface temperature measurement, the most used technique is the infrared (IR) technology, which represents an alternative to core body temperature recording as it also varies rapidly in response to acute stress in farm animals, but its measurement is not invasive (Stewart *et al*., 2005). According to the results of comparative studies, the best anatomical locations ensuring the most reliable IR body temperature variation and prediction of the physiological status of pigs appear to be the inner ear (Warriss *et al*., 2006a), head and ears (Centurión *et al*., 2014), and the orbital and behind-the-ears regions (Schmidt *et al*., 2013; Weschenfelder *et al*., 2013b; Rocha *et al*., 2019).



Fig. 17.2. The I-button monitor records gastrointestinal tract temperature, real time, in the live pig and is recovered in the viscera, post mortem, for data downloading. (Photo: L. Faucitano, AAFC, Canada)

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Blood metabolites

The pre-slaughter environment is mostly a source of physical stress, which pigs hardly cope with due to their limited physical activity during the growth period at the farm. The unfitness of modern pigs is showed by the occurrence of the fatigue syndrome, expressed by the frequency of non-ambulatory, non-injured pigs on arrival at the slaughter plant, which affects up to 1% of the market-weight pig population in North America (Ritter *et al*., 2009b; Schwartkopf-Genswein *et al*., 2012), and the increased levels of lactate and creatine kinase, both indicators of the muscle metabolism response to physical fatigue, in exsanguination blood at slaughter (Correa *et al*., 2010, 2014; Edwards *et al*., 2010a,b,c; Rocha *et al*., 2015; Sommavilla *et al*., 2017).

Muscular activity requires energy, which is provided by the breakdown of glycogen in the skeletal muscles. During intense muscular activity, the oxygen supply is often insufficient, so the energy is released through an anaerobic process which converts pyruvate to lactate (Nelson and Cox, 2008). Therefore, muscle lactate is only produced if the working muscle exceeds its anaerobic threshold (Knowles and Warriss, 2000) and is either released into the blood flow in very disturbed or frightened animals or when there is some muscle damage (bruising), caused by vigorous physical exercise (Broom, 1995). As blood lactate is not influenced by post-stunning handling (Aalhus *et al*., 1991) and is a short-term stress indicator (higher peak in four minutes and return to basal levels in two hours after physical exercise (Anderson, 2010)), the greater lactate level in blood at slaughter definitely mirrors the physiological state of pigs prior to slaughter. Greater blood lactate levels have been reported in pigs frequently prodded at loading (Correa *et al*., 2010), handled through steep ramps in the truck (Correa *et al*., 2013, 2014), transported in winter and for longer time (Mota-Rojas *et al*., 2006; Correa *et al*., 2014), and kept in specific compartments of a stationary trailer under warm ambient conditions (Nannoni *et al*., 2014; Pereira *et al*., 2018). The increased blood lactate levels recorded in pigs at slaughter have been correlated with greater pigs' gastrointestinal tract temperature (r = 0.41) and trailer internal temperature (r = 0.42; Sommavilla *et al*., 2017).

Creatine kinase (CK) is found in the skeletal muscles and is responsible for maintaining energy homeostasis at the sites of high ATP (Dieni and Storey, 2009). When the use of ATP is increased, the CK activity also increases in order to resynthesize ATP. In pre-slaughter studies, CK is measured in the blood serum or plasma as a long-term indicator of muscle tissue damage due to strong physical exercise (Knowles and Warriss, 2000) as it reaches the maximum concentration peak six hours after the stress and does not return to basal levels until 48 hours after (Correa *et al*., 2013). Increased concentrations of CK in blood collected at slaughter have been reported in pigs transported in winter (Correa *et al*., 2014) or in summer (Sommavilla *et al*., 2017), handled through trailer ramps (Correa *et al*., 2013; Weschenfelder *et al*., 2013a), and transported in specific compartments (rear top and bottom decks) and for longer time (18 vs. 6 h) (Sommavilla *et al*., 2017).

Product Quality

Skin damage

The presence of skin damage is both an animal-based criterion in the animal welfare assessment (Welfare Quality®, 2009; European Food Safety Authority, 2011) and an economical issue as it may result in carcass or prime cut downgrading (Faucitano, 2001). During loading and unloading, transport injuries and bruising commonly occur in all animal species (Grandin, 1990). It is observed that 63% of 5484 carcasses from pigs in the EU had some damage, although the damage was moderate to severe in only about 10% of the carcasses (Warriss *et al*., 1998). Common causes of skin damage on the pig carcass are poor handling through alleys, ramps and compartments, and fighting and mounting during mixing and handling (Barton-Gade *et al*., 1996; Faucitano, 2001; Correa *et al*., 2010; Vitali *et al*., 2017). Biting- and mounting-type lesions, characterized by short comma or long scratch shapes, respectively (Faucitano, 2001), are those most commonly observed on the pig carcass at slaughter (Varón-Álvarez *et al*., 2014). Guàrdia *et al*. (2009) reported an increased risk of skin damage with longer loading time, reduced space allowance in winter hauls and greater carcass weight. Based on its positive association with muscle ultimate pH values and blood lactate and CK concentration at slaughter (Warriss *et al*., 1998; Gispert *et al*., 2000; Sommavilla *et al*., 2017), skin damage score may contribute to explaining the physiological stress response and meat quality variation.

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Meat quality

Transport conditions may affect post-mortem meat quality, either via adrenal or other stress responses or by fatigue of the animals. Important meat quality parameters related to stress and muscle exhaustion before slaughter are pH, rigor mortis, temperature, colour and water-binding capacity.

The conversion of muscle to meat goes through the breakdown of glycogen to lactate. The rigor mortis value is indirectly caused by a decrease of the energy store. Temperature is increased by chemical metabolism (Sybesma and van Logtestijn, 1967). Colour and water-binding capacity are determined by protein denaturation, caused by a rapid acidification after death (Tarrant, 1989). The rate of acidification after death is controlled by the degree of hormonal and contractile stimulation of muscle immediately before and during slaughter, whereas muscle temperature at death and rate of cooling are also important (Monin and Ouali, 1992).

It is assumed that stress before slaughter leads to an increased breakdown of glycogen and a greater decrease in the energy store and thus a rapid acidification, an earlier and increased rigor mortis value and an increased post-mortem muscle temperature (Klont and Lambooij, 1995a). The normal range of body temperature in resting pigs varies between 37.0 and 39.6°C (Hannon *et al*., 1990). Pre-slaughter stress factors, such as exercise and high ambient temperatures, might easily elevate the body temperature to values between 39.0 and 41.0°C, with the highest increases in stress-susceptible pigs compared to stress-resistant pigs (Gariepy *et al*., 1989; Geers *et al*., 1992; Gispert *et al*., 2000). An increase to the upper level of the normal range in combination with an increased lactate formation after slaughter may already cause an increased incidence of PSE (pale, soft, exudative) meat (Tarrant, 1989; Gispert *et al*., 2000), especially in stress-susceptible pigs (Klont and Lambooij, 1995a). Recently, an increased proportion of pork with PSE characteristics has been reported in Pietrain crossbreds carrying the HAL gene, regardless of the vehicle model (i.e. pot-belly or flat-deck trailer) used for their transport to slaughter (Weschenfelder *et al*., 2013a). Information from about 5500 pigs killed in the EU has shown large differences in the prevalence of potentially PSE meat (ranging from 2% to 69%) (Warriss *et al*., 1998). The analysis of meat quality data obtained on 2700 loins assessed in 11 trials carried out at the major Canadian slaughter plants revealed issues with either pale or exudative and soft, and PSE pork (Faucitano, unpublished results; Faucitano *et al*., 2010). These quality defects can be of genetic or environmental origin or result from the effects of the interaction of these two factors on the physiological response to pre-slaughter stressors. For example, a number of studies showed a variation in meat quality parameters from pigs of different genotypes, but originating from the same production unit and subjected to identical pre-slaughter handling (Klont *et al*., 1993; Klont and Lambooij, 1995a,b). Ambient and transport conditions can also influence the occurrence of PSE pork, regardless of the genotype. For example, lower pHu values have been recorded in stress-resistant Hampshire pigs (Monin and Sellier, 1985) and a greater incidence of PSE or pale/exudative pork has been reported in pigs of Hal gene-free crossbreds after short transport in summer (Fortin, 2002; Chai *et al*., 2010) and transported in the upper and bottom decks of a PB trailer (Correa *et al*., 2013).

In warm weather conditions, the application of water sprinkling for 30 minutes before unloading will help reduce pork exudation in pigs kept in critical compartments of a stationary truck (Nannoni *et al*., 2014).

The occurrence of DFD (dark, firm, dry) meat is more readily attributable to effects of the environment and is less variable among genetic lines. It occurs due to glycogen energy store exhaustion at slaughter, due to fatigue, resulting in no or poor acidification, increased rigor mortis value and dark colour of meat. In well-fed, rested animals, meat pH falls to about 6–6.5, the rigor mortis value is below 10 and the temperature is below 40°C about 45 minutes post mortem (Sybesma and van Logtestijn, 1967; Klont *et al*., 1993). Common causes of DFD pork related to transport are longer-term stressors, such as long transport (Leheska *et al*., 2003; Mota-Rojas *et al*., 2006), and handling through multiple steep ramps and cold temperatures (Correa *et al*., 2014).

Transport of Pigs to Slaughter

Transportation is a multifaceted event starting with loading pigs onto the vehicle and ending with their unloading at the slaughter plant. Factors that have a major impact on the welfare of pigs during transport are, among others, vehicle design, ambient control, travel time and loading density (Faucitano and Goumon, 2018).

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Vehicle design

The vehicle type for pig transportation to slaughter can vary widely, from small single- or double-decked trucks, common in Europe and South America, to large three-deck trailers, either pot-belly (PB) or flat-deck (FD) models, commonly used in North America due to their versatility, as they can haul large loads (up to 230 market-weight pigs) in a single journey. Vehicle design features that may influence the welfare of pigs during transport include the loading/unloading system (ramps or hydraulic device), the compartment location and the microclimate control (Faucitano and Goumon, 2018).

Loading and unloading systems

The presence of fixed decks and ramps within the vehicle makes the procedures of loading and unloading more difficult, resulting in higher risk of animal losses (Barton-Gade *et al*., 2007) and PSE meat (Guàrdia *et al*., 2004). The PB trailer is an example of vehicle design featuring multiple (2–5) and steep (19–32° angle) ramps (Fig. 17.3a,b) and 180° turns that pigs have to negotiate at loading and unloading. This lower ease of handling has been associated with the greater use of electric prods and longer handling time (Ritter *et al*., 2008; Torrey *et al*., 2013a,b; Weschenfelder *et al*., 2013a), which can explain the greater proportion of DOA and fatigued pigs on arrival at the abattoir in pigs transported in the PB trailer compared with others, such as the FD trailer and the double-decked truck (Fig. 17.4a,b,c) featuring hydraulic decks (Ritter *et al*., 2008; Sutherland *et al*., 2009; Kephart *et al*., 2010; Weschenfelder *et al*., 2012; Correa *et al*., 2013, 2014). Increased pork water exudation was also reported in stress-sensitive (Hal^{Nn}) pigs after short hauls (45 min) using a PB trailer compared with an FD trailer, equipped with a middle and top semi-hydraulic decks (Weschenfelder *et al*., 2013a). However, some handling problems at loading and unloading, in terms of greater proportion of pigs overlapping and moving backwards, and frequency of handler interventions, have been also observed on the FD trailer due to the presence of a step near the trailer gate resulting from the middle and upper semi-hydraulic decks being piled up on the bottom deck floor (Weschenfelder *et al*., 2012, 2013a).

Hydraulic loading devices, i.e. moving deck and tail-lift, are also installed in South American and European vehicles, respectively. In a comparison of two double-decked trucks, one featuring a hydraulic upper deck and the other equipped with a fixed upper deck and an internal ramp, in Brazil, Dalla Costa *et al*. (2007) reported easier and faster loading for the truck model equipped with the hydraulic system, resulting in lower exsanguination blood cortisol levels in pigs. The hydraulic tail-lift system is often installed on small (100 pigs load) European trucks (McGlone *et al*., 2014a). A number of studies reported that, when compared with the use of moderately sloped ramps (16–18° slope), the tailgate system did not result in a different heart rate, body temperature and blood cortisol concentration, but may make pigs more reluctant to get into the vehicle (Brown *et al*., 2005). The novel experience of negotiating the lift has been suggested to explain the lack of difference



Fig. 17.3. Internal ramps to get to the upper deck (a) and bottom deck (b) of the pot-belly trailer. (Photo: L. Faucitano, AAFC, Canada)

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Fig. 17.4. (a) Pot-belly trailer (photo: L. Faucitano, AAFC, Canada); (b) flat-deck trailer (photo: E. Brockhoff, Prairie Swine Health Services, Canada); and (c) double-decked truck (photo: L. Faucitano, AAFC, Canada) are vehicle models assessed in Canadian trials under commercial conditions.

in the pigs' response between the two loading systems (McGlone *et al*., 2014a).

The transport deck and compartment

Canadian transport trials reported a greater propotion of PFN (pale, firm, non-exudative) or RSE (red, soft, exudative) pork in pigs transported in the top and/or bottom decks compared with the middle deck of a PB trailer in summer (Correa *et al*., 2013), likely resulting from the combined effect of handling and heat stress during the loading and unloading process through internal ramps. Similarly, higher body temperature, exsanguination blood cortisol levels, dehydration, carcass lesion score and incidence of PSE or DFD pork has been found in pigs transported on the bottom deck of European vehicles (Lambooij *et al*., 1985; Lambooij and Engel, 1991; Barton-Gade *et al*., 1996). In these studies, these effects were likely caused by poor ambient conditions due to insufficient airflow or the high level of vibrations causing pigs to make a physical effort to keep their balance while in a standing position (Guise and Penny, 1992; Barton-Gade *et al*., 1996; Randall *et al*., 1996).

Recent transport studies also showed increased gastro-intestinal tract temperatures after loading and during transport, higher heart rate after loading and longer unloading time in pigs loaded in the front and rear top, and bottom rear compartments of the PB trailer (Goumon *et al*., 2013a; Torrey *et al*., 2013b; Conte *et al*., 2015). In this trailer type, Correa *et al*. (2014) also reported higher pHu values in the *Longissimus*, *Semimembranosus* and *Adductor* muscles and lower drip loss values in the *Semimembranosus* muscle of pigs transported in the middle front compartment. These DFD pork characteristics were also reported in the same muscles of pigs located in the same compartment of a similar PB trailer after long transportation (18 h vs. 6 h and 12 h) in winter (Scheeren *et al*., 2014).

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These effects may be explained by the physical effort needed to negotiate the steep internal ramps to reach these compartments and the different microclimate conditions across compartments (Faucitano and Goumon, 2018).

Higher body temperature and exsanguination blood cortisol and CK concentrations, resulting in greater DOA and poor meat quality (PSE or DFD) were also reported in pigs transported in the front and rear compartments within European vehicles (Barton-Gade *et al*., 1996; Christensen and Barton-Gade, 1999; Warriss *et al*., 2006b), while extreme pig surface temperatures were recorded in the bottom rear and top middle of US trailers (Xiong *et al*., 2015). In Brazil, Dalla Costa *et al*. (2007) also reported greater bodyweight losses in pigs transported in the front compartments of double-decked trucks. Overall, the results of these studies may be explained by the variation in the airflow rate between compartments across the vehicle and the loading order (Faucitano and Goumon, 2018).

Environmental conditions

During transport, pigs can experience extreme temperature fluctuations, often falling below or exceeding their thermal comfort zone (23–32°C for 100 kg pigs) (Randall, 1993). For example, ambient outdoor temperatures ranging from –28.8 to 1.9°C in winter and from 9.1 to 40.1°C in summer have been reported in recent Canadian swine transport trials (Correa *et al*., 2013, 2014; Goumon *et al*., 2013b; Fox *et al*., 2014; Pereira *et al*., 2018).

A number of studies (Vecerek *et al*., 2006; Werner *et al*., 2007; Haley *et al*., 2008a; Correa *et al*., 2013; Vitali *et al*., 2014) reported greater animal losses in summer, with the highest peaks of DOA being recorded during the months of July and August (Haley *et al*., 2008a; Vitali *et al*., 2014). The risk of increased percentage of dead and panting pigs on arrival at the plant is greater at temperatures ≥ 20°C and 17°C, respectively (Warriss and Brown, 1994; Sutherland *et al*., 2009; Haley *et al*., 2008a, 2010; Kephart *et al*., 2010). More recently, a retrospective observational study using ambient temperature and humidity data collected from weather stations in the area of US slaughter plants over a five-year period (2010–2015) reported that the risk of death for market-weight pigs during transport was 1.4 times higher at temperatures between 29 and 33°C than in a temperature range of 12–26°C (Peterson *et al*., 2017).

However, seasonal effects on total transport losses also correspond with low temperatures. A greater incidence of DOA and non-ambulatory pigs on arrival at the plant has been, in fact, also reported in winter than in summer (Clark, 1979; Guàrdia *et al*., 1996; Sutherland *et al*., 2009), with the highest peaks being recorded between the late fall and early winter months (Ellis and Ritter, 2006). Peterson *et al*. (2017) found that the risk of death can be 0.97 times greater in hauls occurring at 4–10°C than at 12–26°C. Transport losses under cold ambient conditions have been associated with a lower ease of handling at loading and unloading (due to slippery floors and ramps) (Torrey *et al*., 2013a,b), reduced in-transit resting behaviour (due to reduced thermal comfort) (Goumon *et al*., 2013b) and greater physical effort and fatigue as showed by the higher heart rate at unloading and blood CK and lactate concentrations at slaughter (Correa *et al*., 2014). These factors can explain the greater number of lesions and frostbites on the carcass reported in winter compared with summer (Correa *et al*., 2013; Goumon *et al*., 2013b; Scheeren *et al*., 2014).

In addition to variations in ramp access, temperature and humidity, vibrational forces may contribute to explain the effect of compartment on pigs' comfort during transport (Bench *et al*., 2008; Lambooij, 2014). Exposure to vibrations during transport may result in travel sickness (Bradshaw *et al*., 1996), standing behaviour injuries (Barton-Gade and Christensen, 1998; Brown *et al*., 2011a), increased heart rate (Perremans *et al*., 1998) and either exudative or dark pork (Barton-Gade *et al*., 1996; Driessen and Geers, 2001).

Strategies to mitigate the impact of ambient conditions

Within a vehicle, the internal temperature can increase by 0.99°C and 0.11°C at each 1°C and 1% increase in the environmental temperature and relative humidity, respectively (Dewey *et al*., 2009). A temperature peak of 30.3°C has been recorded in the bottom compartments of a PB trailer during transport (Brown *et al*., 2011b). When a passively ventilated vehicle is in a stationary situation, its internal temperatures can increase rapidly (approx. 1°C/min) up to 3–4°C rise in 5 minutes (Lambooij, 1988; Xiong *et al*., 2015). Certain critical locations, such as the middle- and bottom-front compartments, can be up to 11°C warmer than the external

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ambient temperature (Fiore *et al*., 2012; Weschenfelder *et al*., 2012, 2013b; Fox *et al*., 2014). This temperature increase is greater in a PB trailer than in FD trailers while stationary or moving (Ritter *et al*., 2008; Weschenfelder *et al*., 2012; Faucitano and Goumon, 2018) due to the difference in the side-opening types (punch vs. slatted) between the two trailer models, influencing the airflow inside the vehicle (Weschenfelder *et al*., 2012).

To reduce deaths during transport, pigs kept in stationary vehicles should be cooled by fan ventilation or water sprinkling/misting, or, even better, a combination of the two systems (Brown *et al*., 2011b). A recent Canadian study showed that a five-minute application of water just prior to departure from the farm and immediately before unloading at the abattoir at ambient temperatures above 23°C reduced pigs' drinking behaviour in lairage (Fox *et al*., 2014); whereas when water sprinkling was applied at ambient temperatures of 20°C and greater, it reduced pigs' fatigue (as assessed by blood lactate concentration) at slaughter and pork exudation, especially in pigs transported in the middle-front and -rear compartments (Nannoni *et al*., 2014). However, water sprinkling combined with insufficient ventilation can increase humidity levels in the trailer by up to 7.5% (Fox *et al*., 2014), which may prevent efficient evaporative cooling. Pereira *et al*. (2018) investigated the effects of an external fan-misting bank, operated during a 30-minute wait in the abattoir yard before unloading, on pigs kept in a stationary PB trailer in summer (16.5–28.1°C). The authors reported that the fan-misting bank efficiently reduced the temperature-humidity index (THI) inside the trailer, resulting in better pig thermal comfort.

In winter, the thermal comfort of pigs in the truck can be controlled by partially or fully closing the ventilation openings in order to reduce airflow (Chevillon *et al*., 2004) and by adding insulation material (Gonyou and Brown, 2012). When the air temperature is below freezing, boarding is critical to prevent death losses and frostbite on the skin of pigs (McGlone *et al*., 2014a). The use of low boarding level (0–30%) at temperatures below 5°C was shown to produce the highest transport losses, while the boarding level from 0% to > 61% appears to have little impact on animal losses at temperatures higher than 5°C (McGlone *et al*., 2014b). For this reason, the Transport Quality Assurance (TQA) guidelines (http://www.pork.org/tqa-certification/tqa-program-materials/) recommend that at temperatures below –12°C, trucks should be utilizing 90% boarding (10% side-vent opening) and 0% boarding above 9.4°C.

Gonyou and Brown (2012) showed that by simply adding a 5 cm layer of styrofoam insulation to the ceiling of the top compartments, the temperature of these compartments increased by 10°C during freezing winter (–20°C).

To control the thermal comfort of pigs during transport, a correct choice of vehicle floor type and a proper use of bedding are also recommended. The compartment floor should be made of insulating material, i.e. lightweight rubber or polyester (Christensen and Barton-Gade, 1996; Guàrdia *et al*., 2004). As a result of improved thermal comfort, the use of polyester instead of aluminium and iron flooring reduced the incidence of PSE pork by 1.5% in a Spanish study (Guàrdia *et al*., 2004).

The amount and type of bedding material used in the vehicles should be adjusted according to the environmental conditions (season) and should not be excessive to ease footing and handling (Kephart *et al*., 2014). To reduce the rate of DOA or downers, McGlone *et al*. (2014a) recommended no more than six bales of bedding in winter. However, this level should be increased in harsh winter conditions to avoid the risk of frostbite on the carcass skin due to prolonged contact of the pig's body with the metal truck floor (Goumon *et al*., 2013b). No more than three bales of bedding are necessary in warm conditions (McGlone *et al*., 2014a).

Overall, Xiong *et al*. (2015) demonstrated that at outdoor ambient temperatures ranging from 5 to 27°C, the TQA recommendations for bedding, boarding and water application are sufficient to ensure an acceptable thermal environment inside the vehicle.

Journey time

According to Marchant-Forde and Marchant-Forde (2009), transport time more than transport distance should be considered in the evaluation of the effects of transport on animal welfare as these effects are experienced by animals from the time they enter the truck to the time they exit it.

Based on a non-linear relationship between journey time and stress, both long and short journeys can affect the welfare of slaughter pigs during transport (Faucitano and Goumon, 2018). Werner

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et al. (2007) analysed data from large slaughter companies in Germany and showed that both long (8 h) and short (1 h) journeys increased the mortality rates of the animals being transported. While in some studies the risk of animal and bodyweight losses, fatigue and DFD pork increased with transport time, in a fair number of studies shorter transport times appear to be more detrimental than longer ones (Table 17.1). A possible reason for the detrimental effect of short journeys is that the pigs may not have had time to recover from the stress of loading when they arrive at their destination (Faucitano and Goumon, 2018).

However, the effects of travel time on pig welfare and meat quality can be exacerbated by other factors, such as fasting duration, ambient conditions, vehicle design, compartment position, space allowance and pig genetics (Faucitano and Goumon, 2018). Averós *et al*. (2008) showed that the risk of mortality decreased in fasted pigs, independently of the journey duration. Weschenfelder *et al*. (2013a) reported an increased level of fatigue (based on exsanguination blood lactate level) at slaughter in Hal carrier pigs hauled for short duration (45 min) with a PB trailer compared with a FD trailer. Vitali *et al*. (2014) reported increased risk for DOA in hauls longer than two hours in summer, while higher body temperature and heart rate have been found in pigs transported for 18 hours in winter than in those transported in summer (Goumon *et al*., 2013b), with more DFD pork being recorded in pigs transported in these transport conditions in the top and rear-bottom compartments of the PB trailer (Scheeren *et al*., 2014).

Rest during transit

When the allowed maximum travel time is achieved (8–36 h depending on the region of the world), it is recommended or mandated that pigs are unloaded from the truck at a station where they are fed, watered and rested (Faucitano and Goumon, 2018). However, the procedures of unloading and loading at a rest stop combined with mixing in a novel environment may be stressful for pigs, as showed by the greater heart rate recorded in pigs unloaded/loaded at the station compared with those kept in the truck during a nine-hour stop following a 20-hour journey (Chevillon *et al*., 2002). However, to keep pigs in the truck during rest, the vehicle must feature equipment for ambient control (i.e. ventilation fans) and feeders and drinkers. To minimize the negative effect of handling at the station on the welfare of pigs during rest it is recommended to: (i) apply the recommended handling practices and stocking density in the rest pen (0.63–0.96 m^2/pig for an 85 to >110 kg pig); (ii) mix no more than two compartments of the truck; (iii) use well-designed ramps, alleys and pens; and (iv) control the ambient conditions, i.e. light (40 lux), water spraying in the alleys and straw bedding in the pen at outdoor temperatures of >30°C and <5°C, respectively (www.controlpost.eu).

Space allowance in vehicles

Animals should be provided with adequate space to stand in their natural position and to lie down at the same time to allow thermal comfort and prevent injury or suffering to themselves (see Welfare

Table 17.1. Summary of the effects of transport time on animal welfare and pork quality.

Transport time	Results	Reference
15 min vs 3 h	Increased blood lactate and cortisol levels at slaughter	Pérez *et al*. (2002)
≤ 0.5 h	Lower ease of handling at the slaughter plant	Grandin (1994)
0.5 h vs > 1 h	Increased PSE pork	Park *et al*. (2003)
40 min vs 5 h	Increased pork exudation	Chai *et al*. (2010)
50 min vs 2 h	Increased PSE pork	Fortin (2002)
50 min vs 3 h	Increased blood cortisol concentration at slaughter	Hambrecht *et al*. (2005)
< 2 vs > 2 h	Increased PSE pork	Gispert *et al*. (2000)
4 vs 0.5 h	Increased DOA and downers	Sutherland *et al*. (2009)
4 vs 1 h	Increased bodyweight losses	Warriss *et al*. (1990)
8 vs 0.5 h	Increased dark pork	Leheska *et al*. (2003)
16 vs 8 h	Increased dehydration at slaughter	Becerril-Herrera *et al*. (2010)
> 12 vs 6 h	Increased blood CK level at slaughter	Sommavilla *et al*. (2017)
24 vs 8 h	More skin bruises and fatigue, and darker pork	Mota-Rojas *et al*. (2006)

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Codes in the later section). The roof must be well above the heads of all animals (at least 30 cm headroom) (SCAHAW, 2002) when they are standing with their heads up in a natural position and should be adapted to average weight and different category of animals, breeds and species (see Welfare Codes in the later section). This height will ensure adequate freedom of movement for animals and ventilation.

Loading density has a major effect on animal welfare, in terms of animal losses, behaviour, skin lesion score, body temperature, heart rate, (stress) hormones and other blood metabolites, muscle parameters, and post-mortem meat quality (Faucitano and Goumon, 2018). For these reasons, insufficient space allowance is one of the hazards with a major risk characterization score identified in pigs that may be particularly relevant for risk managers (van Reenen *et al*., 2008; Marahrens *et al*., 2011).

A loading density for slaughter pigs of 0.425 m^2/pig or 235 kg/m^2 is suggested to be accepted as a compromise between animal welfare, meat quality and economics of transport (Fig. 17.5; Lambooij *et al*., 1985). When the loading density is higher, not all slaughter pigs are able to lie down, resulting in continual change of position, preventing resting. The consequences of this discomfort are more skin blemishes, rectal prolapses and poor meat quality (Lambooij *et al*., 1985; Guise and Penny, 1989; Lambooij and Engel, 1991). At higher densities muscle pH_1 and pH_u values increased, indicating that those pigs were more fatigued (Lambooij *et al*., 1985; Lambooij and Engel, 1991). Throughout a journey of 550 km, pigs displayed more resting behaviour, and lower body temperature and heart activity when loaded at 179 kg/m^2 compared to 235 kg/m^2 (Gerritzen *et al*., 2014). However, in general, more fighting was also observed in the lower-density groups (Gerritzen *et al*., 2014). The floor space, also, has a major effect on transport losses and it is suggested that these losses are minimized at a floor space of 0.462 m^2/pig or greater (Ritter *et al*., 2007), whereas a restricted floor space (0.39 m^2/pig) increased blood CK values at slaughter, but without affecting rectal temperature, blood acid-base balance and *Longissimus* muscle glycolytic potential (Ritter *et al*., 2009a). In a study with different transport durations (40 min, 3 h and 5 h) and stocking densities (230, 275 and 325 kg/m^2), it was reported that the most adequate pre-slaughter transport time was three hours for medium stocking density (less than 275 kg/m^2) under Chinese transport conditions (Chai *et al*., 2010).

Market-weight pigs remain standing when a trip is under three hours and they lie down for longer trips (Guise *et al*., 1998; Mota-Rojas *et al*., 2006). During long journeys (over 8 h), slaughter pigs become gradually less active during transport, the heart rate returns to baseline in one hour and increases again during breaks, along with body temperature (Gerritzen *et al*., 2014). Based on these observations, the application of the EU requirement for loading densities should be adjusted according to travel time. When compared with longer journeys (3 h), the reduction of floor space from 0.52 to 0.40–0.49 m^2/100 kg during a short transport (<1 h) increased the incidence of fatigued pigs on arrival at the plant (Pilcher *et al*., 2011); whereas the application of higher loading densities (0.25 vs. 0.5 m^2/100 kg) in short journeys (1 h) appears to result in lower risk of PSE pork (Guàrdia *et al*., 2004). This latter result may lead to the conclusion that, to avoid PSE pork, the EU-recommended space allowance of 0.425 m^2/100 kg may be only appropriate for journeys longer than three hours (Guàrdia *et al*., 2004).



Fig. 17.5. Low and high loading density of pigs for transport to slaughter. (From B. Lambooji, Wageningen UR Livestock Research, The Netherlands)

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During hot and humid weather, it is recommended to load 15–25% fewer pigs (CARC, 2001; https://ec.europa.eu/food/animals/welfare/practice/transport_en; FASS, 2010). Guàrdia *et al*. (2009) reported that the risk of skin damage is higher (9.7%) for high stocking densities (0.25 m^2/100 kg) in winter, but increased (28.2%) for low stocking densities (0.50 m^2/100 kg) in summer.

If the truck load size is determined simply by the number of animals that need to be shipped, heavier pigs may be too crowded on the truck (Zurbrigg *et al*., 2017). Nannoni *et al*. (2016) reported more loads with at least one DOA when heavier pigs (160 kg) were transported at the EU-recommended density of 235 kg/m^2. For this reason, specific loading densities are recommended for heavier-weight pigs due to their different physical and thermal needs (Tables 17.2, 17.3). Heavier pigs, in fact, generate more body heat (+ 2% for every additional 5 kg liveweight; Brown-Brandt *et al*., 2004) and are less able to dissipate it, which makes them more vulnerable to heat stress than light pigs (Renaudeau *et al*., 2011). According to the latest North American Meat Institute guidelines (Grandin, 2017), the minimum recommended truck space required by market-weight pigs (e.g. from 114 kg to 136 kg) should increase from 0.40 to 0.46 m^2/pig in winter and from 0.46 to 0.55 m^2/pig in summer. In Canada, recommendations for space allowance during transport by bodyweight are given in the Transport Codes of Practice (CARC, 2001), e.g. 0.45 and 0.52 m^2 for 130 and 150 kg pigs, respectively, but are not adjusted according to ambient conditions (except for a recommended 25% increase in hot, humid weather). Some industry guidelines combine market weight (115–123 kg liveweight) with ambient temperatures (< 16°C to > 29°C; FPPQ, 2007).

Table 17.2. Area occupied by standing and sternal lying pigs at different live weights (LW kg) based on allometric equation (area (m^2) = 0.027 x $LW^{2/3}$)[a] as described by Petherick and Phillips (2009).

LW (kg)	Area (m^2)	LW (kg)	Area (m^2)
10	0.1234	110	0.6007
20	0.1950	120	0.6362
30	0.2548	130	0.6708
40	0.3081	140	0.7044
50	0.3570	150	0.7372
60	0.4027	160	0.7693
70	0.4458	170	0.8007
80	0.4869	180	0.8315
90	0.5262	190	0.8617
100	0.5641		

[a]Minimum space allowance per head that may allow simultaneous lying.

Table 17.3. Comparison of space allowances according to ambient temperature and slaughter-weight variation. (Adapted from Schwartzkopf-Genswein *et al*., 2012)

Country	Factors of variation	Space Allowance (m^2/ pig)	Source
Canada			FPPQ (2007)
Ambient temperature x slaughter weight (kg)	< 16°C	0.40	
	115	0.43	
	123		
	16–23°C	0.43	
	115	0.46	
	123		
	24–29°C	0.46	
	115	0.50	
	123		
	> 29°C	0.50	
	115	0.54	
	123		
USA			
Season x slaughter weight	Winter	0.40	FASS (2010) Grandin (2017)
	114	0.46	
	136	0.61	
	182		
	Summer		
	114	0.46	
	136	0.55	
	182	0.65	

Arrival at the abattoir

On arrival at the abattoir, unloading of animals should start within 30 minutes and be completed within one hour (Fig. 17.6; Faucitano and Pedernera, 2017; Grandin, 2017; Faucitano and Goumon, 2018). This time is calculated from the time the truck arrives at the abattoir to the time when the first pig exits the vehicle (Grandin, 2017). If this process is delayed, the tempearture of the air inside the truck can be very warm, with some compartments being 9°C warmer than the outdoor temperature after 30 minutes wait (Weschenfelder *et al*., 2012; Fox *et al*., 2014). These poor ambient conditions can result in a more-than-two-fold risk of animal losses (Ritter *et al*., 2006; Haley *et al*., 2008a,b; Sutherland *et al*.,

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Fig. 17.6. To avoid excessive heat and humidity rise inside a stationary truck and its negative consequences on animal welfare and meat quality of pigs, the wait time between arrival at the abattoir and start of unloading should not be longer than 30 minutes. (Photo: L. Faucitano, AAFC, Canada)

2009) and greater production of PSE pork (Driessen and Geers, 2001; Van der Perre *et al*., 2010).

International Regulations and Guidelines

Public concern for the welfare of livestock is changing production practices worldwide. In extended public surveys held in Europe, USA and Canada, the issue of humane transportation of livestock was deemed as very to extremely important by the large majority of respondents (Mercy for Animals, 2015; Faucitano *et al*., 2017).

According to the results of a questionnaire distributed by the World Organisation for Animal Health (OIE), 83% of the OIE's member countries have legislation regulating animal welfare during transport (Escobar *et al*., 2018). More particularly, in the Americas, national standards on the welfare of animals during transport are available in Canada and the USA, in 90% of countries in South America and in around half of the countries of central America and the Caribbean (Glass *et al*., 2015).

Since 1991, the EU has provided legislation on animal transport, which was then further developed in a regulation (EC 1/2005) on the protection of animals during transport (https://ec.europa.eu/food/animals/welfare/practice/transport_en). Over the years, the content and impact of this regulation has been the subject of scientific opinion from the European Food Safety Authority (2011) and of a report from the Commission to the EU Parliament and the Council (European Commission, 2011). These actions have been followed by the production of guidelines to assess the animal fitness for transport and to good practices in multiple species, including pigs (http://animal-transportguides.eu/).

Similarly, in North America, Australia and New Zealand, animal welfare regulations for livestock transportation (http://laws-lois.justice.gc.ca/eng/

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regulations/C.R.C.,_c._296/; GPO, 1994; Australian Government, 2012; Minister for Primary Industries, 2016) are supported by guidelines (CARC, 2001; NFACC, 2014; National Pork Board, 2017; https://www.mpi.govt.nz/protection-and-response/animal-welfare/) that provide options on how outcome-based standards can be delivered (Thornber and Mellor, 2018).

However, in a recent survey conducted among more than 1000 Canadian respondents, 90% of them supported the introduction of new regulations to improve protection of animals during transportation and almost half of them required them to be the same as the EU ones or stronger (Mercy for Animals, 2015). In response to these requirements, the Canadian Transport Code of Practice is presently under revision based on scientific inputs on key welfare issues, such as transport duration and distance, time off feed and water, rest intervals, environmental conditions, loading density and transport of young animals, identified by scientific and code development committees (Rioja-Lang *et al*., 2019). Furthermore, in order to align with the standards of Canada's international trading partners, such as USA and Europe, and the OIE welfare standards for animals transported by land, air and sea (http://www.oie.int/index.php?id=169&L=0&htmfile=chapitre_aw_land_transpt.htm), amendments to Part XII of the Health of Animals Regulations dealing with the transportation of animals have been proposed (http://gazette.gc.ca/rp-pr/p1/2016/2016-12-03/html/reg2-eng.html). Among others, the proposed amendments concern the reduction of maximum transportation time (from 36 h to 28 h) and the increase of maximum rest time during transit (from 5 h to 8 h) for pigs (Government of Canada, 2016; Faucitano and Goumon, 2018).

Among current international regulations and guidelines regarding pig transportation, lack of consensus exists on loading densities to apply during warm weather, in terms of definition of maximum ambient temperature threshold and how much loading densities should be reduced during warmer weather (Bench *et al*., 2008; Schwartzkopf-Genswein *et al*., 2012). No agreement exists in regard to maximum transport time without feed and water, ranging from eight hours in Europe to 36 hours in Canada, and minimum rest time during transit, ranging from five hours in Canada to 24 hours in Europe (Faucitano and Goumon, 2018).

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Etcomandog, *Bud Box for Loading Pigs*. A few minor changes to an existing building make it easier to get pigs to exit quietly. The Box helps the pigs because it takes advantage of their natural behavior of returning to where they came from. https://www.youtube.com/watch?v=37150dyQLZY

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18 Transport of Market Pigs: Improvements in Welfare and Economics

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Summary

Transportation losses are concerns as they relate to swine welfare and economics. Different vehicle styles are used globally, and vehicle choices are based on the number of animals to be transported, regional weather conditions, facilities, laws and professional judgement. Transportation for the majority of pigs is novel or unfamiliar, which can be stressful. Transportation stress can be affected by events even before actual transportation starts or after the trip has ended; these include the swine–human interaction quality, rearing environment, enrichment access and the loading and unloading processes. Appropriate handling-tool selection can ease loading and unloading in terms of pig welfare, efficiency and handler safety. Pig and handler stress can be minimized when ramps are built with pig behaviour at the forefront and elevators (lifts) are used during loading and unloading. On the trailer, space per pig, group size, bedding levels and quality, boarding, sprinkling, distance transported and other on-board facilities such as feed and water can have impacts on pig welfare, transportation losses and overall economics.

Keywords: loading ramps, pigs, space allowance, stocking density, transport, transport losses, welfare

Introduction

Focusing on the USA, pigs are transported from: (i) a farrowing barn to a wean-to-finish barn; or (ii) from a farrowing barn to a nursery and then from the nursery to a finishing barn; and (iii) to the slaughter plant. This approach helps prevent disease transmission from older finisher pigs to younger pigs and breeding pigs (Zhao *et al*., 2016). Additionally, breeding sows and boars are transported to and from commercial farms.

Therefore, transport is either a novel or unfamiliar experience and can include numerous stressors for the individual pig. Stressors can include varying temperatures/climates, geographies and transport equipment. Stressors can affect transport losses that include conditions in pigs such as non-ambulatory (NA) and in extreme cases dead-on-arrival (DOA). There are two types of non-ambulatory pigs observed under US commercial conditions: fatigued and injured. Fatigued pigs display signs of acute stress (open-mouth breathing, skin discolouration and/or muscle tremors) and a metabolic state of acidosis without showing any physical signs of disease or injury, while injured pigs have a compromised ability to move due to structural unsoundness and/or an injury sustained during the marketing process (Ritter *et al*., 2009). Non-ambulatory pigs can also be further classified into non-ambulatory, non-injured (NANI) and non-ambulatory, injured (NAI). Based

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on the proportion of pig DOA, NA status, behaviours and physiological responses (including heart rate, body temperature and blood parameters), transportation, including loading and unloading, is considered the most stressful process that pigs must experience (Bench *et al*., 2008; Ritter *et al*., 2009; Schwartzkopf-Genswein *et al*., 2012). Reducing transportation losses improves pig welfare and results in positive economic gains for the pork chain.

This chapter summarizes age-related effects during transportation, and discusses pig management and transport equipment that is used pre- and post-transport with the aim of improving pig welfare and economics. The data included throughout are primarily from the USA, which is important to note as pork production differs in other regions of the world. However, some swine production features are common around the world, and where this is known, non-USA data will be included.

Definitions and Truck Designs

Vehicle definitions

The truck or tractor generally refers to the part of the vehicle that has the engine and the driver compartment. The trailer is the part of the vehicle that contains the pigs and is sometimes referred to as a lorry. Most trailers are removable from the tractor (or truck). Sometimes the tractor and trailer are referred to as a truck, but here truck is used to mean either the tractor portion of the tractor-trailer or the entire vehicle, if the trailer is not detachable. Older-style trucks that are found around the world carry pigs in a structure not detachable from the engine.

Trucks/trailer in the USA

Pigs are typically transported in the USA by use of a tractor-trailer. USA trailers come in two general styles: straight-deck and pot-belly. Sutherland *et al*. (2009) reported that market-weight pigs were transported 50% in pot-belly and 50% in straight-deck vehicles. Pot-belly trailers (Fig. 18.1) are often called 'pots', and pots can have a shallow or deep belly. The deep-belly pots are more stable on curved roads because they have more weight with a lower centre of gravity. However, this design can be a challenge to get pigs in and out around the trailer belly. For this reason, shallow-belly pots were developed. Straight-deck trailers (Fig. 18.2) do not require pigs to go up and down slopes



Fig. 18.1. Typical US trailer (attached to a tractor). This is a 'pot-belly' trailer. 'Pots' can have either a deep belly or shallow belly.

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Fig. 18.2. Typical US trailer. This is a straight-deck trailer. It is loaded with an adjustable ramp.

within the trailer, but they have a higher centre of gravity than pots. At the same time, loading into and unloading from the top decks can be an issue for both trailer designs. An additional issue with pot-belly trailers is that compartments in the middle and bottom of a stationary pot-belly trailer are up to 6°C warmer than the external ambient temperature (Weschenfelder *et al*., 2012).

The construction material of USA trailers is typically aluminium to minimize weight. Lighter-weight trailers hold more pigs than heavy steel-bodied trailers. US federal and state laws limit the tractor-trailer weight to 80,000 lb or 36,287 kg (some heavier weights are allowed in some midwestern and western states and in Canada). The length of USA trailers is limited to 53 ft (16.3 m). Pots are shorter, but have about the same floor space as straight-deck trailers. Trailer lengths of 48 and 51 ft are common (14.8 and 15.7 m, respectively). US trailer heights are limited to 13.5 ft (4.2 m). For finishing pigs, the trailer weight, length and height restrictions mean that the space to contain pigs is fixed. Due to the long length and tall height of US tractor-trailers, and because the trailer itself has no engine or power, these semi tractor-trailers cannot travel securely on poor roads (muddy, narrow or overgrown with vegetation) and may have other limitations.

Trucks/railers from around the world

The transport vehicles in Latin America are typically trucks with a single rear axle (Fig. 18.3). Shorter-bed-length trucks without a trailer attached can more easily manoeuvre on narrow, curved and non-paved roads. Trailers may be equipped with on-board watering for drinking or cooling, or the operator can spray the pigs prior to transport manually. Normally, on-board drinking water is only provided for very long transport periods (over 28 hours in the USA, shorter in Europe).

In less-developed countries, the roads are often not paved nor wide enough for long trailers; thus trailers in those countries are commonly single-deck trucks with no trailer. These shorter trucks can travel on less-developed roads, typically from smaller-scale farms.

In Asia, trailer designs are more simplistic. The trailers are made of steel and weight limits are not common (Fig. 18.4). Asian trucks and trailers are larger and would have four decks (or more) and are open compared to a US tractor-trailer. The trailer with many decks is often not aligned with a loading ramp that is at the same level as each deck, nor can they be moveable. When the trailer deck and the loading ramp are not the same level, the pigs must either be dropped or lifted to get in or out of each

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Fig. 18.3. Two-deck truck for transporting pigs in Colombia. The majority of pigs are transported in Colombia (and many Latin American countries) by truck (not tractor-trailers).



Fig. 18.4. Four-deck trailer (pulled by a tractor) in China. The pigs on the top deck are held in by a net.

deck. Trailers in the European Union are more sophisticated and heavier (Fig. 18.5). Side ventilation can be opened or closed, and ventilation can be passive or assisted by powered fans. There also can be an elevator (tailgate lift; Fig. 18.6a) at the rear with the intended goal of easing loading and unloading without the need for a ramp (Fig. 18.6b). The extra structure of the European-style trailer

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Fig. 18.5. European trailer for transport of pigs. Note the mechanical ventilation by electric fans. The side louvres open and close automatically through either a driver's control or based on outside air temperature.

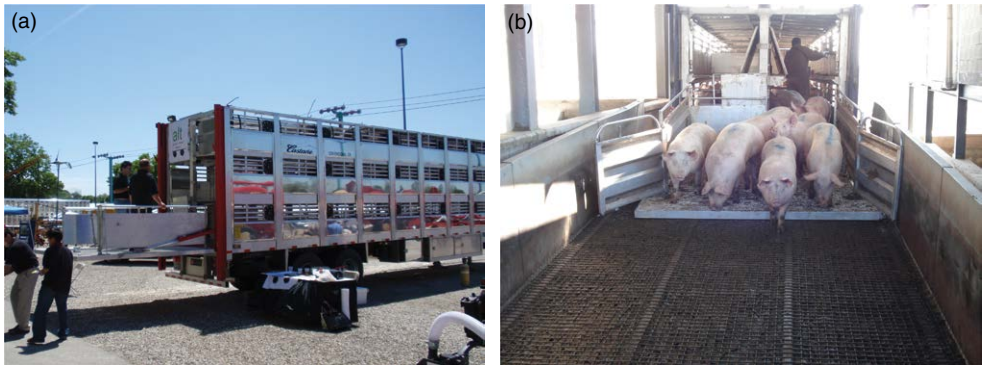


Fig. 18.6. (a) Trailer with an elevator (tailgate lift). This is a European (Spanish) three-deck trailer with mechanical ventilation. The lift obviates the need for a ramp for pigs to climb up or down on. (b) Elevator for ease of loading and unloading.

results in fewer pigs being transported due to the vehicles' heavier weight and the roads' maximum weight allowance. European trailers cost about twice as much as lightweight US trailers and their operation costs are higher because fewer pounds or kilograms of pigs can be transported per trip. If 10% fewer pigs are transported, the transport costs increase by at least 10%.

Transport loss definitions

Definitions of commonly used transport loss terms are found in Table 18.1, although different farms and slaughter plants use different terms. Some plants have only one term for NA pigs, whereas other plants will distinguish between NANI and NAI for NA pigs. Some pigs that become mildly fatigued will recover with rest. Other NANI pigs are unable to move; these pigs may recover with time or they may not recover. Fatigued, NANI, NAI or slow-moving pigs cannot be pushed, dragged or prodded, nor can other pigs or people climb over them (Common Swine Industry Audit, 2018). These pigs can be gently moved by sled or a bucket on a tractor or they need to be euthanized in place.

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Table 18.1. Definitions of transport losses used in this chapter, adapted from those used by the North American Meat Institute (NAMI) (2017) and those used by industry convention.

Pig status	Definition
Dead on arrival (DOA)[a]	A pig that died during the transit from the farm to the slaughter facility. If pigs are non-ambulatory or injured to the point of not being able to unload from the trailer, the pig may be euthanized on the trailer and considered DOA
Non-ambulatory, non-injured (NANI)	A non-ambulatory pig that is not injured, also called a 'suspect', 'subject', 'down' or 'fatigued' pig
Non-ambulatory, injured (NAI)	A non-ambulatory pig that is injured. This pig will have one or more limbs that are damaged (broken, swollen or with a wound) that impedes its walking
Non-ambulatory (NA)[a]	Non-ambulatory is the sum of pigs injured (NAI) and fatigued (NANI). Non-ambulatory pigs will not keep up with the rest of the pigs unloading from the trailer and may even lie down. They will be assisted or carried to a nearby pen and allowed to rest. Another term used for these pigs is 'cripples'. In some cases, 'cripples' includes both NAI and NANI, while in others it includes only NAI
Euthanized on arrival (EOA)	A pig euthanized at plant arrival. These are typically more severe cases of NANI or NAI pigs. Some plants euthanize all NANI and NAI pigs on arrival; others only euthanize severely non-ambulatory pigs
Euthanized in pen (EIP)[a]	If pigs do not recover in a reasonable amount of time or are unable to walk normally (e.g. they have injuries such as a broken leg), they will be euthanized and considered euthanized in pen. Pigs rarely die in the holding pens before being processed
Total dead and down (D&D)	This is the sum of all non-ambulatory, dead or euthanized pigs
OUT[a]	Pigs that are not up to plant marketing specifications are identified, culled and are sold to a plant that processes cull pigs
Injured in trailer (IOT)	Pigs that are injured inside the trailer, if they are unable to walk, are usually considered as NAI and euthanized in the trailer

Definitions marked with superscript letters are from the NAMI guidelines.

Transport Losses in the Field Indicate Opportunities

Transport losses are multifactorial. The loading and unloading procedure is one of the most stressful experiences for pigs. Stress associated with the loading procedure can result from a combination of different factors such as group splitting in the finishing pen, distance moved from the pen to the load point, group size, handling system, alley design, light and sound environment, loading device and the close contact with humans (Goumon and Faucitano, 2017). The pig–human interaction is critical and the use of untrained loading crews can result in an increase of 0.22% in down pigs arriving at the plant (Fitzgerald *et al*., 2009). The USA Department of Agriculture (USDA) and its Food Safety and Inspection Service (FSIS) agency tracks the rate of DOA pigs at federally inspected slaughter plants. However, there is no federal database that summarizes the incidence of NANI and NAI pigs at plants. DOA and NANI rates are often correlated – when one goes up (or down), so the other one moves in the same way. The average DOA values for the last two decades based on the USDA-FSIS reports are presented in Fig. 18.7. An epidemiological study conducted in Canada reported 0.17% DOA and 0.27% NA pigs on arrival at the plant and identified the major source of pig losses as being 25% at the farm followed by 16% by the transporter and the packer (Dewey *et al*., 2009).

Field observations have provided new hypotheses related to transport losses involving both DOA and NANI pigs. Several authors have collected field data at plants in the USA. Most were collected retrospectively from plant records, but Sutherland *et al*. (2009) reported a one-year prospective study in which plant personnel collected data and sent it to the university for analysis. These authors collected data on over 2.7 million pigs over the 12-month period studied and the dataset represented over 16,000 trailers. Trailers averaged 167 pigs each, but most contained 160–180 pigs. Some interesting findings of this study on

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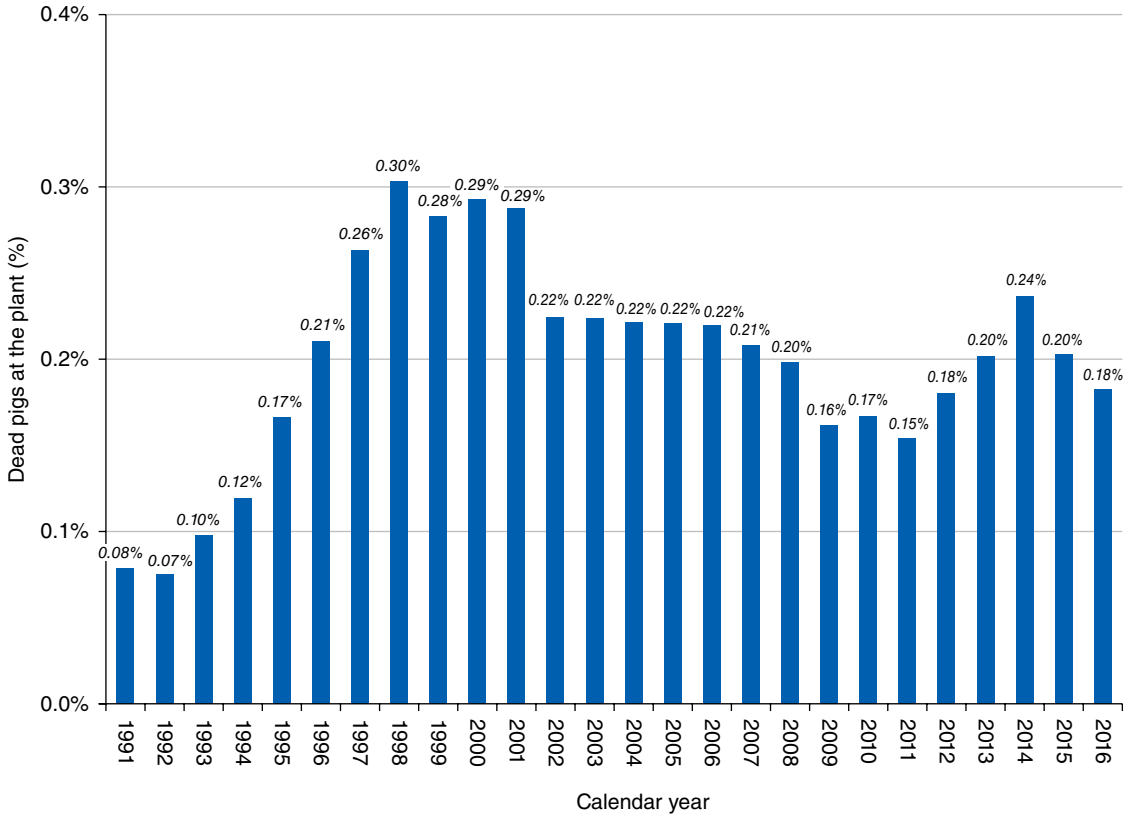


Fig. 18.7. Percentage of dead-on-arrival (DOA) pigs delivered to federally inspected plants in the USA from 1991 to 2016. Note that the rates of DOA rose from 0.08 in 1991 to over 0.30 in 1998. A decrease from 2001 to 2011 of about 0.15% was observed, but the rate began to increase to 0.24% in 2014. DOAs have continued to decrease from 2014 to 2016. (Data from USDA FSIS reports, 1991–2016)

the rates of DOA, IOT, NANI and D&D, worthy of further investigation, include:

- Average rates were:
  - DOA = 0.19%
  - IOT = 0.05%
  - NANI = 0.22%
  - Total D&D = 0.46%
- The rate of DOA increased during warm weather, in a linear fashion from 15°C and warmer (Fig. 18.8a).
- The rate of NANI increased during cold weather (Fig. 18.8b).
- Barrows had a 55% higher total D&D rate than gilts.
- Barrows had a 76% higher NANI rate than gilts.
- Barrows had a 42% increase in rate of DOA compared with gilts.
- Percentage of NANI pigs decreased ($r^2 = 0.93$) in a linear fashion with longer travel times (short trips had an increased risk for NANI pigs).
- Wet bedding increased the rate of NANI pigs by 51% compared with dry bedding.
- Pig losses increased if the wait time at the plant was over 2 hours, and increased more if the wait was over 4 hours (although sample size was limited at the very long waiting times).
- The rate of IOT was 43% greater with very short wait times (less than 10 min) compared with waiting times of 20–60 minutes.

Other field studies found additional factors that can have a significant impact on transport losses. Fitzgerald *et al.* (2009) collected retrospective data on over 12,000 trailers and 2 million pigs transported to slaughter at a midwestern abattoir. They

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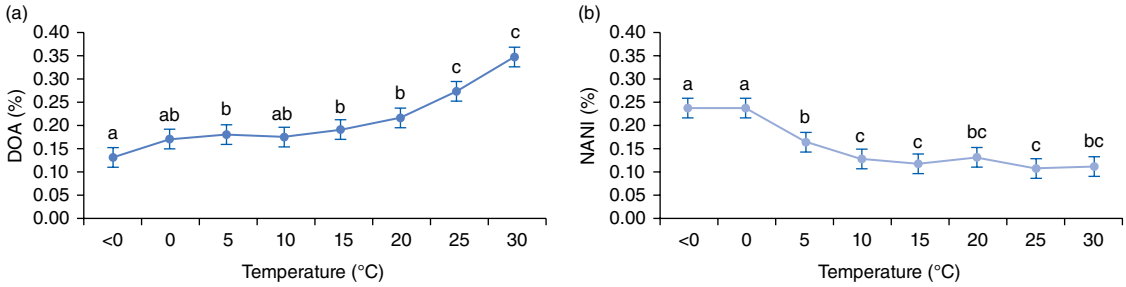


Fig. 18.8. Transport losses over a range of air temperatures: (a) shows the percentage of dead-on-arrival pigs increasing linearly above 15°C (and decreasing below 0°C); (b) shows the rise in percentage of non-ambulatory, non-injured (NANI) when the air temperature was below 10°C. Points on the graph with different letters (a, b, c) were significantly different from one another. ($P < 0.05$).

found many factors varied and they represent opportunities to reduce pig losses:

- week, temperature, humidity index and wind speed;
- driver, load crew and farm;
- trailer pig-stocking density;
- load time at the farm and wait time at the plant;
- pig removal order (first cut or later cuts from the barn);
- type of finishing barn.

A recent study by Dalla Costa *et al.* (2017) looked at truck suspension and its effect on pig welfare and meat quality. The authors assessed the effects of commercial suspension (leafspring; LS) versus air suspension (AS) and their effects on blood cortisol, lactate, lairage behaviour, carcass skin lesions and pork quality traits of 120 crossbred pigs. They found that LS increased the number of skin lesions in the back and thighs of pigs, and produced thighs with lower pH and yellow colour and paler back muscles compared to AS. They did not see a difference in welfare measures (cortisol, lactate, behaviour) but they concluded that the AS system can improve carcass and meat quality traits of transported pigs.

Transportation of young pigs occurs simultaneously with weaning or after nursery, when their physiology has not fully developed, thus exacerbating transport stress (Zhao *et al.*, 2016). Several factors have been reported to impact market-weight pigs but compared to early-age pigs (those < 9 weeks of age), weaned pigs (2.5–5 weeks of age), and feeder pigs (6–9 weeks of age), much less has been established (Zhao *et al.*, 2016). Of the few studies published on early-age/weaned/feeder pig transport, the focus is primarily on: (a) feed consumption, dehydration and additive fatigue of weaned pigs during transition to different feed (Lewis *et al.*, 2008); (b) space allowance and its impact on physiology and behaviour of weaned pigs during short-distance transport (Sutherland *et al.*, 2009); (c) loading and unloading weaned pigs during different seasons on ramps with different angles, bedding moisture and its effect on heart rate (Garcia and McGlone, 2014a); and (d) transportation of weaned pigs with/without the provision of feed and water over a 32-hour period (Garcia *et al.*, 2015, 2016). However, comparisons between age differences and the effect transport has on different-aged pigs have been minimally reported. One publication compares weaned and feeder pigs and the following findings are based on Zhao *et al.* (2016). This study used 7056 pig transportation records:

- Strong interactive effects among pig type (weaned and feeder pig), ambient temperature, and travel distance on pig mortality during transport.
- Weaned pigs have higher mortality rates compared to feeder pigs during transport.
- Pig transport during adverse weather conditions may lead to higher mortality; weaned pigs show higher mortality than feeder pigs during transport in warm/hot conditions.
- In mild conditions (15–25°C), travel distance (up to 2525 km) has little effect on mortality rates of both pig types.
- In warm/hot conditions (>25°C), weaned pigs have higher mortality rates and care should be taken with feeder pigs transported > 1200 km.
- In cold conditions (<15°C), >900-km travel distance increases the mortality rate of weaned pigs but not feeder pigs.
- Post-transport mortality of weaned pigs may be affected by ambient temperature during transport (but only for the second week) and travel distance is still uncertain due to confounding factors.

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The field data suggest some controlled studies that may confirm methods for improving pig welfare and transport losses. From here on, the focus is on controlled studies that indicate methods and procedures that might improve transport losses and pig welfare.

Handling of Pigs

Novelty and enrichment

The main stressor associated with transport is the novelty or unfamiliarity of the experience. Lewis *et al*. (2008) directly compared pigs that had previous experience to those that had no experience with alleyways and loading ramps. Pigs that had previous experience with the ramp and alley did not have elevated heart rates compared with pigs that had no experience.

The quality and quantity of the pig–human interaction varies greatly on commercial farms. Stewart *et al*. (2008) evaluated the effects of previous handling (moving pigs out of their home pen to the load-out area on the day before loading) on transport losses. These authors reported that previous handling tended to reduce total transport losses compared with pigs that had not been previously handled (0.07% versus 0.38%, respectively). Hill *et al*. (1998) exposed pigs to environmental enrichment in the form of weekly normal management, daily normal management plus enrichment, a negative control (limited human contact), a positive control ('pleasant' experience of gentle talking to and petting of the pigs for 2 minutes by the human subject) and positive control plus enrichment. The absence of human exposure caused a significant fear response (running and avoiding humans) among pigs when they experienced people at transport. Increasing human contact from weekly to daily basis did not improve pig handling or pig performance, or change meat quality. Enrichment did not affect the handling and time required to move the pigs. The authors concluded that weekly human interaction was sufficient to avoid fearful responses among finishing pigs.

Tönepöhl *et al*. (2012) wanted to determine the effects of environmental and social enrichment during rearing on pig behaviour during handling. The enriched pen used in the study differed from the barren pen in that it had more toys, a larger number of pigs, and two different types of feeders (as opposed to a single type in barren pens). Both pen types were kept at the same stocking density. The pigs' behaviour in a novel area test, novel object test and handling to move them to the (weighing) scale were measured. There was no difference between treatments for the novel area test, although pigs in the enriched pens touched the novel object more often than the pigs in barren pens. Pigs housed in the barren pens were more difficult to move to the scale than those housed in the enriched pens. Additionally, pigs in the barren environment were less active (had a lower handling-load score) and more excited (had a higher handling-scale score) in the scale than the animals housed in enriched environments. Pigs housed in the barren environment also had more skin lesions than those housed in the enriched environment, indicating a higher level of aggression in those animals housed in barren environments. The authors concluded that a barren environment reduced the pigs' ability to handle new situations, a finding not consistent with Hill *et al*. (1998). Even a small amount of enrichment may improve the issues associated with pigs housed in barren environments. However, the lack of agreement between Hill *et al*. (1998) and Tönepöhl *et al*. (2012) suggests we have a poor understanding of housing systems, genotype and human interaction effects among commercial pigs.

Handling tools

Handling tools recommended by the US swine industry to move finisher pigs include sort boards, flags, rattles, witches' capes and/or paddles (NPB, 2008). The use of electric prods, also called goads and 'hot shots', is controversial within and across the pork production chain. Grandin (2011) noted that electric prods should not be used to move finisher pigs onto the trailer. The USA guidelines (Pork Quality Assurance Plus and Transport Quality Assurance, PQA and TQA, programmes, respectively) suggest that the use of electric prods is a stressful event and should be avoided or minimized. Furthermore, the guidelines state that pigs must never be prodded in sensitive areas such as the eyes, nose, anus or testicles. Additionally, the duration of the shock must not exceed one second and pigs should be given five seconds to respond before another shock is applied (CSIA, 2018). If regular use of an electric prod is needed, the adequacy of the handling facilities should be examined.

Research on the use and implications of the electric prod is sporadic. Veum *et al*. (1979) looked at

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physiological responses (plasma creatine, phosphokinase (CPK), blood pH, plasma lactic dehydrogenase (LDH), plasma glucocorticoids, rectal temperature, heart rate and respiration rate) of three stress-susceptible and three stress-resistant purebred Hampshire pigs that weighed 100 kg (220 lb) to electrical stress. This study indicated that stress-susceptible pigs would be more sensitive physiologically to the electric prod effects. Stress-susceptible pigs had a greater decrease in blood pH than stress-resistant pigs. Guise and Penny (1989), in the UK, compared the use of high and low stocking density loading onto trucks either with or without the use of a prod. They found that skin blemish incidence was related to electric prod use during transport and to stocking density. Brundige *et al.* (1998) looked at the effects of two loading techniques. A total of 48 market-weight pigs were assigned to either hurdles (H) or electric prods (EP). Pigs subjected to the EP had higher activity levels after loading on the truck than H pigs. Heart rates and rectal temperatures were higher in EP pigs after loading than in H pigs, though salivary cortisol was not different between the two treatments. These results suggest that the use of electric prods to load pigs has a significant negative effect on welfare.

In another study, Correa *et al.* (2010) studied the effects of moving devices on 360 crossbred pigs. The pigs were distributed evenly into three treatment groups: movement from home pen to truck using an electric prod and sorting board; movement from home pen to truck using a paddle and sorting board; and movement from the home pen to truck using a paddle and sorting board and the use of a compressed air prod in the ramp. Those pigs moved with an electric prod moved faster than those in the other treatment groups. Of all the treatments, pigs in the compressed air prod group moved the slowest. The authors attributed the slow movement of pigs from the compressed air prod treatment to (i) the noise made by the air; and (ii) the handlers' inexperience with the compressed air prod. Pigs moved with the compressed air prod also turned around more often than those animals in the other treatment groups. Additionally, pigs moved with the compressed air prod slipped and fell more and vocalized more and for a longer duration than those pigs moved with other devices. Physiologically, the pigs handled with the compressed air prod had a higher heart rate during loading, before departure, and in lairage than pigs moved by different tools.

Several of the studies mentioned describe the adverse effects of prod use at the time of marketing. A recent study, however, examined the amount of prod use on physiological measures and reported no differences in rectal temperature or blood acid-base balance for market-weight pigs moved at their own pace for 75 m through a handling course using either plastic livestock paddles or two shocks from an electric prod (Ritter *et al.*, 2008). McGlone *et al.* (2004) compared the efficacy of the electric prod, board, paddle and flag, using a total of 99 barrows and gilts. Efficacy was measured in seconds to move through the course, and by vocalizations (assumed negative) and the number of times pigs' turned around. Only 3.7% of pigs vocalized when a board was used, but over 50% vocalized when either an electric prod or paddle were used (52 vs. 59%, respectively). In terms of the time required to move through a course (less time meaning more efficacious or effective), the electric prod and paddle were found to be equally effective, but the board was more effective than either the prod or the paddle. Upon moving the pigs a second time, the use of a flag had the same efficiency for moving pigs as the board. This indicated that pigs can be effectively moved using boards or flags and that there was no advantage in using electric prods, which are believed to produce a negative welfare experience for the pigs.

Handling intensity

Bertol *et al.* (2005) evaluated the effect of feed withdrawal and handling intensity on blood acid-base responses and muscle glycolytic potential in 60 crossbred finishing pigs. Pigs were allocated to a high-intensity group defined as moved around a facility (12.20 m long × 0.91 m wide) for eight laps, and a handler used an electric prod twice per lap, versus a low-intensity group that was moved around the course for eight laps at their own pace with a handler using a board and paddle. Although rectal temperature did not differ between treatments, the high-intensity group had higher blood lactate values than the low-intensity group. The high-intensity group had lower levels of blood pH, bicarbonate, base excess and total CO_2.

Hamilton *et al.* (2004) studied various handling intensities and their effect on live weight and plasma acid-base response of 80 crossbred pigs. Pigs were allocated to a high-intensity treatment defined as rapidly moving pigs through a course

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and subjecting them to 16 shocks (approx. 5 s) with an electric prod or a low-intensity treatment defined as pigs moved at their own pace with a moving panel and a paddle. The study showed that pigs moved with electric prods required more time (>2 hours; 2 hours' rest was the time suggested for blood acid-base status to return to baseline in low-intensity pig handling) to recover than pigs moved with the moving panel and paddle, as pigs moved with electric prods had higher blood lactate and lower blood bicarbonate and base-excess values two hours after handling.

Collectively, these studies demonstrate the adverse effects of moving pigs rapidly with electric prods on blood acid-base status and the fatigued pig incidence. Additionally, these studies have established that pigs handled aggressively with electric prods have similar changes in blood acid-base status to fatigued pigs at the slaughter plant, and thus validate the use of blood acid-base measurements for studying fatigued pigs (Anderson *et al*., 2002; Ellis *et al*., 2003).

Carr *et al*. (2008) looked at the physiological effects of handling on market-weight pigs using two handling treatments (passive or conventional). Passive handling consisted of loading pigs onto the trailer at a moderate to slow speed with little to no handler vocalization and limited utilization of paddles and boards (no electric prod use). Conventionally handled pigs were loaded more rapidly with vocalizations by handlers and the use of boards and paddles (an electric prod was used once). The passively loaded pigs took almost twice as long to load as conventionally handled pigs (40 and 25 minutes, respectively). There was no effect of treatment on digestive tract temperature during loading; however, when transported at a lower stocking density (0.31m^2/100 kg), the passively handled pigs tended to have lower temperatures than conventionally handled pigs.

Ramps, ramp angles and lifts

Pigs are loaded into and out of trailers before and after transportation, respectively. The design of loading and unloading facilities may vary with the size, scale and design of the farm as a whole. Steep loading ramps can compromise pig welfare and are commonly associated with injuries and prolapses (Guise and Penny, 1989; Warriss and Brown, 1994). Wood or metal ramps usually have solid sides at least to pig height. It is recommended that ramps have a slope of < 25°. Lighting, floor surface, distance between and height of cleats, and the length and width of ramps should be considered when designing the facilities, and will differ depending on the age and size of the pigs (Phillips *et al*., 1988, 1989; Grandin, 1990; Warriss *et al*., 1991; Grandin, 2008).

Usually, pot-bellied trailers are equipped with internal ramps. However, trailers used in Europe may include hydraulic tailgate lifts (Grandin, 2008; Fig. 18.6). In a hydraulic tailgate lift, pigs are directly loaded into the back door of the trailer and moved into a certain deck of the trailer, thus eliminating the need for them to walk up the ramp. In some of the trailers, the back door can be used as a sloped ramp. In an experimental modular system, pigs are first moved into a closed box (module) and a forklift is used to transfer the module to the top of the trailer. Less common is the use of conveyors to load pigs. Lay *et al*. (2017) used a mobile conveyer ramp (7.6 m long, 0.9 m wide, 2.5 m high, at a 16° slope) that moved at 11.3 m/min to load 150 nursery pigs and 280 weaned pigs onto the top deck of a trailer. Behaviour, slips, falls, vocalizations, time to load and heart-rate data were collected. They found that pigs using the mobile conveyor versus using the stationary conveyor (control) needed more assistance loading. Overall, they found that although the conveyor is feasible to use, the results did not show that it was any better than a stationary ramp in improving welfare measures. Thus, it may not be advantageous to use.

Mayes and Jesse (1980) reported an elevated heart rate when pigs ascend the ramp compared with when they descend. A study by van Putten and Elshof (1978) reported higher heart rates with greater ramp angle. Brown *et al*. (2005) loaded and unloaded pigs into and out of the trailer using three different systems: a tail ramp (18°), a hydraulic tail lift and a modular system. The results showed that skin temperature tended to be greater in the pigs loaded using a ramp and hydraulic lift than in pigs loaded using the module, and that when loaded, skin surface temperature increased for the ramp pigs and decreased for the hydraulic tail lift and module pigs. In the same experiment, heart rate increased for each method during loading compared with resting. In contrast, heart rate at resting in the home pen and resting in the lorry were similar for pigs loaded using the ramp and hydraulic tail lift, but were less for pigs loaded using the module. While unloading, heart rate increased for

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pigs unloaded using the ramp, hydraulic tail lift and module. This finding indicated that there was a significant increase in heart rate when loading and unloading for all the treatments. Salivary cortisol concentrations were shown to increase in pigs handled using the module compared with those handled using the ramp and hydraulic tail lift. Salivary cortisol was greater during all the handling events (loading, rest in lorry, unloading and rest in the home pen) despite similar cortisol concentrations at resting in the home pen before the pigs were handled. Sapkota (2012) loaded and unloaded pigs using a ramp and a lift and measured the effect on pig heart rates. The methods used to load the pigs were not different, indicating that the lift might be a novel experience. Berry *et al.* (2012) developed an experimental ramp called a loading gantry. The traditional ramp had a slope of 19° with an internal trailer ramp slope of 23°. The gantry was a covered ramp with a 7° slope to the bottom deck and an 18° slope to the upper trailer deck. More than 500 loads of mixed-sex marketweight pigs were evaluated. Vocalizations were significantly reduced in the loading gantry versus the traditional chute (85% vs. 40% at the first pull, and 87% vs. 49% at barn closing), as were slips, falls and electric prod use. Total market losses (dead, down and injured) were reduced among first-pull pigs but not at closing by use of the gantry (first-pull total losses were 1.0% and 0.6% for the traditional and the prototype gantry, respectively).

Although guidelines have been established for the slope of ramps to be used, there have not been any guidelines established on the use of non-slip material to be used on ramps to further help reduce the incidence of slips and falls. When using potbelly trailers, there is a high number of internal ramps that can cause pigs to slip and fall leading to injuries (Warriss *et al.*, 1991). Garcia and McGlone (2014a,b) used various bedding materials (dry and wet) on ramps with different slopes over different seasons. Bedding included feed (that the pigs were currently being fed), wheat straw hay, sawdust and sand that was compared to a bare ramp. Garcia and McGlone (2014a,b) conducted the same type of study on weaned and finished pigs, except heart rate was not measured on weaned pigs due to the difficultly of keeping heart rate monitors on. A 'score' was created that summed slips, falls and vocalizations. Garcia and McGlone (2014a) found that weaned pig scores increased as ramp slope increased. All bedding (sand, shavings and hay), with the exception of feed (as the score was similar to using a bare ramp), provided protection against slips, falls and vocalizations. There were numerous statistical interactions between bedding, moisture, season and slope. Therefore, recommendations varied based on the occasion. Some bedding worked better than others or did not work at all to reduce scores because the weaned pigs were distracted by playing with the bedding and did not want to move up the ramp. Thus they vocalized when moved with the sort board. The use of bedding on ramps to reduce slips, falls and vocalization is still inconclusive and requires further study in weaned pigs.

For finisher pigs (Garcia and McGlone, 2014b), season affected the total time it took pigs to load and unload the ramp and heart rate and total time increased as the ramp slope increased. Heart rates were also higher in the summer than the winter and increased as the slope of the ramp increased. The use of feed on the ramp reduced heart rates compared to other bedding during the summer in the bedding by season interaction. The bedding by slope interaction showed that the use of sawdust and sand on the ramp kept heart rates the same regardless of the slope of the ramp. Bedding, bedding moisture, season and slope were also reported to significantly interact with and affect the total time to load and unload finishing pigs. Based on the interactions, it seemed to be difficult for the authors to make specific recommendations. In general, during the summer, the use of bedding increased the total time pigs spent loading and unloading the ramp or was similar to using a bare ramp. However, in winter, sawdust had the lowest loading and unloading times along with feed and sand. Overall, the general recommendation was to use sawdust as it is the most economical and most accessible.

Trailer Conditions

Trailer space needs

The TQA programme recommends loading fewer pigs in hotter weather to help reduce transport losses, but does not give further details on pig density on a trailer. Density or pig stocking density on a trailer has been considered in several studies. Some report space as m^2/100 kg (or ft^2/220 lb) (Barton Gade and Christensen, 1998); others look at kg/m^2 (Lambooy and Engel, 1991; Fitzgerald *et al.*, 2009) and still others look at m^2/pig (Lambooy *et al.*, 1985).

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Space needs are difficult to study in terms of the size, scale and time required to obtain accurate and statistically reliable information. Some of the studies were done in the EU, where conditions are sufficiently different and not applicable in North America (e.g. transport trailers are different). In addition, for space allowance, there are few papers that do not confound space/trailer compartment and pig numbers. If one put 10, 11 and 12 pigs at 0.44, 0.33 and 0.66 m^2/pig, how does one know if any observed effect was due to group size or space per pig? It is assumed, at this point, that the difference is mostly due to floor space (or pig density), but we cannot be sure of this.

Fitzgerald *et al*. (2009) studied the effects of density on the trailer. Data were collected on 12,333 trailers of market-weight pigs. This study suggested that pig density on the trailer accounted for a majority of the variation in transport losses between loads. As such, it is important to include a density measurement in any study regarding transport. There was a 7.55-fold difference between the minimum (212.38 kg/m^2) and maximum (338.64 kg/m^2) densities observed.

Barton Gade and Christensen (1998) measured density as m^2/100 kg on Danish market-weight pigs. Four stocking densities were used for this study: pigs were transported at densities of 0.35, 0.39, 0.42 and 0.50 m^2/100 kg for an average of 1.78 hours. This study measured blood creatine kinase (CK), meat quality and blood profile. The 0.50 m^2/100 kg stocking density had the lowest CK levels of all the densities. Stocking density was shown to have relatively little effect on meat quality or blood profile. At lower stocking densities, there was a correlation for more skin damage and a higher risk of trampling.

In addition, stocking density may affect pig behaviour during transport. Lambooy *et al*. (1985) compared pigs transported at three stocking densities: 0.66, 0.44 and 0.33 m^2/pig. This study found that muscle pH increased when stocking density increased. Additionally, pigs in compartments with the lowest density sat or laid down within two hours of the beginning of the journey. Because the highest stocking density did not allow all the pigs to lie down simultaneously, they were continuously shifting positions.

Lambooy and Engel (1991) looked at loading density during a 25-hour journey on a trailer hauling market-weight pigs at three loading densities (186, 232 and 278 kg/m^2 or 0.59, 0.47 and 0.39 pig/m^2, respectively). Lower loading densities (0.47 m^2 and 0.39 m^2) resulted in a higher number of pigs lying down than other loading densities. Continuous change of position was higher when pigs were loaded at the highest loading density owing to the unavailability of space to lie down.

On shorter trips of four hours or less, pigs observed by video recordings showed more standing behaviour than sitting or lying behaviour, irrespective of stocking rate during the trip (201, 241, 281 and 321 kg/m^2) (Guise *et al*., 1996). Climbing behaviour occurred at all stocking densities as the pigs changed position in the compartment. More climbing behaviour incidents were reported for pigs in the highest stocking density (321 kg/m^2). Once the vehicle had stopped at the slaughter plant and the engine had been turned off prior to unloading, lying became the predominant pig behaviour with a stocking density of 201 kg/m^2; however, this change in behaviour was not exhibited when the vehicle was stopped in traffic with the engine running for 50 minutes in pigs at a stocking density of 241 kg/m^2.

Recommendations can be made on the needed space amount for market pigs during transport using current published scientific data in the USA. Under modern US conditions, these recommendations are for pigs of bodyweight 120–140 kg (264–308 lb). Data from two recent papers on this topic are summarized in Table 18.2. Note that few pig measures were significantly different between the six space allowances compared. This is not because biological effects are at play; rather, the sample size needed to detect differences, and the degree of experimental control needed for this type of work is extraordinary. The data that are presented in Table 18.2 are from two studies (Ritter, 2007; Pilcher *et al*., 2011), both from Dr M. Ellis's laboratory at the Department of Animal Sciences of the University of Illinois (Urbana). Both studies used modern genetics and facilities, but both confounded space and group size and, in some cases, other factors. Still, as based on the best studies available, these data enable an examination of the space needs of modern USA market pigs. On the basis of skin discolouration (a sign of stress), these papers suggest that pigs need over 0.462 or over 0.437 m^2/pig during transport; on the basis of total D&D, both studies point to a need for 0.462 m^2/pig (although there is one non-significant trend in that recommendation). For shorter trips, the penalty of increased NANI pigs is greater if less than 0.462 m^2/pig is provided.

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Table 18.2. Summary of two recent papers (Ritter, 2007; Pilcher *et al*., 2011) on the space needs of modern finishing pigs during transport in the USA based on subsequent measures of injury and death.

Measure[a]	Space allowed per pig as ft² (m²)					
	4.26 (0.396)	4.5 (0.415)	4.6–4.7 (0.437)	5.0 (0.462)	5.3 (0.489)	5.6 (0.520)
	Ritter (2007); 131 kg (288 lb) pigs					
DOA	1.37	0.81	0.11	0.09	0.0	0.32
NAI	0.23	0.23	0.25	0.13	0.0	0.0
NANI	1.23[c]	0.74	1.37[c]	0.76	0.13	0.49
D&D	2.84[c]	1.88[c]	1.87[c]	0.98	0.13	0.98
Skin discolouration	8.24[c]	7.23[c]	6.19	7.59[c]	5.58	4.59
	Pilcher *et al*. (2011); 124.7 kg (274 lb) pigs					
DOA	0.10	0.0	0.0	0.07	0.0	0.04
NAI	0.07	0.10	0.02	0.05	0.04	0.04
NANI (short trips)[b]	0.19	0.25	0.38[c]	0.09	0.10	0.08
NANI (long trips)[b]	0.05	0.0	0.07	0.29	0.25	0.17
D&D	0.29	0.22	0.25	0.31	0.21	0.20
Skin discolouration	2.51[c]	2.14[c]	1.63	1.15	1.34	1.34

[a]DOA, dead on arrival; NAI, non-ambulatory, injured; NANI, non-ambulatory, non-injured; D&D, dead and down.
[b]Short trips were <1 hour; long trips were 3 hours.
[c]Differs from the value for the most space (i.e. that furthest to the right of the table) value at $P < 0.05$.

Temperature effect

One consideration that is often overlooked is outdoor temperature. Overstocking pigs during hot weather can result in in-transit losses (Lambooy *et al*., 1987; Lambooy and Engel, 1991). Haley *et al*. (2008) conducted a study in Canada and found that in-transit losses were higher in the summer months (with temperatures >31°C over the months of June, July and August) compared with the rest of the year. The combination of high temperature and humidity can reduce the pigs' ability to dissipate heat through radiative, convective or evaporative cooling (Schrama *et al*., 1996). The inability to regulate core body temperature can lead to metabolic acidosis and cardiovascular failure (Marple *et al*., 1974). Thus, fans on trucks, shipping at night and reducing pig density on trucks may reduce in-transit death during extreme temperatures and humidity (Lambooy and Engel, 1991; Guise and Penny, 1989; Whiting and Brandt, 2002).

Peterson *et al*. (2017) looked at ambient temperature and humidity data from weather stations near US slaughter plants from 2010 to 2015 and used this data to predict the incidence of risk and death associated with in-transit losses. They found that the risk of death for market swine at a heat index (HI; a measure combining temperature and humidity to indicate hot weather conditions) between 29.4 and 33.3°C was 1.37 times greater than that of the baseline temperature range of 12.2–26.1°C and at a minimum of 4.4–10°C was 0.97 times that of the average temperature. For cull sows at an HI of 29.4– 33.3°C, it was 1.93 times greater than that of the average temperatures, ranging from 12.2 to 26.1°C and at a minimum of 4.4–10°C was 0.81 times the risk at the average temperature. Roaster swine had 0.80 times the risk when the HI was 29.4–33.3°C compared to baseline, and at a minimum temperature between 4.4 and 10.0°C was 1.21% greater than the average temperature. Forgone revenue due to condemnations was estimated to be $18.6 million for cold temperatures and $4.3 million for high temperatures (above the baseline). They concluded that current mitigation measures are not sufficient to prevent swine deaths due to extreme temperatures.

A recent survey involving 310 million marketweight pigs was conducted by Yoder *et al*. (2017) to determine the incidence, seasonal variation and economic impact of dead and non-ambulatory pigs from unloading to stunning at US slaughter facilities. These authors reported that the incidence of dead and non-ambulatory pigs was 0.26% and 0.63%, respectively, and these values represent $89 million in lost opportunity, annually, for the US swine industry. This survey also confirmed that the rates of dead pigs and non-ambulatory pigs peak during the summer months and late fall/early winter months, respectively. Now that

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industry benchmarks and seasonal patterns have been established for dead and non-ambulatory pigs, it is important for the US swine industry to understand risk factors for transport losses and to identify and implement management strategies that minimize the stress throughout the marketing process.

Trailer bedding levels

McGlone *et al*. conducted a study to determine whether bedding level in the trailer affected pig performance and welfare in cold and mild weather. The study was conducted using 112,078 pigs of mixed genetics and they observed a total of 572 trailers. The pigs were transported to a slaughter plant where skin-surface temperature, DOA, NA and D&D data were collected. In cold weather, bedding level (using more or less bedding; 12 bales vs. 6 bales) did not affect DOA, NA or D&D. In mild weather, there was no advantage to providing more than three bales of bedding. Overall, they found that losses per trailer were higher during the winter than during mild weather (mainly due to fatigued pigs), overuse of bedding may be ineffective, and that skin temperature may be a good indicator of pig welfare during and after transport.

In the winter and spring, bedding had no effect on the rates of D&D in market-weight pigs hauled in the Midwest. In the summer, as more bedding was used, the rate of D&D increased in a linear manner (Fig. 18.9). Most of the increase in total D&D was due to an increased rate of DOA pigs when more bedding was used. So pork producers can save money by using less bedding in the winter and spring with no negative consequences on the rates of D&D pigs. In the summer, transporters are strongly encouraged to not overuse bedding, as there will be an increase in pig losses.

Trailer boarding

Trailers are operated with all side holes and slats open during warm weather during transportation. As the weather becomes cooler, the trailer is fitted with boards or plugs to block the ventilation holes; this is known as boarding. When the air temperature is below freezing, boarding is critical to prevent frostbite on the pigs' skin. In relatively mild temperatures, the TQA programme recommends boarding levels, although this is based on professional judgement rather than scientific investigation. Below –6°C (20°F) the trailer should be 95% boarded to block out the cold and contain the pig heat in the trailer. Above 10°C (50°F), the trailer ventilation holes should be fully open to allow the ventilation to dissipate pig heat.

In addition, Sapkota (2012) examined rates of transport losses over a temperature range from just below freezing at –6°C to over 10°C. A total of 308 trailers (about 50,000 pigs) were used in these trials. The TQA programme guidelines were examined along with two other boarding levels at each temperature range. From –6 to 4°C, trailers could use 50% or 75% boarding, but when the boarding was too light (25% or less), then the rate of D&D increased. At air temperatures above 4°C, having the trailer boarded at levels of 25, 50 or 75% did not change the rate of transport losses. Thus, transporters should be given flexibility in boarding levels from 4°C to 10°C. New boarding recommendations based on these data are given in the second part of Table 18.3.

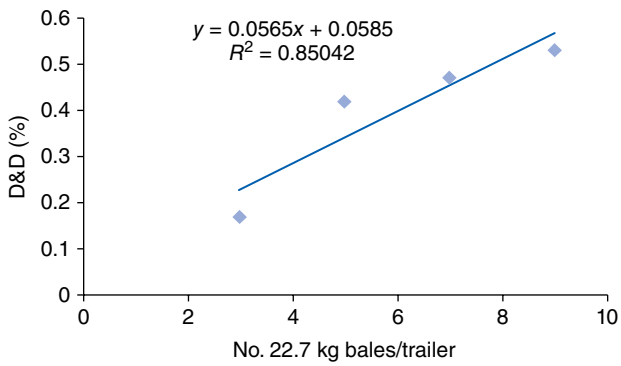


Fig. 18.9. Effects of increasing the amount of bedding (22.7 kg (50 lb) bales/trailer) on total dead and down (D&D) rates. There were 34–104 trailers of pigs per data point in warm weather (16–45°C or 60–113°F). Note that the rate of D&D increased with more bedding, supporting the recommendation for the use of less bedding in warm weather.

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Table 18.3. Effects of varying trailer boarding on the rate of D&D (dead and down) pigs during transport at different temperature ranges.

Temperature range	TQA Guideline on percentage of trailer boarding[a]	% D&D at 25, 50 or 75% trailer boarding		
		25	50	75
20–40 °F (–6–4°C)	50%	0.92[b]	0.22[c]	0.23[c]
40–50°F (4–10°C)	25%	0.54	0.47	0.34
50–60°F (10–16°C)	0%	0.60	0.55	0.38
SE pooled			0.06	

New percentage trailer boarding recommendations at different temperatures based on the above.

Temperature	New % boarding recommendation
Less than 20°F (–6°C)	Fully boarded (~95%)
20–40°F (–6–4°C)	50–75%
40–60°F (4–16°C)	25–75%
60°F (over 16°C)	0%

[a]TQA (Transport Quality Assurance)
[b,c]Least square means with different superscripts within the same row differ ($P < 0.05$). Trailer boarding did not differ among treatments from 40°F (4°C) and above.

Sprinkling of the trailer during warm weather

There are very few studies on the efficacy of sprinkling procedures to minimize losses of pigs during transport in warm weather. A study was recently completed by the authors (McGlone *et al.*, unpublished) that examined the effects of wetting either the pigs, the bedding or both in temperature ranges from 29°C to 37°C. There were similar overall rates of D&D pigs when water was applied to the pigs, the bedding or both (Table 18.4), but the rate of down pigs was higher when only the bedding was wetted compared with only wetting the pigs. Also, because the DOA rate was higher when just the pigs were wet, the overall D&D rates did not differ. When internal misting systems were used (which happened when the air temperature was above 37°C (100°F), the rate of D&D was 0.188% (lower than in the main study). So wetting pigs and/or bedding is recommended either by direct hose or, preferably, by using the internal trailer misting systems.

Table 18.4. Effects of water application by various methods on transport losses during warm weather 85°F (29°C)–100°F (37°C) (Kephart *et al.*, 2014). Overall, the D&D rates did not differ with the different water application methods.

Treatment	No. of trailers	Losses (%)		
		DOA + EOA (dead)[a]	NANI + NAI (down)[a]	D&D
Wet bedding	24	0.110	0.119[b]	0.222
Wet pigs	35	0.261	0.021[c]	0.352
Wet bedding and pigs	53	0.353	0.047[bc]	0.466
Standard error pooled	–	0.075	0.106	0.188

[a]DOA, dead on arrival; EOA, killed on arrival; NANI, non-ambulatory, non-injured; NAI, non-ambulatory, injured.
[b,c]Least square means with different superscripts differ ($P < 0.05$) within a column.

Nannoni *et al.* (2014) used a water-sprinkling (WS) system inside pot-belly trailer compartments that were activated every five minutes in a stationary truck on a farm at the end of loading and at the slaughter plant before unloading. Pigs in the WS system had lower lactate levels and the pH of the *Longissimus dorsi* muscle one hour post mortem was greater than control pigs (transported under commercial conditions), regardless of temperature. They also found that the WS system interacted with the truck locations and the inside temperature. Overall, Nannoni *et al.* (2014) concluded that the WS system was effective, more so in some compartments of the pot-belly trailer than others (such that lactate levels were lower at exsanguination for pigs in compartments at the front and rear of the middle deck, respectively); it reduced stress and improved pork quality of pigs. Further research is warranted, as it would not be economical to have a WS system where only some pigs benefit from reduced stress measures and improved pork quality.

Conclusion

Transportation is inevitable in commercial swine production globally. Several factors play a role in transport loss and changing just one factor might not significantly affect transport loss rates. However, the effect of one factor might act as a predisposing factor to aggravate the condition. There might be some synergistic effects, too. Based on the results of

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Table 18.5. Recommendations to improve pig welfare and transport losses.

Recommendation	Reference(s)
Use dry bedding; avoid wet bedding	Sutherland *et al*. (2009)
Barrow pigs need special attention because their transport losses are higher	Sutherland *et al*. (2009)
Use no more than six bales of bedding/trailer in the winter. In Canada and other parts of the world, where winter temperatures are lower than in the midwestern USA, more bedding may be required to prevent frostbite. Bedding that is allowed to get wet or frozen may be very detrimental to pigs	Sapkota (2012)
Use no more than three bales of bedding/trailer in summer	Sapkota (2012)
Reduce novelty of handling experiences when possible so the final transport experience is less stressful	Lewis *et al*. (2008)
Train animal handlers to minimize variation among load crews	Fitzgerald *et al*. (2009)
Provide spacing of 0.465 m^2 (5.0 ft^2)/pig	Ritter *et al*. (2008); Pilcher *et al*. (2011)
Provide a ramp angle <20°	Brown *et al*. (2005); NPB (2008)
Use loading systems that improve animal welfare	Berry *et al*. (2012)

different studies, recommendations have been made in this chapter to improve pig welfare during transport and the economics associated with such recommendations (Table 18.5). Handling and management before, during and after transportation of pigs, as well as the events associated with these stages, should be kept in mind. Major factors to be considered in improving pig welfare are: bedding quality and weather conditions; trailer boarding level and ventilation; misting during transportation; reducing novelty during handling; training handlers about proper handling; using proper loading and unloading ramps; humane handling tools; proper group size; and proper space allowance.

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19 Handling and Transport of Horses

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Abstract

This chapter reviews various horse handling methods, including imprint training, positive methods of training and horse transport. The review of imprint training studies indicates that there have been mixed positive and negative results, and that the process may interfere with foal bonding with the mare. Brushing and stroking the mare will facilitate approaching and handling the foal. Positive methods of training, such as clicker training, are very helpful for training horses to enter a trailer. Horses can become stressed when they travel alone, and the position facing rear to the direction of travel may be less stressful. Stalls in horse trailers should be designed so that horses can see each other. During transport, horses will drink less water and there should be stops every three to six hours for feed and water.

Keywords: equine, horses, social behaviour, handling, training, trailering

Introduction

The chapter is arranged in two main parts, the first covers horse handling and the second horse transport.

Handling of Horses

Livestock species, with the exception of dairy cows, are handled rarely. Most livestock are neither trained nor is their value dependent upon their trainability. In contrast, most horses are usually handled daily as individuals. Their ability to be handled safely and trained to respond to physical and verbal cues is the reason for their existence and the basis of their value. For these reasons, most of the handling methods described in this chapter will be for individual animals. The handling methods that are covered include 'imprint training' of the newborn foal and training the young horse, methods of catching and methods of restraint. The discussion also encompasses equine social behaviour and learning, including specific types of horse training, such as round pen training.

Early handling

The easiest way to ensure that a horse will be tractable is to handle the foal from birth (Fig. 19.1). One method of handling foals is termed 'imprint training' (Simpson, 2002). The term itself is probably something of a misnomer because the foal does not become imprinted onto humans, as would a duckling, for example. The foal does not follow people, nor does it show sexual behaviour towards people.

Imprint training involves handling the foal as soon after birth as possible. The goal is to accustom the foal to manipulations that will be done to it in the course of saddling, shoeing and medicating. For that reason, the handler puts his/her arms around the foal's chest and squeezes as if a girth were tightening. The hooves are each tapped with the hand 50 times, or until the foal does not respond, to simulate shoeing and hoof care. Foals seem to resist manipulation of their hooves more than the other forms of handling. The foal is also rubbed all over. Fingers are inserted into its mouth, ears and (while wearing a rubber glove) the rectum so that the foal will not be frightened by bits, thermometers or

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Fig. 19.1. Foal handling: (A) a foal being led from the paddock with use of a halter and butt rope; (B) a foal voluntarily approaching a human handler.

otoscopes. Clippers are held, while running, against the foal's head, neck and body so that it will not be afraid of their sound or vibration.

There is some controversy about how soon after birth foals should be handled. If the foal is manipulated before it can stand, the phenomenon of 'learned helplessness' is probably involved. In learned helplessness, an animal that cannot escape a situation will not even try to escape or avoid it later when escape or avoidance are possible; the animal simply gives up (Maier and Seligman, 1976). The neonatal foal cannot escape and so, in later life, may not try to escape from a farrier or a pair of clippers. Handling the foal a few hours or days later may not be as effective because the foal can then move vigorously. This would indicate that early handling is desirable.

However, care must be taken to avoid disturbing the mare. Some mares will become so agitated at the presence of a person that they will either attack the person or redirect their aggression towards the foal. The odour of the handler may interfere with the mare's recognition of the foal, although in some cases the smell of the handler may reassure the mare. More importantly, the process of imprinting – especially applying stimuli until the foal fails to respond – may take so long that antibodies in the colostrum will no longer be absorbed (gut closure), resulting in the failure of passive immunity.

Evidence has been presented to suggest that intense neonatal handling and maternal separation result in strong dependence of foals on their dams at six months of age and impaired socialization with peers at 12 months of age (Henry *et al*., 2009). In this study, French Saddlebred foals were divided into two groups. Foals in the control group were left undisturbed following birth with disinfection of the naval stump being the only intervention. Foals allocated to the experimental group were handled within 10 minutes of birth and before the foal stood. Handling procedures were those described above. The experimenter restrained the foal in a recumbent position and stroked several parts of its body. Additionally, each foal was exposed to novel tactile stimuli, including a white towel, a plastic bag and a spray of water. The presentation of each stimulus was repeated until the foal accepted the procedure. The early handling procedure was performed by a single handler and lasted, on average, 72 minutes. Subsequent to this early experimental handling protocol, both control and experimental groups received minimal human contact. Prior to weaning, when the foals were six months of age, the researchers observed and recorded mother–foal relationships as well as exploratory and play behaviour. When the foals were 12 months of age, affiliative and agonistic behaviours with same-age peers were evaluated.

The results of the study demonstrated that at six months of age, experimental (early handled) foals appeared more dependent upon their dams, as supported by the finding that they kept shorter distances from their mothers and preferred interactions with their mothers over those with same-age peers. Early handled foals also engaged in less play and exploration behaviour and were more reluctant than controls to approach a human standing motionless in the paddock. Differences in responses to weaning were also observed between control and experimental foals. Two days post-weaning, experimental foals continued to display high frequencies of vocalization and non-nutritional sucking. When foals were one year of age, experimental foals tended to show more aggressive and agonistic behaviour (e.g. threat displays, biting, kicking, chasing) toward their peers

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than control foals, which displayed substantially more affiliative behaviours such as social play, olfactory investigation and mutual grooming (Henry *et al*., 2009).

Handling extending over the first few weeks of life is important, as was found in the study of Mal and McCall (1996), in which foals were handled for 10 minutes/day, five days a week for either the first or the second seven weeks of their lives. The foals handled for the first 42 days were easier to halter break than those handled later. The handling involved rubbing the foals all over their bodies. In an earlier study, Mal *et al*. (1994) had found that foals handled for 10 minutes twice a day for the first week were no easier to manage at 120 days old than were unhandled foals.

Jezierski *et al*. (1999) tested the effects of environment and handling on Konik (Polish primitive) horses. There were four groups: SIH (stable reared, intensively handled), SNH (stable reared, not handled), RIH (reserve reared, intensively handled) and RNH (reserve reared, not handled). Stable-reared foals were raised under typical domestic conditions in a stable. Reserve-raised foals were born in and lived in a harem group within a semi-reserve and were not handled at all until they were 10 months old. At that time, they were divided into intensively handled (RIH) and non-handled groups (RNH). Handling occurred 10 minutes/day, five days a week from two weeks until two years of age for SIH foals and from 10 months until two years of age for RIH foals. Handling consisted of haltering, rubbing the foal all over its body and picking up the hooves. The two non-handled groups (SNH and RNH) were not handled except for routine management and veterinary care. The subsequent test, given at six months (for the SIH and SNH foals only) and at 12, 18 and 24 months for all groups, consisted of three people catching the horse in a paddock, leading it to and from the stable, picking up its feet and holding it while a stranger approached. The horses were given a score for each test, with high being easy to handle and low being difficult to handle. The intensively handled foals were easier to manage than the non-handled foals and the stable-reared horses were easier to manage than the reserve horses at 12 months old but, by 18 months, handling had proved more important than early rearing environment. Fillies had higher heart rates than colts, but their test scores were similar.

There have been eight experiments testing the effects of early handling. See Table 19.1 for a summary of researchers' methods.

Perhaps the best and least invasive way to obtain socialized, tractable foals is to handle their dams (Henry *et al*., 2005). If mares were softly brushed for 15 minutes/day and hand-fed pellets daily for the first five days of their foals' lives, the foals were friendlier, less frightened and more tolerant of handling (saddle pad placement) – not only at one month, but also at one year of age. A passive human standing in the stall did not have any effect. Another worthwhile technique is to handle the foal daily for the first two weeks after weaning/haltering, petting the entire body, picking up the feet and leading; this results in foals that are easier to restrain and less reactive than foals that are only handled later (Lansade *et al*., 2004). Schmidck *et al*.

Table 19.1. Summary of imprint training methods.

Imprint age	Repetitions	Test	Age at test	Author
Birth	Twice a day for 7 days	Approach, responses to stimuli	4 months	Mal *et al*. (1994)
10 min after birth	At 24 h	Hoof, restraint halter,[a] worming	3 months	Spier *et al*. (2004)
10 min after birth	Repeated until foal submitted	Approach person, social behaviour	6 months	Henry *et al*. (2009)
2 h	12, 24, 28 h	Approach, haltering, stimuli	1, 2, 3 months	Williams *et al*. (2002)
2–8 h	5 days	Approach,[a] hoof, responses to stimuli	4 months	Simpson (2002)
24 h	Until 42 days	Halter training[a]	84 days	Mal and McCall (1996)
1–2 days	3 times a day	Approach person, response to novelty, suckle mare	6 weeks	Søndergaard and Jago (2010)
14 days	Until 24 months	Hoof, lead, approach	6, 12, 18, 24 months	Jezierski *et al*. (1999)

[a]Imprinted foals performed significantly better.

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(2018) report that gentle handling during the first two weeks of life produced animals more willing to be touched by people.

A study by Sankey *et al.* (2011) demonstrated the impact of training experience on the lateralized responses of young horses to an approaching human. Asymmetry was observed in the responses of one-year-old 'naïve' horses; specifically, they exhibited more negative reactions when approached on the left than on the right side, with most horses displaying escape or threat behaviour in response to the approaching handler. In contrast, 'trained' two-year-old horses were accepting of approach and contact from both the left and right side. Increasing age or maturity and habituation from regular handling may explain this acceptance, but the authors suggest that younger, naïve horses are more accepting of human approach in their right monocular field. Others have demonstrated valence (in which the left hemisphere of the brain mainly processes neutral or positive emotions and the right hemisphere mostly processes negative emotions) in adult horses (Larose *et al.*, 2006; Austin and Rogers, 2007). In the study conducted by Larose *et al.* (2006), adult horses exhibited greater reactivity when a human holding a novel object approached in the horse's left monocular field. This area of research emphasizes the importance of understanding how the horse perceives its environment.

Stroking and massaging

One method of handling horses that has gained considerable popularity is that of Linda Tellington-Jones (Tellington-Jones and Bruns, 1985). The basis of this method is no different from most training in that the horse is rewarded for correct or desirable behaviour and reprimanded for incorrect or undesirable behaviour, but the emphasis is on positive methods, particularly pleasurable tactile stimuli. The massage method, commercially termed the (Tellington) TTouch®, is good for calming an anxious horse and is a useful adjunct to veterinary examination. The manual contact is in the form of light digital pressure. The digital pressure is applied in a circular motion. A small (3 cm) circle is made, usually in the clockwise direction from 6 o'clock, 360° and beyond to 9 o'clock. The amount of pressure is no more than that which is comfortable when applied to a person's eyelid, i.e. a light touch. The massage can be done anywhere on the body.

Massaging the area around the tail can make a horse much more relaxed and willing to accept a thermometer. Head shyness can be improved by massaging the head closer and closer to the ears or other sensitive areas. Stroking the head may be helpful (Janczarek *et al.*, 2018). The circular motion should not be applied again and again at the same spot during one session or the horse will be irritated. Instead, the procedure is to work across a given area. Pretreatment with massage can relax a horse sufficiently for it to accept a thorough veterinary examination without becoming tense. This technique is also useful for reassuring a horse on first acquaintance. The horse's head will drop and its upper lip will lengthen when it is relaxed, especially when pleasurable sensations are being perceived. Thorbergson *et al.* (2016) found that a rider scratching the withers had a greater calming effect compared to patting the neck.

Pheromones

A pheromone (a chemical released by one animal that affects the behaviour of another) has been synthesized based on the secretions produced by the skin of the mammary gland of lactating mares. This substance, Equine Appeasing Pheromone, can be used to reduce fear both behaviourally and physiologically in horses led through a curtain of plastic fringe. The time to pass through the curtain and the heart rates were lower in horses given the spray in their nostrils 20 minutes before the test than in horses sprayed with the diluent that was used (Falewee *et al.*, 2006).

Physical and chemical restraint

Tying

Horses are restrained by tying or cross-tying. Descriptions of the methods used to train a horse to be tied can be found in Wright (1973) and in Miller (1975). Ideally, a horse should be taught to lead and be fully accepting of the pressure of a halter before tying is attempted. Then, the first tie session should be accomplished in a safe, non-confining place using a halter and lead (including snaps) that will not break. Few horses that respect the halter will do more than 'test' the tie and the few that do usually give up quickly if they don't 'escape' the tie when they pull hard the first few times.

There are several important points to remember here. Quick-release knots or safety fasteners should always be used so that the horse can be freed if it becomes entangled. Ideally, the point to which the

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horse is fastened should be higher than its eyes. Although well-trained horses may be tied to hitching rails, fences etc., this is not recommended because a downward pull exerts pressure on the poll and is more frightening to the horse than an upward pull. These tying situations are not recommended by 4-H horse manuals,[1] even for quiet horses.

Equipment for restraint

Most movement of horses is achieved by means of a halter and lead. Descriptions of training to lead can be found in McGreevy and McLean (2010). A trained gelding or mare can usually be handled by means of a rope and snap fastened to one of the rings in the noseband of the halter. For stallions and fractious horses, a little more control can be exerted using a lead shank with a chain. There are various techniques of restraint using a chain shank, the effectiveness of which depends on the amount of leverage afforded the handler and the sensitivity of the area contacted by the chain.

In all methods using a chain on the face, the chain should be threaded through the noseband rings, with the snap opening facing down towards the horse's face. For minor restraint by this method, the chain is threaded from one side ring to the other across the horse's nose. The reason for placing the chain across the nose is that pressure applied to the nose is painful and will cause the horse to stop or back up. A properly fitted and used chain should release quickly and not apply painful pressure for more than a second or two. The principle is that punishment must be applied instantly, preferably as the horse misbehaves, and should be removed as soon as the misbehaviour ceases. This is the same principle as that used in dog training, in which leash corrections are applied with a choke-chain collar. In both cases, the quick application and release is much more effective than a steady pull, because the animal quickly habituates to a steady pull or begins to fight it if too painful.

The chain can be threaded through the lower-left halter ring and fastened to the upper-right ring; it can then be tightened to pass through the horse's mouth. The chain applies pressure to the gums and the commissure of the lip, causing the horse to stop and raise its head. Placing the chain behind the chin applies pressure to the sensitive soft tissue there and causes the horse to raise its head and move forward rather than stop.

The lip chain – which is very severe – should be a last resort. To use this severe method, the chain is run through the left lower ring and attached to the right lower or upper ring, and is worked under the upper lip with the left hand. This method of restraint should only be utilized by experienced handlers and with the lightest degree of pressure applied to the lead line. It should only be applied to make the horse stand still.

A method of restraint used almost exclusively on horses is the twitch. The twitch is made of a loop of rope or chain attached to a pole. The horse's upper lip is grasped and the loop slipped over the lip and twisted. This applies pressure and, presumably, produces pain. Most horses will stand quietly when the twitch is applied. It had been assumed that this was to avoid more pain that would ensue if the horse moved against the restraint. Lagerweij *et al.* (1984) found that administration of the opiate blocker, naloxone, greatly reduced the effectiveness of twitching, indicating that horses are being sedated by endogenous opiates. Apparently, the pain sensed when the twitch is first applied leads to release of opiates, which sedate the horse. The calm facial expression and hanging head of many horses when twitched indicates that they are somewhat sedated. It is important to remember that an apparently sedated horse can become reactive (in layman's terms the horse 'blows through'). The application of a nose twitch should not be used for extended periods of time, for example during lengthy procedures. The twitch applied to the horse's lip lowers heart rate unless applied for more than five minutes, whereas an ear twitch immediately increases heart rate and cortisol. A twitch should be applied only to the nose and then only for 5 minutes (Flakoll *et al.*, 2016).

There are multiple head and neck postures used in either dressage or reining events, with some considered to be severe and potentially detrimental to horse welfare, but there has been only one study of the behavioural response to one such posture, the extreme hyperflexion known as the Rollkur. The horse exhibited more tail swishing, head tossing and bucking when ridden in the Rollkur position and reacted more strongly to frightening stimuli. Fourteen of the 15 horses chose to avoid being ridden in this posture when tested in a maze, one arm of which led to being ridden in the Rollkur position and the other in a normal poll flexion (von Borstel *et al.*, 2009). For a further discussion of different head and neck positions in equestrian sport and associated welfare implications see the International

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Society for Equitation Science Position Statement on Alterations of the Horse's Head and Neck Posture in Equitation (https://equitationscience.com/equitation/position-statement-on-alterations-of-the-horses-head-and-neck-posture-in-equitation).

Stocks and chutes

Although most handling of horses can be done by tying or holding the horse, there are occasions when it is necessary to further restrain the animal. These occasions are usually for veterinary care or any painful procedure. Stocks consisting of pipes at the level of the horse's chest serve the purpose well when the horse is fairly tractable. The vertical pipes should be 80–90 cm apart, attached to the ceiling and provided with cleats so that ropes can be attached to cross tie the horse. The horizontal pipe should be approximately 120 cm from the floor, which must be non-slip, as animals panic when they start to slip.

The purpose of the stocks is to prevent lateral movement. If more restraint is needed, solid panels can form the front and back of the stocks. This type of arrangement is ideal for rectal palpation, ultrasonic examination and other reproductive procedures. If an unhandled horse must be restrained, solid sides are necessary. This is the manner in which halters can be placed on feral horses that have never before encountered humans.

Typical livestock chutes with metal panels separated from the next panel by spaces are very dangerous for horses, as a horse can easily thrust a limb through the space between the panels and injure itself.

Chemical restraint

The methods discussed above are physical, but it is also possible to use chemical restraint on horses. The most commonly used drugs are the tranquillizer acepromazine (0.04–0.10 mg/kg intravenously [IV]) or the alpha-adrenergic agonist xylazine (0.4–2.2 mg/kg intramuscularly (IM) or 0.21.1 mg/kg IV). A more potent alpha-adrenergic agonist, detomidine, has been developed and is useful for restraint and pain control: the dose is 0.005–0.04 mg/kg IV or IM (Robinson and Sprayberry, 2009). Another drug that can be used for restraint is romifidine (0.08–1 mg/kg IV). Perhaps the most useful product is the oromucosal gel containing detomedine which, given sublingually, produces sedation in 40 minutes that lasts for an hour or two. These drugs should be used only under veterinary supervision.

Catching

Horses are prey animals that have evolved flight as the best means of defence against predators. Therefore, it is not surprising that they quickly learn to escape, especially if they are not too eager to be ridden.

One of the easiest ways to catch a horse is to teach it to come. In general, horses will not come when called simply for the reward of attention. The exception is the single horse – especially a young horse – that may want companionship. Food is the best reward for most horses, although even grain may not be more attractive than a field of young grass. The technique is to: (i) approach the fence and call the horse; (ii) offer it grain, apples or carrots to entice the approach; and (iii) try to accustom the horse to being caught by repeating the catch-and-feed routine many times. The ratio of catches to catches followed by something unpleasant should be low, so do not catch the horse only to work it; catch the horse and let it go, or catch the horse and take it out of the pasture to let it graze or be groomed and massaged.

The problem with using food as a reward is that some horses at all times, and most horses at some times, are more motivated to avoid capture than to eat. In that case, another technique must be used, but even then it is best to have some food to reward the horse when it is caught. Eye contact and posture apparently have no effect, but moving quickly will cause the horse to move away (Verrill and McDonnell, 2008; Birke *et al*., 2011). To catch the horse, move with it at the level of its shoulder, but stop when it stops. Horses will approach a person who leans away from them in a round pen, this does not happen on pasture (Krueger, 2007). When a difficult horse is to be caught, plan to take several hours. Horses would rather not be in continual motion (the basis of round pen training), so most will eventually allow themselves to be approached unless the field is big enough for them to run off and rest while the human has to walk a considerable distance to approach them. When the horse is caught, stroke and reward it. No matter how frustrating the process may have been, do not reprimand or yell at the horse.

Social behaviour

Aspects of social behaviour covered here include social facilitation and methods of introduction of new horses, and the equine flight response.

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Social facilitation

Social facilitation is the technical term for a behaviour that is influenced by the behaviour of other animals. There is considerable social facilitation of behaviour in horses. For example, horses will graze and rest together (Tyler, 1972; Arnold, 1984). When handling horses, it must always be borne in mind that they are herd animals. This is reflected in their behavioural (Houpt and Houpt, 1988) and physiological (Mal *et al*., 1991) response to isolation. The handler should take advantage of this to move horses and to keep them calm in a strange environment. Conversely, extra care must be taken to prevent escape or injury of a horse that is isolated.

Horses will work for social contact with one another, indicating their motivation for this behaviour (Lee *et al*., 2011; Søndergard *et al*., 2011). They should probably be kept in groups because that is their natural social state, but owners are reluctant to expose their horses to the risk of injury. The result of this concern has been a series of studies comparing methods of introduction. Hartmann *et al*. (2009) found that five minutes of exposure in adjacent box stalls that allowed tactile contact through a window reduced aggression, especially biting, by two-year-olds when the horses were released in the same paddock immediately afterwards. However, exposure in adjacent stalls does not reduce the aggression of adult horses when they are placed in a paddock together for the first time (Hartmann *et al*., 2011). If one horse must be placed with two others, first placing one of the familiar horses with the new horse does not reduce the total amount of aggression among the three horses, although the aggression is less intense (Hartmann *et al*., 2011). Unfortunately, fence line contact for a week does not appear to reduce aggression when a single horse is added to a group (Hartmann *et al*., 2012). Horses do not habituate to regrouping – adding a new horse weekly did not reduce the rate of agonistic interactions (Christensen *et al*., 2011).

Flight response

When moving horses, whether as a group or while riding, driving or leading a single horse, one should be aware of those things that frighten horses. Horses are reluctant to enter a dark area from a brightly lit one; they are also reluctant to step on anything that sounds or feels unusual. They often shy when crossing a drain, presumably because of the hollow sound made by their hooves. Many horses are reluctant to cross a stream – or even a puddle. The unfamiliar sound of rushing water probably frightens them and then the feel of water only serves to increase the fear factor. A horse can be desensitized to water by starting with a trickle of water from a hose in a familiar situation. When the horse will cross the trickle, the trickle can be increased to a stream, or allowed to create a puddle. Colours are also of importance; the first time a horse had to walk down an alley, it took more time to walk over the colours of black, white, blue and yellow than over red, green, brown or grey (Hall and Cassaday, 2006). Horses have only a limited ability to generalize; habituation to novel objects will generalize to different-shaped objects if the objects are the same colour and approximate size (Christensen *et al*., 2008a). Training programmes to expose horses to both novel visual and auditory stimuli may reduce shying or being frightened in the future (Drewek and Scofield, 2016).

Windy days are particularly apt to result in problems. Some horses seem frightened by the feel of the wind. In addition, many will shy from bits of paper or light-coloured leaves blowing near them. Pennants or flags can also frighten them. Horses may be reluctant to pass through gates with flapping flags. This can be especially dangerous if the horse is pulling a wagon that can catch on the gate as the horse swerves to avoid the flag.

Learning

The value of a horse depends on its learning ability, so this section discusses the types of learning in horses and the techniques used to train them – specifically, a technique that is favoured in the USA, round pen training. The application of learning theory to horses is also covered.

Observational learning in horses

Multiple experiments have been conducted to investigate whether horses can learn by observation. The first studies, which were based on visual discriminations (Baer *et al*., 1983; Baker and Crawford, 1986; Clarke *et al*., 1996; Lindberg *et al*., 1999) did not reveal that horses could learn by observation; however, a later study, based on learning to 'join up' (Krueger, 2007), indicated that horses were faster to learn to approach the human if they had observed another horse doing so. What was most significant was that this was true only if

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the observer was subordinate to the demonstrator. In a recent review, Rørvang *et al*. (2018) suggested that horse behaviour is influenced by social facilitation and local enhancement (where the behaviour of a demonstrator results in an increase in the salience of a particular stimulus or location), and that, at present, there is no solid evidence of true social learning in horses. The authors caution against overestimating horses' higher mental abilities as this can result in detrimental welfare implications, e.g. isolating horses with stereotypical behaviour under the assumption that neighbouring horses can learn these behaviours through observation. Studies by Christensen *et al*. (2008b) and Rørvang *et al*. (2015) have shown that in fear-eliciting situations (exposure to a fear-eliciting stimulus or crossing a novel surface, respectively), a calm, habituated companion or demonstrator horse attenuated fear-related behaviour and reduced heart rate in naïve or observer horses, thus reflecting social facilitation. The latest study of observational learning used horses that were either the leader in initiating new behaviour or were dominant as demonstrators and found that the presence of another familiar horse increased the likelihood of solving a detour task (navigating around a series of three panels to access a food reward); otherwise the horses turned in the direction of a gate leading to their herd mates (McVey *et al*., 2018).

Emotionality or nervousness has been shown to interfere with learning. If a horse is frightened before attempting to remember, its performance – working memory – falls by almost 50% (Valenchon *et al*., 2013).

Furthermore, injuries to itself and to handlers are often the result of the horse's response to a stimulus it perceives as frightening. Therefore, it is useful to be able to predict which horses are likely to shy, bolt or balk in fear. McCann *et al*. (1988a,b) have developed a temperament or emotionality test for horses based on their response to being herded, isolated and approached by people. The subjective rating of the observers correlated well with the heart-rate response. Handling, or treatment with the drug reserpine, did not improve the heart-rate response of the horses to frightening situations.

Positive and negative reinforcement

One of the most difficult training concepts is distinguishing negative reinforcement from punishment. Negative reinforcement is not punishment. Punishment follows behaviour or misbehaviour. The behaviour will be performed less often when the animal learns that the punishment is contingent upon the behaviour. Negative reinforcement proceeds until the horse performs the desired behaviour. The reason it is so important to make the technical distinction is that most horse training uses pressure cues that are negative reinforcement. For example, the untrained horse is 'nudged' with the rider's heels or tapped with a whip until it moves. Gradually, subtle cues such as a slight pressure by the rider's legs can replace the more forceful ones. When the rider pulls on the reins, he or she is applying negative reinforcement – pressure or pain on the gums or lips until the horse slows down – followed by release of pressure as the horse offers the desired response (McLean and McGreevy, 2004).

Clicker training is a method in which sound is used as a secondary reinforcer. It is very popular, but apparently does not speed learning to touch a target in comparison with using a primary reinforcer – food – alone (Williams *et al*., 2004). Clicker and target training, however, have had positive effects on equine learning and will be discussed later in this chapter (in the section on training the horse to load, haul and unload).

Positive reinforcement is a reward given when the desired behaviour is performed, and should be used in horse training. The horse is rubbed, for example, when it walks up to the trailer, or is given a piece of sugar for coming when called. Sankey *et al*. (2010) found compelling evidence that giving a food reward speeds learning and makes horses friendlier, not only to the person that trained them, but also to strangers. In five-minute daily sessions, yearlings were taught to stand and then to accept brushing, hoof cleaning, surcingle placement, tendon boot application, spraying of the coat and insertion of a rectal thermometer. The rewarded horse learned these tasks faster and accepted the procedures when tested six and eight months later. The rewarded horses also showed fewer instances of kicking or biting. They approached people more often and allowed people to touch them more easily than the non-rewarded horses. An earlier study that compared clicker training using food rewards with negative reinforcement – the application of a whip until the pony performed the desired behaviour – found that the positively reinforced ponies were more likely to approach people than the ponies of the negatively reinforced group (Innes and McBride, 2008). Circus and trick horse trainers make much

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more use of positive reinforcement: the horse is rewarded with a food treat for bowing, for example. Figure 19.2 shows a horse that has been trained to be ridden with no bridle or saddle. Although horses will learn for a reward of scratching their withers by the trainer, they learn better for food rewards and pay more attention to the trainer (Rochais *et al*., 2014). Scratching can be used as a reward in suckling foals (Martinez de Andino and McDonnell, 2017). Training can be hastened by altering the horse's brain with medication. Ponies treated with Zylkene®, a casozepine-containing supplement, learned basic ground manners more quickly than untreated animals (McDonnell *et al*., 2013).

One of the most interesting examples of horse-to-human communication is the study of Mejdell *et al*. (2016). Horses can be taught to use symbols to communicate their preference for blanketing or not. The horse could choose between a 'no change' symbol and the symbol for either 'blanket on' or 'blanket off', depending on whether the horse already wore a blanket or not. We could use this technique to learn much more about making our horses comfortable.

Dougherty and Lewis (1993) studied stimulus generalization. They taught horses that they would receive a reward if they pressed a panel after having felt a touch in a particular spot on their backs; the touch was then moved away from the original location. The horse's response decreased with distance from the original spot. This technique is certainly applicable to horse training. If a horse is taught to move sideways to a touch on one location on his flank, but the next rider cues it in a slightly different location, it may not respond.

The secret of a good trainer is excellent timing. Any negative reinforcement should be removed as soon as the horse begins to perform the desired behaviour; and the positive reward should also be given as soon as the horse performs the desired behaviour (both within a few seconds). Another



Fig. 19.2. Dr Angelo Telatin demonstrates riding a horse with no bridle. The horse responds to subtle body movements of the rider, such as leaning forward to induce the horse to move forward and leaning back to stop. Turning is accomplished by the rider turning his/her head and shoulders in the desired direction. A collar allows for more precise communication of the rider's body cues to the horse. Accurate application of equine learning theories in training reduces stress, and colts and fillies that are treated gently will usually respond well to these methods, and can be ridden with little to no pressure applied from the bit. Jumping novel fences can be trained by taking advantage of horses' natural behaviours; more specifically, horses' investigative behaviour.

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important point is to give only one signal for each behaviour to avoid confusing the horse and to avoid signalling two behaviours simultaneously (McLean and McGreevy, 2004).

Most important here is the timing of punishment. A punishment is a punishment only if it reduces the frequency of a behaviour. The frequency will be reduced only if the horse realizes which behaviour is being punished. The punishment must occur within a second of the misbehaviour. If the horse kicks and is immediately struck with a whip, it will be less inclined to kick, but if it kicks and the handler must walk across the barn to get a whip and then strikes the horse; the horse will not be punished for kicking: the horse will be punished for allowing someone to approach with a whip.

There has been a change in equine training methods over the past 50 years. Gentling has replaced 'breaking', so that inductive methods rather than intimidation and physical force are used. The Jeffrey method of horse training (Wright, 1973), first used in Australia on their feral horses (brumbies), uses an approach and withdrawal technique with a horse in a paddock wearing a halter and lead rope. The trainer approaches when the horse is calm, but withdraws if the horse is even slightly evasive. Using that method, a horse can be saddled, bridled and ridden within a few hours.

Round pen training

In the USA, round pen training is favoured. The main thrust is to move the horse around the pen – at first, simply in a circle, but later inducing the horse to turn towards the outside of the pen and reverse, and to turn towards the inside of the pen and reverse, according to the body movements (mostly head and hip) of the person in the centre of the ring.

Many trainers use a whip or a rope to keep the horse at the perimeter of the circle and to keep it moving fast. At least part of the technique is simply to tire the horse, but what may be more important is that it teaches the horse to watch the human and to pay attention to his or her movements. A galloping horse will turn its ear towards the trainer (Krueger, 2007). The theory is that the human is assuming a dominant or leadership role over the horse; however, it is unlikely that horses perceive us as part of their dominance hierarchy and assuming so can lead to undeserved punishment of the horse (Hartmann *et al*., 2017). Round pen training does not correspond to actions of horses to other horses as claimed, but rather involves habituation, operant and classical conditioning (Henshall and McGreevy, 2014).

There may also be an element of predator avoidance, because to push the horse forward, the person leans forward assuming an almost quadrupedal stand and 'nips' at the horse with rope or whip. To encourage the horse to approach him or her, the person stands up straight and leans back, avoiding eye contact. One of the most interesting aspects of round pen training is that horses will make a mouth movement, opening their mouths enough to run their tongues in and out. The same mouth movement is used by horses when anticipating food or when giving in to a farrier's demands. It may be a care-soliciting expression or simply subordination, but it is not the 'snapping' behaviour of immature horses that open and close their mouths, and also show their teeth.

The principle of round pen training seems to be that horses would rather not run, and they are rewarded by being allowed to stop: they appear to be attracted to the trainer when he allows them to stop. The horse is then rewarded further by stroking. Some trainers stroke the horse before they begin the circling manoeuvre. The next steps are bridling and saddling the horse. Once the saddle is in place, the horse is again induced to circle until it stops bucking or, if it does not buck, until it has become accustomed to the feel of the saddle and of the stirrups flapping against its sides.

Skilled trainers can induce a horse to approach them – 'join up' – within a few minutes. The less skilled rely on exhaustion to control a horse. When a horse has been run for hours around a pen, the owners are usually not happy. Those who master the technique have the ability to observe subtle changes in the horse's demeanour – ears, tail and muscle tension – and an excellent sense of timing, so that the horse can be rewarded instantly for obeying or for approaching. In the traditional round pen training, the horse is moved around the periphery of the pen and then encouraged to approach the trainer, but in interactive training, the trainer removes any stimulus to which the horse responds by avoidance or fear and only gradually reintroduces it. This method takes longer, but the horses approached people sooner and were attentive to them (Baragli *et al*., 2011).

There is one impediment to the application of round pen training – or free lungeing, as it is also called: it requires a round pen. If a conventional

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square or rectangular enclosure is used, the horse will run into a corner. Good practitioners of free lungeing can use a cornered area, but it is much easier – especially for a neophyte – to use a round pen. The best round pens have solid walls so that the horse is not distracted by anything outside the pen. A solid-walled round pen is also much safer than either a rectangular pen or one with rails because the horse does not have so many opportunities to injure itself.

Application of learning theory

Handling of horses requires both an understanding of horse behaviour and a willingness to patiently apply the principles of learning. Creighton and Hockenhull (2012) reported that problem behaviours under the saddle are related to the training techniques and equipment used. The use of 'natural horsemanship', clicker training, or the TTouch® method were associated with fewer problems than the use of traditional training methods. Unfortunately, there is no standard definition for traditional training. The more aids (martingale, spurs, dropped noseband) used the more problems the horse exhibited. There may have been a cause-and-effect relationship here – the more the horse misbehaves the more aids are used. Bitless bridles were associated with fewer behaviour problems. Bitless bridles have become a popular alternative to riding with a bit. However, it should not be assumed that removing the bit removes all pressure from the horse's head. The greatest determinant of severity is how the bridle is used. Whenever the rider takes up the reins, pressure is transmitted to some part of the horse's head. Literature investigating pressures exerted by various styles of bitless bridles and behavioural and physiological responses of horses ridden in bitless bridles compared to those ridden with a bit is limited, and the topic remains controversial.

In their review of the horse–human relationship, Hausberger *et al.* (2008) argue that an important theoretical framework could be that of Hinde (1979), who defines a relationship as an emerging bond built upon the basis of a succession of interactions, in which positive or negative interactions each operate as a step for the next interaction. It seems, then, that a better knowledge of learning rules is necessary not only to train the horse successfully but also to counterbalance the unavoidable negative inputs that there are in routine procedures and reduce their impact on the relationship.

Transportation

Horses were probably transported first across seas, as the earliest reports have warhorses disembarking near Carthage in the 9th century BC, fit enough to proceed immediately to battle (Cregier, 1989). The use to which a horse is put – work, meat or recreation – has a large influence on the frequency, distance and method of transport to which the horse is subjected. Horses used for livestock ranch work, farm work and the hauling of produce and passengers in extensive agricultural enterprises or developing countries are unlikely to travel very far from the area where they were born and used.

Recreational horses include a very large, diverse group of individuals that vary greatly in their frequency, distance and method of movement. The simple pleasure mount is likely to be transported less distance and less frequently than a competitive show horse or racehorse. Most transport of recreational horses is accomplished using private towed horse trailers or large commercial-type vans; in nearly all cases, these horses have individual stalls and care during transit. An increasing number of the international – and some national level – competitors and imported breeding stock are transported by air, a method that significantly reduces travel time over long distances.

Transport via sea shipping may be used and, as with air shipment, the horses are normally placed in individual stalls in customized, containerized, freight-type crates (Doyle, 1988). Some welfare groups have mentioned inhumane conditions in the shipment of slaughter horses via sea.

It is difficult to establish the number of times or distance that an average horse may be moved in its lifetime. Certainly, this would be much greater than for other large livestock, such as cattle or pigs, simply because of their use and longer lifespan. Casual observation of today's equine competitions indicates that during the most active portion of the competition season, a horse might easily be transported every 2–3 weeks to some type of competition.

Many brood mares are also annual commuters from their home farms to the stallion's location, covering distances of a few to over 1500 km, while heavily pregnant or with foal at side. Acceptance and use of shipped semen by the breed registries will greatly reduce the necessity of transport for breeding animals.

Recreational horses are often handled by non-professionals who have minimal experience. This

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can contribute to behavioural problems and injuries acquired both during loading/unloading and transit. Some of the horses subjected to extremely long transport, especially when combined with pre or post stresses from infectious diseases, contract serious illnesses, such as pleuropneumonia.

Requirements for transport

Reasonably safe, low-stress and humane transport of horses from point A to point B can be accomplished if the following points are addressed:

- Use of a transport vehicle suitable to the type of horse(s) being moved and its proper maintenance and operation.
- Preconditioning of the animal, both behaviourally and medically, to be transported; injuries can be reduced by training and habituating horses to loading, transport and unloading. There is still a need for improvements. Two surveys of people transporting horses to equine events showed that injuries occurred in 25–45% of the horses (Padalino *et al*., 2016; Riley *et al*., 2016). Many of these injuries were minor.
- Completion of required governmental medical vaccinations, tests and quarantine specifications necessary for leaving and entering controlled areas (country/state).
- Careful loading, movement and offloading that avoids traumatic injury to the animals.
- Proper care during transit to assure that the horses arrive in healthy condition, free of long-term stress and ready to perform; in a study conducted by Giovagnoli *et al*. (2002) horses transported by inexperienced drivers had higher heart rates and more muscle activity indicating continual postural adjustment to maintain balance.
- Monitoring of the stress accumulation of horses subjected to repeated and/or prolonged transportation situations, especially when additional stressful factors precede or follow.
- Trained handling and medical personnel to properly accomplish the above.

The vehicles that are used for horse transport, usually called vans, are motorized trucks in which the bed is enclosed and fitted with individual stalls to accommodate two or more horses. Horse trailers (also called boxes or floats) are beds made to be separable from the motorized portion, which are enclosed and may or may not be fitted with individual stalls. Trailers that are 'loose' or not fitted with individual stalls are called stock trailers. Trailers that connect over the pulling vehicle's rear axles (gooseneck and tractor-trailer) are more stable for towing than trailers connected to the rear of the vehicle (bumper pull or tag along). Space and engineered weight restrictions (axle-carrying weight, etc.) determine the number of horses that may be carried, which may range from one to over ten animals for individual-stall vehicles and trailers. Large stock-type trailers may carry more horses.

Individual stall construction

An average-size horse (height 158 cm, weight 550 kg) should have approximately 90 cm in width and 2.4 m in both length and height of standing space. This allows the horse to use its head and legs to balance during the motion of the transport vehicle. The standing space should be void of projections, edges and protrusions that could cause injury or be contacted by the horse's head or legs. Padding can be added around the walls to prevent bruising when the horse bumps into the walls.

The construction of the box should be exceedingly strong and include the use of durable material capable of withstanding the forces of weight, pressure, striking, chewing and excrement of the horse. This usually means strong timber (>5 cm thick) and heavy-gauge metal, often in combination with each other. Construction of the sides, floor and ceiling should be mostly solid. Openings that could trap the horse's head or limbs should be avoided.

Other important factors that need to be considered include adequate ventilation and light. The horse in one stall should be able to see other horses nearby to facilitate ease of loading and calm behaviour. Adaptation of the stall to prevent extremes of hot (>25 °C) or cold (<10 °C) temperatures is critical to the horse's life and general health (Leadon *et al*., 1989).

The construction of rear-facing (opposite to the direction of travel) transport stalls should be considered, as there is evidence here that in this position horses maintain balance better and show less muscle fatigue (Clark *et al*., 1988; Kusunose and Torikai, 1996; Partaino *et al*., 2012), have a lower heart rate and a lower stress postural stance (Waran *et al*., 1996); horses also have a preference for this position when transported untethered in large boxes (Smith *et al*., 1994; Kusunose and Torikai, 1996).

Slant-stalled trailers are now popular because they provide for more horses and storage space in

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an overall shorter length of trailer and may increase ease of loading for some horses. Further, designing the front of the stall to allow the horse to lower its head to shoulder height has been shown to be important to normal respiratory function during transits of more than a few hours (Racklyeft and Love, 1990). Most transport stalls have head ties and chest bars that require the horse to maintain its head at 0.25 in or more above the shoulder. Researchers have recommended that feed, including hay, be maintained at shoulder level or below.

Floors need special consideration in both construction and maintenance. Wooden boards of 5 × 15 cm or larger are usually used in smaller trailers, but heavy-gauge metal can also be used. Rubber mats and/or bedding are almost a necessity to prevent slipping on most floors once they get wet. Bedding also encourages the horse to eliminate wastes during long transits, which is desirable. Cleaning, maintenance and inspection for wear, rot, rust and weakness are constant requirements. Unfortunately, horses can and do take fatal falls through improperly maintained floors while in transit.

Stall and vehicle entrance

A horse's heart rate increases dramatically during the loading and unloading process (Waran *et al*., 1996); therefore, its behavioural requirements should be considered in the construction of both the transport stall and the entrance to the trailer or van. Because the horse is, by instinct, afraid of confinement, and its eyes neither adapt rapidly to light changes nor see items clearly at close range, the ideal entrance should be wide, well lit and uncomplicated (no steps or ramps) to traverse. A level, funnelled walk into the transport vehicle — such as that provided by the special ground-loading ramps seen at most large horse facilities – is the most ideal. However, loading in less than ideal situations is often necessary.

The two most common types of entrances are: (i) the step up, where the horse steps upwards directly from ground level into the trailer (see Fig. 19.3); and (ii) the ramp type, where the horse walks up a sloped platform into the trailer. In both cases, the horse should be allowed to go slowly and look down at its footing during loading. The step-up design, which should have a rubber bumper guard on the leading edge of the floor to prevent injury to the horse's shins, usually allows the horse to get closer to scrutinize the inside of the stall before entering. This design requires the horse to learn to pick its feet up to enter, whereas the platform of the ramp type, which solves the stepping up problem, may yield to the horse's weight, be too colourful, slippery and hollow sounding, all of which may frighten the horse.



Fig. 19.3. The yearling is standing quietly with one leg in a step-up 16 ft (0.48 m) stock-type trailer and being rewarded with a pat on the neck. (Photo: Dr Sandi Lieb)

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The disadvantages of both designs need to be minimized and combined with careful preconditioning and patience to teach the horse to accept the loading situation. Doors that swing out with side ramps create a funnel effect to help the horse to gradually enter the more confining area of the stall. Also, stall construction that allows one of the side walls to be swung wider for entry and then back into place after the horse enters is very advantageous for young and large horses. Entrances with low step-ups or very short, sturdy ramps are adapted to by most horses very quickly. The longer, steeper loading ramps required by high-bedded vans should always have sides for guiding and safety.

Horse restraint in the transport stall

As the horse enters the stall, a prompt, quiet and easy method must be available to solidly close off the rear (or front) of the stall. Open latch handles should not stick out where the horse can be impaled on them and injured during the loading process. Many trailers and vans have very cumbersome or dangerous closures, including tailgates that must be raised from the ground. A simple-to-latch but strong, side-swinging door that closes off one stall at a time is probably the best. The latching mechanism should be quick and easy to operate to avoid injury to handlers should the horse bump into the door and the latch come undone prematurely. Where butt or chest bars are used, they must be adjustable to the height of the horse to prevent the horse slipping under them. Head restraint must always be accomplished after the exit from the stall is closed off by putting in place the chest or rump bar.

When unloading the horse, the head restraint should be removed before the chest or butt bars are released. Head ties may be installed, but should be adjustable and fitted with quick-release snaps. Total stall size and restraints should allow 0.3 m or so of movement forward and back, and any head tie should remain slightly slack when the horse's rear is touching the butt bar or back wall. The purpose of the head tie(s) is to prevent the horse from turning around in an individual stall. It is questionable whether a horse's head should be restrained under conditions where there is no rear quarters restraint.

The horse inexperienced in tying or one that becomes afraid during transit is likely to pull against a head tie and be injured when it is the only restraint used. If a horse is not accustomed to restraint by the halter, as is often the case with youngsters, then it should not be tied, but preferably be transported in a large loose box of approximately 1.5 × 2.0 m. Obviously, vehicles hauling loose horses should not have openings in any cross gates or an entrance door large enough to encourage the horse to attempt to escape.

All transport stalls should allow safe and easy access to the horse's head for tying and care purposes. Shipping crates for air and sea transport may, additionally, require access to the horse's rear quarters, as it would otherwise not be possible to remove the horse in an emergency. In the case of road trailers, extreme care must be taken by both manufacturers and horse owners to properly construct and use escape doors meant for humans only, so that horses do not attempt to use them for exit and, thereby, become trapped or injured.

Transport equipment choice and operation

All transport equipment used for livestock, especially that used on roads, should be properly engineered for stability and weight-carrying requirements. Transport equipment soundness is paramount to safety on the road. There are few governmental standards for transport equipment, in particular the trailers pulled by a vehicle that are currently being used to transport the majority of recreational horses.

When a single horse is loaded into a two-horse trailer, the horse should be placed with most of its weight towards the front (over or in front of the axles) and driver's side of the trailer, because the vehicle may weave when most of the horse's weight is behind the trailer's axles. In addition, putting the horse on the non-driver's side places it on the low part of the road camber, thus causing the trailer to drift to the outer road edge.

Low or uneven tyre pressure on either the pulling vehicle or trailer can cause swaying and weaving of a moving trailer. Various trailer equipment attachments are available to help adjust the tongue weight of bumper-pull loads and to help reduce swaying, thereby aiding the stability of the set-up. Most US states require a safety chain near where the trailer is attached to the pulling vehicle, and some, in addition, require a breakaway system that automatically sets the brakes on the trailer should the trailer become disconnected during travel. It is highly recommended that the driver make a last, careful inspection of the entire rig just before the start of a journey to catch hook-up and other safety problems.

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Smith *et al*. (1996a,b) found that a two-horse bumper-pull trailer with leaf-spring suspension with bias-ply tyres produced a smoother ride than the same trailer with torsion bar suspension and normal-pressure radial tyres. No difference in horse well-being was found between the two types after a 24-hour journey (Smith *et al*., 1996a,b). Purswell *et al*. (2010) found that fully enclosed slant load trailers may not provide sufficient ventilation. When yearling horses that are naïve to transport were hauled in either individual stalls or groups, increases in plasma cortisol and corticosterone were similar (Garey *et al*., 2010).

It is up to the purchaser to check for sound engineering design and to purchase only equipment made for the purpose intended. The hitch, axle and brake capacity for trailers, and the pulling capacity and weight ratings of pulling vehicles and vans, should be acquired from the trailer/vehicle manufacturers to determine their suitability for the purpose intended (i.e. the maximum total weight that can be carried). A safety margin should be included in the assessment of the equipment, if possible.

Horse owners must consider that they are transporting an animal that is large, top-heavy and, at inopportune times, fractious. These factors readily contribute to swaying and weaving of the vehicle/trailer at high speeds. Other factors under the control of the driver that contribute to trailer and vehicular stability on the road are uniform tyre pressures, weight distribution of the load and sound undercarriage structure. Poor driving technique, neglect of maintenance, improperly used equipment and the transport of valuable horses do not mix, and, more often than necessary, can result in a tragic accident. Using a mobile phone while driving or lack of sleep are, of course, dangerous and may contribute to horse injury or fatality (Riley *et al*., 2016).

The International Air Transport Association (IATA) has standards for horse stalls carried on aircraft in their Live Animals Regulations (Doyle, 1988).

Training the horse to load, haul and unload

Horses to be transported can be separated into two groups, halter trained and untrained (or insufficiently trained). Recreational horse users and trainers have been dealing with the situation by a great variety of methods. What follows are some suggestions based on the horse's normal behavioural patterns.

Horses that have been well trained to be individually handled by halter should be taught to properly load well before the day of an anticipated transport, in order to reduce the stress of the first haul. Habituating horses to the vehicle and transporter will reduce stress (Yngvesson *et al*., 2016). Loading training may take as little as a couple of days to as long as several weeks. Generally, a longer training period is required for teaching horses to enter and stand in two-horse trailers than in more spacious transports (stock trailers or vans). Loading training should be slow and deliberate and without scaring the horse or using excessive force. If the animal panics and fights or falls, the procedures are in error and need rethinking.

Frequently, loading a horse that is already a good loader first, and in the presence of the horse that is learning to load, and/or careful use of food rewards – along with asking for only one step at a time – will load most horses. Mares and foals are best loaded by holding the mare at the trailer entrance and loading the foal using two people, one on each side, locking arms behind the foal and nudging it gently forward straight into one side of the trailer. One handler restrains the foal in the trailer while the mare is loaded. This method has an added advantage of enticing a poor-loading mare to load in order to stay with her foal. Loading the mare first usually causes the mare to lose sight of her foal, which may cause her to struggle in the trailer. If there is insufficient time for the loading training, then these horses should be treated as untrained horses when they are loaded and transported.

Tranquillization sometimes helps with problem or inexperienced loaders when there is insufficient time for proper training. Horses – such as suckling foals and youngsters that may lead using the halter but do not tie, back up or stand well – need special treatment when loading and hauling in individual stalls.

A survey of American owners of horses with trailer problems revealed no breed differences in the prevalence of these problems (Lee *et al*., 2001). Loading was the most common problem, closely followed by problems in transit. A smaller number of horses caused trouble unloading. Many horses misbehaved both when loaded and during travelling; in this case, presumably the aversiveness of travel accounted for their reluctance to load. Changing the trailer type, especially from a small two-horse to a spacious livestock trailer, was most likely to result in an improvement. Horses that had once travelled well were more likely to improve

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than those that had always had problems. Swedish and Australian surveys showed that 21–38% of owners reported behavioural problems during loading (Yngvesson *et al*., 2016; Padalino *et al*., 2016). Weeks *et al*. (2011) recommends familiarizing horses to loading methods and vehicles before travel.

An excellent method of improving trailer loading behaviour and simultaneously reducing stress is that of Shanahan (2003) and York *et al*. (2017). Horses were trained during six 30-minute sessions to carry out four operations: (i) walk on a lead using a sequence of back stroking and light taps on the croup; (ii) lower the head in response to a gentle downward pull and stroking the chest and front legs with a whip; (iii) stop at a light tap of the chest with the whip; and (iv) back up after being stroked against the hair on the leg they were being asked to move. They were also taught to walk up to and on to tarpaulins, to cross poles on the ground, to step on planks on the ground, to step onto a raised platform, to walk through a narrow space and to walk under a tarpaulin held overhead. The Tellington Touch Equine Awareness Movements (TTEAM) (see 'Stroking and massaging' section above) were used to relax the horse. Cortisol levels, heart rate and time to load were all reduced by this regimen.

The application of positive reinforcement in the form of clicker and target training (see 'Positive and negative reinforcement' above) has also been successful for teaching horses to trailer load. Ferguson and Rosales-Ruiz (2001) and, more recently, Slater and Dymond (2011) demonstrated shaping of behaviour through clicker training to be effective in working with problem loader horses. Slater and Dymond suggest that the implementation of target training provided horses with greater control over their environment, results in quicker acquisition of desirable behaviour, and made training sessions more enjoyable, enriching and safe through the reduction of undesirable and potentially dangerous escape behaviour. In support of these suggestions, when treating horses that would not load previously, Hendriksen *et al*. (2011) found that using positive reinforcement (food as a primary reinforcement and a clicker as secondary reinforcement) to load horses into trailers resulted in a shorter loading time, lower heart rate and fewer signs of discomfort than using negative reinforcement (taps by a dressage whip on the shoulder). Recently, Padalino *et al*. (2018a) conducted a survey of transport-related behavioural problems in the New Zealand equine industry and found that the use of negative reinforcement and positive punishment as training methods, using a whip or food for loading, and travelling in a straight load trailer/float while offering food were associated with a higher likelihood of trailer-related behavioural problems. The associations identified between use of food for loading and offering food while traveling are interesting, although a level of caution should be exercised in their interpretation. For example, it should be taken into consideration that survey respondents may have used food inappropriately to motivate the horse to load rather than as a proper reward given in response to the desired behaviour. Additionally, it is possible that respondents used food at loading in attempts to minimize transport-related problem behaviours. Therefore positive reinforcement may have been used to treat problem behaviours and represent a response to, or strategy implemented to, mitigate transport-related behaviour problems. Finally, many owners believe offering food en route calms horses. Offering feed during transport may have been employed to reduce behavioural problems and thus should not be interpreted as a causal factor.

Medical preconditioning, care in transit and stress monitoring

Several weeks before moving a horse, a licensed veterinarian should be consulted to determine the proper disease testing, vaccinations and paperwork required for the horse's intra-state and inter-state transit in the USA, or its international transit. Requirements vary from state to state and country to country, and two or more weeks may be needed to accomplish the vaccinations and required tests. The inter-state health certificate issued by a veterinarian is usually acquired a few hours or days before transit.

Transits of four to 12 hours or longer tend to be measurably stressful in that heart-rate variability and both blood and faecal cortisol increase (Schmidt *et al*., 2010). During air transport, a horse that appeared behaviourally calm had the highest heart rate (Munsters *et al*., 2013). This shows that not every stressed horse shows behavioural reactions to transport. Horses will reduce their water and feed intakes significantly while in a moving vehicle or trailer (Anderson *et al*., 1985; Traub-Dargatz *et al*., 1988; Mars *et al*., 1992: Smith *et al*., 1996b; Friend *et al*., 1998). Therefore, consideration

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should be given to body temperature monitoring (pre-, post- and during transit) and the giving of immunostimulants, prophylactic antibiotics and fluids (pre- and during) (Nestved, 1996). These precautions aid the immune system and functioning of the renal and gastrointestinal systems.

Transport personnel should stop for brief rest periods and offer water every three to six hours of transit to encourage the consumption of water and hay; after every 16–24 hours of transit, a complete offloading of the horse for an extended 12-hour rest period is recommended. Research has shown that even normal, healthy horses offered water en route will dehydrate, and that the consumption of food and water is greatly increased when the van/trailer is standing rather than moving (Kusunose and Torikai, 1996). Transits of up to 24 hours were tolerated by healthy horses that had been rested in stopped transport and offered water for 15 minutes out of every four hours en route. They made an uneventful recovery from mild dehydration (Smith *et al*., 1996b). In a recent study, Padalino *et al*. (2018b) documented the effects of an eight-hour journey on behavioural, clinical, haematological, environmental and respiratory parameters, and identified associations between behavioural and physiological responses to transport. Transportation caused mild, but significant, effects on fluid and electrolyte balance and an acute phase response, characterized by neutrophilia, hyperfibrinogenaemia and hyperglobulinaemia. The proportion of neutrophils in tracheal wash (TW), tracheal mucus and TW bacterial concentration increased, with preferential replication of *Pasteurellaceae*. Horse behaviour en route predicted clinical and respiratory outcomes. The frequency of stress-related behaviours was greatest in the first hour and balance-related behaviours were most common in the final hour of the journey, respectively. Horses which lowered their heads less frequently en route and showed more stress-related behaviours had higher physiological stress (serum cortisol and heart rate on arrival), increased tracheal mucus and inflammation scores, and higher TW bacterial concentration following transport. The authors recommend en route monitoring of horse behaviour and allowing horses a 24-hour rest period upon arrival to reduce the incidence of transport-related respiratory disease.

Very cold weather conditions may require that horses, especially in more open trailers, be blanketed while en route; conversely, in hot environments, care should be taken not to leave a horse in a parked trailer/van in the sun, as heat stroke can occur from extreme temperature rises within the vehicle. The use of leg wraps to protect the lower limbs and head bumper guards is not recommended unless: (i) the horse is completely accustomed to them; (ii) they are properly applied and checked periodically en route; and (iii) they are not kept on for overly long periods of time.

Horses that have an elevated temperature and show signs of infectious disease should not be transported, especially over long distances. A horse that begins to show a fever during transit should be offloaded at the earliest opportunity and receive veterinary supervision and rest until it is healthy enough to resume travel.

Transport stress and post-transport performance

Limited research indicates that short (<1 h) transits just before a sub-maximal exercise performance are not detrimental to a horse (Beaunoyer and Chapman, 1989; Covalesky *et al*., 1992). For normal, healthy horses, longer transits (4–24 h), even though they produce some measurable physiological changes (weight, heart rates, dehydration and some metabolites, hormones and other blood factors, including cortisol – see Clark *et al*., 1988, 1993; White *et al*., 1991; Smith *et al*., 1996b; Friend *et al*., 1998), do not appear to be injurious to a horse's general well-being or health, and require only one to two days of recovery for most horses. The horse's performance may be affected, though. Transport the day before an event can affect blood values after the event. Transport for 70 km before trekking caused horses to have higher cortisol, urea and protein levels than horses that were not transported before trekking (Medica *et al*., 2010). Transport by van for four hours also increases acute-phase protein, which is a sign of stress (Casella *et al*., 2012). Ohmura *et al*. (2012) found that air transport was associated with higher heart rate for a more prolonged time than transport by road, during which the heart rate increased initially, but then fell.

Inexperienced show horses, young horses being hauled for the first time, and horses experiencing very rough transport conditions where they had been exposed to quick starts and abrupt stops, were found to be moderately to highly stressed (Russoniello *et al*., 1991; Covalesky *et al*., 1992; Kusunose and Torikai, 1996). Continuous transport of breeding mares for 9–12 hours, which produced

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measurable stress, did not interfere with the normal reproductive functions of the oestrus cycle and early gestation (Baucus *et al*., 1990a,b). Horses are social animals and they do not like being alone, and both physiological and behavioural responses are reduced when a horse travels with a companion horse (Kay and Hall, 2009). A mirror reduces some of the behavioural symptoms of stress but has little effect on the physiological measures.

Mild to severe respiratory dysfunction and disease changes, and even pneumonia, can occur during or following transportation by ground and air, and tend to remain for several days or weeks after the clinical signs of disease disappear (Anderson *et al*., 1985; Traub-Dargatz *et al*., 1988). These respiratory problems may be related to restraint in a high head position during transit (McClintock *et al*., 1986; Racklyeft and Love, 1990). However, Smith *et al*. (1996b), who studied horses during and after 24 hours of transit, speculated that the factors responsible for the development of respiratory disease post-transport could include: exposure to pathogenic agents that may initiate injury to the respiratory epithelium before or during transport; trailers that are not well ventilated; and horses that have a greater individual stress response.

Transport of injured and rescued horses

Many racetracks and large horse facilities now have specially designed horse trailers for the transport of severely injured, non-ambulatory horses. After sedation and stabilization of its injury, the horse is loaded into the special trailer either by a very low mobile floor onto which it is initially slid or rolled, or it is raised and moved in a harness using an overhead hoist system suspended from a beam that extends from inside the trailer. Horses have even been rescue airlifted out of inaccessible areas via helicopter using a special overhead support device and body sling developed by C.D. Anderson (Madigan, 1993).

Research related to transportation

There is still very little research addressing horse trailer and van design in the scientific literature. As previously mentioned, Smith *et al*. (1996a) evaluated several combinations of vehicle suspension (leaf-spring and torsion bar), tyre types and inflation rate and shock absorber use for smoothness of ride and common frequencies of vibration using a two-horse, bumper-pull, tandem-axle, forward-facing trailer. The leaf-spring suspension with low-pressure radial tyres (or bias-ply tyres) and without shock absorbers provided the smoothest ride. The torsion-bar suspension combined with normal-pressure radial tyres was the roughest. Shock absorbers did not improve the ride quality. Horses travelling on the right side of the trailer experienced more vibration than horses on the left side, which the researchers thought might be caused by the poor conditions of asphalt roads near the shoulders.

Several researchers have looked at the relationship of the horse's position in the trailer and others have worked at evaluating well-being during longer transits and transport conditions for slaughter horses. It has been found that horses may have a preference for certain body positions when in transit. Waran *et al*. (1996) and Partaino *et al*. (2012) found lower heart rates and cortisol levels in horses facing rearward than facing forward. Horses facing backwards tended to rest on their rumps more. When facing forward, they tended to move more frequently and hold their necks higher than normal and vocalize more frequently. Even loading methods and entrances may make a difference to the horse, as walking into a van from a platform at the same level and backing into a stall produced lower peak heart rates than walking up a sloped ramp directly into the stall.

Kusunose and Torikai (1996) observed the behaviour of six pairs of untethered yearling thoroughbred horses (which had been transported only once previously) in a horse-carrying vehicle; they found the time spent feeding was only 10.5% of the total behaviour activity when the vehicle was moving, compared with 67% and 64%, respectively, when it was parked or parked idling. Half of the driven pairs were exposed to five repeated abrupt stops during each driving trial and the other half to normal, slow acceleration and deceleration driving conditions without the abrupt stops. The normally driven pairs increased their amount of backwards- (to the direction of travel) facing behaviour and decreased the number of body position changes with each succeeding driving trial, while the abrupt-stop pairs maintained a high incidence of changing positions and could not seem to settle into a favoured standing position.

Smith *et al*. (1994) found that mature horses spent more time facing backwards to the direction of travel when the trailer was in motion, but not when it was parked. Several horses displayed strong

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individual preferences for the direction they faced during road transport. They also found higher heart rates when the trailer was moving, but no difference in heart rate when the horse was tethered facing forward or backward versus untethered.

A later study by Smith *et al*. (1996b) studied four horses before, during and after transport for 24 hours in a two-horse trailer. After transport, no decrease was detected in pulmonary (respiratory) function using aerosol clearance rates; however, changes were observed in the red blood cell count, packed cell volume and levels of haemoglobin, plasma protein and cortisol. The horses had lost weight and were slightly dehydrated after transport, and water and hay intake rates were lower during transport than before transport. Heart rates were higher during only the first 120 minutes of travel. Smith *et al*. (1996b) also looked at the trailer environment during transit and found that ammonia and carbon monoxide concentrations were within acceptable limits for human exposure, though the concentration of respirable particulates (dust particles, probably from the hay) in the atmosphere was too high. In a study of ten shipments of horses transported for journeys of 390–2300 miles (625–3680 km) with transit times of 8–50 hours, Nestved (1996) further substantiated the seriousness of respiratory illnesses during transit by finding a 60.9% illness rate (upper respiratory diseases requiring treatment) in control horses (142/233) that were not given a pre-shipment prophylactic treatment. Respiratory illness was reduced to an incidence of 18.4% (40/217 horses) by the administration of the immunostimulant *Propionibacterium acnes* (EQSTIM™ Immunostimulate).

Friend *et al*. (1998) made extensive physiological measures of 30 untethered horses in four treatment groups: penned with water, penned without water, transported with water and transported without water. Twice as many horses were assigned to the transported as to the penned groups. The transported groups contained in one 16 m-long, open-top livestock trailer-and-tractor rig were driven for four hours and offloaded for one hour out of each five-hour period continuously, until after five trips (24 h) it was determined that three horses (all in the transport without water group) were not fit enough to continue. Body temperature, serum sodium and total serum protein concentrations were useful for revealing hypertonic dehydration. It was concluded that 24 hours is probably the longest period horses should be transported without access to water.

Notes

[1] 4-H stands for head, heart, hands and health, and the 4-H horse programme aims to promote knowledge of horsemanship and responsible, ethical equine use, care and management.

[2] The hackamore is a type of horse bridle that controls a horse via pressure points on the face, usually with a nosepiece instead of a bit.

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20 Deer Handling and Transport

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Summary

In a relatively short time, farmed deer have become less flighty. This may be the result of selection for temperament, a better understanding of deer behaviour, of training deer to handling procedures and of better facility design. Improvements in human–animal interactions when working with deer have resulted in better safety for handlers and enhancement of deer welfare. Regular exposure to calm handlers and training deer to move through facilities for food rewards is helpful, and handling systems work best when they take advantage of natural deer behaviour to return to where they came from. All people working with deer should be adequately trained (including in relation to human and animal safety) and, in some countries, this is required by legislation, welfare codes and industry guidance. This chapter covers best handling and transport practices for red deer, fallow deer, wapiti (elk), bison and other species, where relevant, but does not directly address the production of trophy deer.

Keywords: cervids, handling, restraint, transport, welfare

Introduction

Since its development in the 1970s, deer farming in the modern context has come of age, founded on practical experience and, where available, scientific evidence (Hanlon, 2011). During this period, management and handling systems were developed based on the behavioural traits of the deer and on a developing understanding of deer seasonality and nutrition. Species such as red deer (*Cervus elaphus*), and also the much larger North American variety, the wapiti, or elk (*Cervus canadensis*), and the Rocky Mountain elk (*Cervus elaphus nelsoni*), were found to be the most suitable for, and adaptable to, the constraints imposed by farming conditions, and are therefore the most commonly found species. For clarity, in this chapter, the name 'wapiti' rather than 'elk' will be used, as the term elk is potentially confused with the North American moose or European elk (*Alces alces*) – though even in Europe the term moose is becoming more widespread. Fallow deer (*Dama dama*) are also commonly farmed, as to a lesser extent are rusa deer (*C. timorensis rusa*), sika deer (*C. nippon*), chital or axis deer (*Axis axis*) and white-tailed deer (*Odocoileus virginianus*). Much less frequently farmed are musk deer (*Moschidae* sp.) – partly as a conservation exercise (He *et al*., 2014) – and there are also novel systems looking at the adaptability of other deer species (recently, e.g., Timorensis deer, *Cervus timorensis*) (Zakaria *et al*., 2016).

For centuries before this modern era, red deer in Europe provided a staple meat. Selective hunting (and possibly the tempting of deer with feed to places where they could be ambushed) was followed by enclosure (and possibly even early domestication). Game husbandry was adopted by the Romans and, more recently, deer were managed in parkland settings in Europe to provide a ready hunting resource; large tracts of land were often devoted to this. Deer parks and forests were quite numerous in medieval Britain and western Europe, primarily for venison production and sport. Long before modern farming, reindeer (*Rangifer tarandus*) were followed on their migratory routes, with organized culling taking place. Later, the now traditional herding of semi-domesticated reindeer in Fennoscandia and some northern Asian areas brought humans into closer contact with a primary source of food and clothing

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and, in fact, very little of the carcass was wasted. A number of other deer species are managed under a degree of captivity in order to make a particular resource readily available (musk deer species, *Moschus* spp., in China, for example) but it is really only those species noted above that have become easily handled and transported. Interest is growing in a number of other large ungulates, such as water buffalo (*Bubalus bubalis*), which have also been used traditionally by humans for draught power in a number of regions but are now being found in larger numbers around the world, along with bison (*Bison bison*) in North America.

The primary products obtained from farmed deer are meat (venison), velvet antler and skins. The history of keeping deer for the medicinal properties of their velvet antlers probably goes back over 2000 years. While venison is produced around the world, velvet antler production is limited by national legislation and thus is undertaken in fewer countries, and often under regulated conditions to protect deer welfare and ensure product quality.

Over a relatively short period of time, farmed deer have become less flighty, probably as a result of an interaction between selection for temperament, a better understanding of deer behaviour and the effects of training for handling, and advances in facility design based on a good knowledge of behavioural characteristics – which may differ between species. The result has been an improvement in human–animal interactions when working with deer and, thereby, working conditions and safety for handlers, as well as, importantly, an enhancement of deer welfare.

This chapter will focus on the handling and transport of the deer species that are commonly encountered and aims to give a comprehensive account of best practice in terms of safeguarding the welfare of the animals themselves and also the ease of work and safety of stockpersons. All these aspects are reliant on systems designed with both the natural behaviour of deer in mind and the existence of effective animal–stockperson relationships, based on good knowledge and training. It should go without saying that all those responsible for deer should be adequately trained in relevant aspects of deer management and handling to be able to discharge their duty to protect deer welfare. In some countries, this is required by governmental or industry codes of welfare practice.

Although the focus of this chapter is on red deer, wapiti and fallow deer, it includes shorter sections on less commonly managed species. Both handling and transport aspects are dependent on the species of deer concerned and the underlying management system. In general, systems are likely to be of an extensive nature with limited housing, restricted, for example, to use when needed to protect weaned calves from winter weather at a time when they are physiologically poorly adapted to benefit maximally from additional food resources. Deer are generally managed in artificial groups enclosed in large paddocks on farms (or walled enclosures, in China particularly), with many elements of management akin to outdoor beef production, or in a more extensive way, where there is less human contact or programmed intervention, other than the provision of supplementary food. For more details of farming systems, see Hanlon (2011).

Domestication of Deer

It is generally recognized that there are around 60 species of deer, yet only a small number of these have been considered suitable for being managed. Use of the term 'managed' here carefully avoids the use of the term 'domesticated', but clearly the concept of domestication is implicit to some extent. It has been asserted that deer are one of the few new species to have been domesticated for over 10 millennia (Fletcher, 2003), and while this term can reasonably be applied to farmed red and fallow deer, it would not necessarily be applicable to some other species that are managed. Some species, roe deer (*Capreolus capreolus*), for example, seem entirely unsuited to managed systems, even when bottle-reared from birth. The term 'semi-domesticated' is readily applied to reindeer, which are herded over considerable distances and, on occasion, held in corrals, transported in vehicles and slaughtered in abattoirs. In the early stages of Scottish deer farming, some highland estates built catching and handling facilities so that their annual hind and calf cull was taken alive instead of being shot for meat. For red deer (including wapiti) and fallow deer, it seems that a process of domestication occurred in a much-accelerated manner, which included positive selection for suitable temperament (along with production characteristics).

Suitability of deer for farmed systems

In many ways, deer are an ideal species to farm. Their size is such that handling can be relatively

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straightforward and modelled on that of cattle and sheep. They thrive on a pasture-based diet (and can also make good use of poor-quality grazing); breeding can be managed in appropriately sized groups; females have a high degree of reproductive success for many years (thus a low replacement rate is needed); and, crucially, venison as an end-product is of high value with (for a red meat) particularly low levels of saturated fat and cholesterol, and a high lean meat-to-bone ratio. (For a review of carcass characteristics see Kudrnáčová *et al*., 2018.) In some systems, velvet antler is a valuable commodity, and some herds are run primarily to satisfy this demand. Stags can be dangerous and, compared with facilities for cattle or sheep, deer facilities need to be designed correctly and are likely to be more expensive to construct at the outset. Without such facilities, deer cannot form part of any farming enterprise. The underlying biological seasonality and stage of maturity of youngstock mean that the quality and availability of fresh venison can vary across the year. While this has been a disincentive for some supermarket chains to stock venison as a regular item, chilling and freezing processes are always improving.

For those deer species currently farmed, it appears that there was a very rapid adaptation to farmed conditions and, currently, with correct handling and management, farmed deer are among the healthiest of farmed livestock, though this may in part be due to the relatively low stocking rates usually seen. In some low-density systems, clearly there is less management control over grazing resources and areas of utilization, which may have impacts for maintaining the grassland resource in the longer term (Wall *et al*., 2018). By accommodating the innate behavioural characteristics of deer into facility design (Kilgour and Dalton, 1984), an efficient, safe and high-welfare system can be created. With an increasing awareness of the contribution ruminants make to greenhouse gas emissions, there is an urgent need for mitigation strategies, but in some cases, those suggested are a potential welfare threat (Shields and Orme-Evans, 2015). It will be important for the deer farming industry to play its part in environmental stewardship through, for example, optimizing health and welfare in high-quality management systems and maximizing genetic gain (e.g. Thompson *et al*., 2015).

Ranching/extensive systems/deer parks

Some deer enterprises have the properties of ranched or extensive systems. There is enclosure but less human interaction on a daily basis. Supplementary feed may be provided during certain times of the year; mineral supplementation may also be given and, occasionally, veterinary prophylactic measures may be implemented. In such extensive farming systems it may not be easy to ensure that deer are subject to statutory animal health and welfare regulations. In these systems there is often seasonal offtake but, otherwise, limited contact. This means that handling approaches need to reflect the relative lack of habituation to humans in such animals; gathering can be particularly difficult. Further, in these systems, there is more opportunity for deer to express their natural social behaviour and group hierarchy, which is good for their welfare.

Interactions with Deer in a Wildlife Management Context

In many countries, deer are the subject of game management protocols and, on some occasions, need to be handled and translocated. There is less information available to inform best practice here, but a number of regulatory systems (sometimes voluntary) exist around the world. Scottish Natural Heritage (SNH, 2018) in the UK, for example, produces a large amount of guidance on the management of wild deer through its Best Practice guides; the topics covered include deer welfare, firearms and carcass preparation. This guidance aims to safeguard public safety, ensure food safety and take full account of deer welfare. Collisions between free-roaming deer and vehicles are a major problem. Various deterrents have been tried to keep deer off heavily travelled roads, and the best is a well-constructed fence (Mastro *et al*., 2008). As white-tailed deer become more numerous, dangerous interactions with people have increased. For example, from 2005 to 2006 there were 13 attacks by does protecting their fawns on an Illinois university campus (Hubbard and Neilsen, 2009); does defending male fawns were more likely to attack (Grovenburg *et al*., 2009).

In some cases, there is a need to control deer abundance to mitigate harmful ecological consequences or the incursion of excessive numbers of deer into populated areas (reviewed by Warren, 2011). These activities often create considerable local controversy and, indeed, societal issues are often more of a difficulty than the management actions themselves. These actions often involve shooting or bow-hunting deer, but there has been a

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growing use of methods designed to reduce fertility, commonly through darting females with immunocontraceptive vaccines, generally focused on gonadotrophin releasing hormone (GnRH) preparations or porcine zona pellucida (PZP) (Gionfriddo *et al*., 2009; Miller *et al*., 2009). The impact of a number of methods of culling wild red deer was evaluated by Cockram *et al*. (2011), who concluded that there was no difference in the risk of accidental pre-culling injury in relation to method. However, these authors recommended that measures should be taken to minimize the disturbance of deer during culling exercises.

The handling methods described in this chapter are generally not appropriate for wild deer, for which expert advice should be sought.

Using Deer Behaviour as the Basis for Good Handling

Natural behavioural characteristics

Deer in the wild display a highly organized social structure. Marked reproductive seasonality is one key driver for their behaviour, with mating during the rut in the autumn and subsequent calving in late spring. There is a considerable body of work on the behaviour of deer, which serves to inform facility design and management practice in order to handle the animals safely, efficiently and in a way that respects their welfare. For example, males during the rut and hinds with newborn calves can be especially dangerous. The size of deer, wapiti in particular, regardless of the additional danger posed by antlers, means that there are always potential risks to handlers. Deer are also very agile and have physiological adaptations of their muscles geared to short bursts of intense activity (Harris *et al*., 1999). Most species of deer can clear fences of 2–2.5 m in height, and they can also accelerate very quickly (Drew and Kelly, 1975). These characteristics need to be considered in the design of handling facilities.

Red deer and wapiti are natural open forest-dwelling animals; protection from natural predators, some insect pests and the weather is afforded by the trees, and the open areas provide grazing. They are classified as intermediate feeders and have the capacity to be opportunistic in the food they consume. Reindeer also fall into this category, whereas fallow deer tend to be more grass roughage eaters. Forest clearances have forced some deer to become adapted to open ground, and in these animals, in particular, the high level of vigilance commonly observed in prey species is a readily observable behavioural characteristic (Jayakody *et al*., 2008), with deer easy to frighten. Vigilance may be at a cost of reduced feeding behaviour, and the disturbance of animals (particularly if recurring) in poor nutritional state (e.g. wild stags after the rut) may be prejudicial to their survival over winter. The predominant daily behaviour pattern of deer is one of grazing, ruminating and resting. Feeding behaviour varies across the year, driven by photoperiod and natural food availability. Deer also graze in bouts, mostly around dawn and dusk.

Wild deer are known for their large flight distance, strong flight response and associated bunching together when disturbed. Thus they are often described as being 'flighty', meaning that they are very reactive to external stimuli and appear to adopt extreme responses to a range of situations. In the wild, deer, as a prey species, will principally seek to distance themselves from a perceived threat and, once disturbed, they tend to seek terrain that affords them a good view of the surrounding landscape. When disturbance is at a distance, deer orient their heads towards the source of concern and bunch together (Humphries *et al*., 1990; Bullock *et al*., 1993). When approached more closely, the lead animals move away with the remainder of the herd following; this leader–follower tendency can be exploited during handling. If disturbance occurs rapidly, the deer may initially scatter, only to regroup at what they consider a safe distance, usually at a vantage point.

In deer, anatomical adaptations of the special senses result in good sight (Prince, 1977) and hearing. The position of their eyes on the head is similar to that in cattle and sheep, and is likely to lead to a similar wide visual field of about 300°, with blind spots to the rear and under the head (Hutson, 1985), but with good depth perception. Deer, like other ruminants, appear to detect moving objects well but respond less to static objects (Cadman, 1966; McNally, 1977). Their capacity for colour vision is not known. Because deer are often active at dawn and dusk and at night, it is generally assumed that their vision is good under low-light conditions. Their prominent and mobile ear pinnae result in a good sense of hearing (stalkers confirm this) and deer are also known to respond to silent dog whistles. Possession of a good sense of smell is inferred from the practice of stalkers approaching deer from downwind of the deer and the prominent use of scent marking by many deer species (McNally, 1977).

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Isolation of individuals, as with other livestock species, can cause considerable agitation and extreme, sometimes self-harmful, behaviour. Pollard *et al*. (1993) showed that spatial and visual isolation of farmed yearling red deer stags was associated with increased heart rate and increased frequency of escape behaviours and concluded that confinement in isolation was more stressful than confinement with familiar conspecifics. The visual isolation imposed by handling was also shown by Price *et al*. (1993) to result in a non-motor increase in heart rate, and approaches by familiar and unfamiliar people and noises in the handling area also cause increases in heart rate, though of a lesser magnitude. Interestingly, these authors also showed a seasonal variation in underlying heart rate with baseline heart rate in May being higher than in January. It has been shown that isolated deer in the presence of a human also have an elevated plasma cortisol response, but these changes are attenuated by previous human exposure (Goddard, unpublished data).

The annual antler cycle of male deer (and female reindeer too) is a very characteristic feature. Soft, velvet antlers grow throughout the spring and summer. As concentrations of testosterone increase in response to shortening day length, the antlers 'harden'; the soft covering of skin is shed and they become devoid of a blood supply and insensitive. As the velvet becomes frayed on their antlers, stags are often seen to rub them on branches to clean them.

As the rut approaches, additional anatomical changes are seen in males: a dramatic increase in neck musculature, growth of a shaggier mane and increase in testicular volume. These changes accompany and facilitate antagonistic behavioural events such as threat behaviours and fighting between competing males. This range of behaviours also includes high-head threats, which precede strikes by the forefeet, or rearing on the hind feet and boxing with the forefeet, kicking with the hind feet and biting, or biting threats. The tongue may protrude and there may be tooth grinding (Lincoln *et al*., 1970; Bartos, 1985). A submissive response to these threats includes an outstretched neck turning the head away or walking or running away. Body size is the main determinant of ultimate social ranking. A range of distinct behaviours, primarily threats, is seen in advance of the rut during the antler growing phase; this includes urine smearing of the skin (urine has a distinctive odour at this time) and wallowing and covering the coat in mud. During the winter and early spring, testosterone concentrations are low, and old, possibly broken, antlers are cast; stags are least aggressive at this time (Darling, 1937). When agonistic behaviours between females are seen, these are similar to those exhibited by males in velvet antler. It is important that stockpersons recognize these behaviours, which also occur in farmed situations. During the rut, stags become particularly aggressive, and human contact in an open environment should be avoided. Stags that may have been bottle-reared are a particular danger, and in a 'pet' or farmed environment, these animals present a very high risk to the owner, so this practice should not be encouraged.

Reproductive behaviour is necessarily a key driver of the farm management cycle. Using red deer as the example, the seasonal cycle commences with breeding in the autumn and, on farm, single or multiple stags are introduced to groups of females for just a few weeks to allow a compact calving season in early summer when grass growth is optimal for milk production. Females, pregnant over the winter, calve in the late spring and have calves at foot over the summer. Gestation length in red deer is around 231 days (247 days in wapiti and 234 days in fallow). While hinds are generally amenable to handling most of the year, they should be approached with caution when they have young calves at foot, and the handler should avoid coming between the calf and the hind. In farmed systems, calves are weaned either just before or just after the rut when around 4–5 months old. Hinds about to calve seek isolation, something that may be difficult for them to achieve in a farmed situation. For the first few days, the calf will 'freeze' in response to an intruder (such as a stockperson) but after that will show a remarkably strong flight response. Once more than a few days old, after sucking from their dam, calves will move away and seek a sheltered, often secluded, place to lie down. This behaviour is characteristic of 'lying-out' type species (Lent, 1974), and is seen for up to three weeks. Thereafter, calves will run with their mothers and join the matriarchal group.

Under optimal farming systems, yearling deer are marketed for venison at around 20–24 months of age. Physiological changes in males associated with breeding characteristics mean that meat quality in entire older males – depending on the time of the year – is sometimes considered less good, being tougher particularly after the rut. It should be noted here that unlike many other livestock species, male deer calves are rarely castrated.

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Handler–animal interactions and behaviour during handling

Farmed deer may be unable to express their inherent flight response during close handling (i.e. it is not possible for the deer to distance itself from the perceived threat), and this can lead to them adopting alternative strategies. In an attempt to escape, and in the face of an obstacle such as a fence, deer often put their heads down and try to go under or through this (Clift *et al*., 1985), so can easily injure themselves; hence there is a need for appropriate facility design. Agitated deer will also exhibit increased inter-animal antagonistic behaviour. Characteristic signs seen in animals, particularly when isolated or in small groups, include teeth grinding or salivation. These signs need to be recognized by handlers and acted upon, if possible, especially as they may be a precursor to aggressive behaviour towards the handler. However, the process of domestication has tended to accustom deer to handling practices, and selection has tended to eliminate lines of animals with more extreme reactions. Recent studies have shown that the common handling procedures used on New Zealand deer farms are not particularly stressful (Ingram *et al*., 1994, 1997, 1999; Carragher *et al*., 1997). For example, Carragher *et al*. (1997) showed that on return to pasture following a handling experience, animals' maintenance behaviours and physiological indices of stress returned rapidly to normal. As the flight and distancing responses are generally dictated by the lead animal, it is on the behaviour of this animal that handlers should focus. If the handler stays motionless, a deer may advance towards him/her owing to its inquisitive nature.

While it is not known whether the flight distances of farmed deer have declined across generations, it is clear that deer in New Zealand have become generally less reactive to handling over 40 or more years of farming and artificial selection (Kelly *et al*., 1984). Also, a range of techniques for measuring stress and temperament have been developed since the 1990s (e.g. Matthews *et al*., 1994; Pollard *et al*., 1994a; Carragher *et al*., 1997; Goddard, 1998). It appears that behavioural reactions in New Zealand red deer are relatively stable within individuals, so approaches that allow selection based on behavioural responses to handling are worthwhile (Chaya *et al*., 2006). A study by Czech researchers showed that red deer that struggled during restraint had a greater incidence of preorbital gland opening (Bartosova *et al*., 2012); deer that threatened handlers were 30 times more likely to open the preorbital glands, and there were large individual differences between animals.

Given these general comments, ideally, stags should not be handled during the rut; if handling is necessary, extreme care should be exercised and the stockperson should never handle stags alone. There is less chance of injury to themselves and to their handlers if hard antlers have been removed from stags, the animals are worked in small groups and they are penned individually if necessary. Immature deer are particularly flighty and need to be handled as little as possible and with the least necessary physical restraint. Leaving animals in handling pens for a short period immediately after gathering can result in them being calmer and easier to work through a race system. Animals that are overly stressed by the handling procedures may lie down, and such animals should be left alone in the company of other deer and allowed to stand before further activity is undertaken. Some deer remain flighty or otherwise difficult in the handling system and can cause others to become a problem. These animals should be removed from the herd.

Deer that are farmed or otherwise held in captivity (and some wild-caught animals as well) habituate relatively rapidly to human presence and their flight distance reduces to 30–35 m or less (Clutton-Brock and Guinness, 1975; Blaxter *et al*., 1988). Yarded deer show a further reduction in flight distance when approached by familiar stockpersons, particularly when the initial arrival is in a vehicle rather than on foot, and especially when this is associated with feeding.

Ideally, deer are handled by stockpersons who are familiar to the deer and who act in a calm and predictable way. Deer habituated to the arrival of an individual stockperson often become agitated if a greater number of people appear. Gentle handling of stock and regular exposure to humans and feeding (particularly in the period immediately after weaning) habituate deer to humans and make them much more tractable. Deer fed in paddocks will learn to come to the call or the rattle of a feed sack. This training can be put to good use when moving deer out of paddocks and into handling areas and raceways. Experience suggests that more can often be achieved by a single familiar stockperson, knowledgeable about his or her deer's behaviour, than by a stranger or a larger group of people which present as novel to the deer. Equally, places where aversive handling experiences have occurred

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are generally avoided (Pollard *et al*., 1994b; Grigor *et al*., 1998a), so there may be value in offering a positive experience (e.g. concentrate feed) following aversive handling to mitigate any negative effect. Adopting a quiet and unhurried approach also pays dividends in the ease of handling of deer.

Hand-reared deer have a zero flight distance, but this can lead to problems when trying to move them as part of a mob. Hand-reared entire males are extremely aggressive towards humans during the breeding season and should not be kept (Gilbert, 1974), and hand-reared roe deer are especially aggressive too. This is because hand-reared deer become imprinted to people and, when they mature, they view people as conspecifics with whom they have to compete for mates or food. It is not a tameness issue; these are deer that view humans as their own species.

Through their size and behaviour, deer can pose a physical threat to handlers. This happens particularly in pens or yard situations, where deer are often worked from within their flight zone, which may elicit extreme reactions. So it is important that warning signs are recognized. Grinding teeth and salivation are signs of impending aggression. A prolonged head-up look and eye contact by the deer, or ears flattened back, can also be signs of threatening behaviour that indicate an impending attack. Deer may snort and stamp their forefeet and threaten with their antlers as well, and ultimately they may lower their head and charge (especially stags). The main risk to the handler is from the antlers, if present, and from the forefeet, as deer can rear up on to their hind feet and box, delivering powerful blows with great speed. In closely confined conditions, deer can kick out, especially if the tail area is handled, using both the forefeet and hind feet. Their hooves are generally hard and sharp and can cause considerable injury to other deer and humans. Deer may also bite.

Maintenance of a dominant position by the handler over a mob of deer (especially stags) eases handling and lessens the risk of injury. Holding a hand high above the head, working from slightly above the deer (e.g. on a catwalk) or confrontation with a shield are useful in increasing the apparent size and dominance of the handler. More generally, for wapiti and stags, close handling in pens is not undertaken; the extra height and body mass of wapiti, compared with red deer, means that wapiti are generally taller than handlers and so less easy to dominate.

Particularly around the rut, dominance hierarchies are important (Clutton-Brock *et al*., 1982) and the stockperson must assert a dominant position, especially if animals are handled at close quarters. In general, stags in full rut are not handled; if any number of stags are kept in close confinement, injuries are very likely. As noted previously, hand-reared deer have a reduced (possibly zero) flight distance and sometimes dominance over particularly aggressive deer is difficult. That said, the level of restraint applied needs to be commensurate with the task to be performed and never excessive.

Within handling facilities, deer are less likely to trample one another, and, if of appropriate temperament, stockpersons can find it relatively easy to work among them directly in small group sizes – around six individuals. With animals quite tightly packed (approximately 0.5 m^2/100 kg), the stockperson can handle animals relatively easily within a pen. In these pens, handlers can hold deer against the pen wall to restrict movement by placing a hand in front of the brisket, or pushing a knee in front of the hind leg. The construction of pens sometimes allows the creation of variably sized enclosures to deal with different group and animal sizes. In these situations, ear tagging and oral drenching can be undertaken. However, it is becoming more common to have facilities in which deer can be run into single-file alleyways and treated from across a low partition. This provides greater handler safety and a reduced level of human contact, which seems less stressful for the deer. For procedures requiring a greater level of restraint (e.g. de-antlering) a squeeze crush or chute will be needed.

Handling Methods and Facilities

This section will consider common approaches to handling red deer, with additional comments on methods relevant to other species, including wapiti, where appropriate. While many general livestock husbandry techniques are applicable, there are a number of crucial differences relevant to the flighty and agile characteristics of deer that have already been noted. These necessitate the adoption of handling techniques that are calm and are considered in advance, along with handling facilities that are designed appropriately (e.g. fences and partitions high enough to discourage deer from attempting to leap over them). Planning should also involve making a contingency plan to cover what might happen

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during the handling event. The 'Three Ts' approach advocated by Haigh and Hudson (1993) is a sound one to follow; the three Ts being Training, Taming and Tempo. Appropriate handling techniques ensure a high level of animal welfare, make the stockperson's tasks easier and are based on a good understanding of deer behaviour by stockpersons, particularly in relation to aggressive threats. Fallow deer have a reputation of being more nervous than red deer and are treated accordingly, sometimes being handled under subdued lighting conditions.

Human and animal safety

In any work with deer, but especially in any handling and yarding facilities, human and animal safety must be the prime consideration. It is important to bear in mind that around 23% of all accidents on farms are caused by livestock. To this end, WorkSafe New Zealand has produced excellent good practice guidelines on safe deer handling (WorkSafe New Zealand, 2015). Many handlers wear protective clothing, including a helmet, padded trousers and jackets, and boots with steel toe-caps. Worksafe NZ also considered the use of cricket boxes to protect the genitals from kicks. For young male deer with spike antlers and unaccustomed to close handling, or for rutting stags, some handlers use transparent 'riot' boards or shields when it is necessary to enter pens and move animals. These devices are also used by those entering pens with wapiti hinds. Even if some classes of deer still pose a risk, handlers can feel more confident and handle deer more easily, but they should not become complacent as protective clothing and devices such as shields do not eliminate the hazards.

Because of their size, speed of movement and, in males, the presence of antlers, deer present a physical risk to themselves and to their handlers. Neither red deer nor wapiti are necessarily aggressive, except at rutting time, but their size and strength (particularly of the wapiti) demands respect and special care should always be taken around stags. That said, while deer can be unpredictable when handled, they very rapidly learn handling routines and can be moved and managed with no more difficulty than other livestock. Habituation of deer to facilities and routines will result in very few injuries occurring and more job satisfaction for stockpersons. Avoiding overcrowding and allowing time for deer to move of their own volition is helpful in some situations. Where deer are handled only infrequently, such as in ranching situations, or if the facilities are novel, adequate planning must be undertaken, and enough suitably trained personnel must be on hand if problems are to be avoided. The age and previous handling experience of the deer will need to be considered before any handling operation. Common injuries to deer include bruising, hair loss, abrasions or other skin damage and, rarely, more serious injuries such as limb fractures following entanglement with fencing or solid pen structures. Inter-deer aggression can also be a problem where animals are confined, particularly if they are unused to handling or being held for excessively long periods. Thus, efficient planning should ensure that handling duration is minimized.

For male deer with antlers, particularly spikers (yearlings during the summer grow a single or minimally branched set of antlers), there can sometimes be traumatic injuries to other deer due to antler penetration wounds. Stags with velvet antlers are very wary of other deer and tend to be very careful to avoid contact. However, if velvet-antlered animals are handled (see antler/velvet removal later in the chapter), there is always a risk of damage, and considerable blood loss can occur. The damaged areas can subsequently attract flies and there can be secondary infection as a result. Once the antlers have hardened, they are serious weapons; the antlers of breeding stags are generally removed as soon as possible once this has occurred, to protect both other stags and handlers. During the rut, males (with or without antlers) should only be dealt with (and on an individual basis) when absolutely necessary. Handling at this time is usually confined to allocating stags to different groups of hinds. It is good practice to display public warning notices on farm premises where stags are present during the rut, even if members of the public would be trespassing.

The handling of hinds with calves generally happens at the time of weaning, and once the herd is gathered into a confined space it is important to shed calves from the hinds as soon as possible to avoid injuries to the calves occurring as a result of the larger hinds milling around. It is unusual to gather hinds and calves before weaning, but if this does occur it is important that adequate supervision ensures that hinds and calves are reunited once they are returned to pasture. Hinds with newborn calves at foot are also potentially dangerous and stockpersons should act accordingly; they are generally left alone until after hiding behaviour by all the calves in the group has ended, although this

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does not mean that adequate supervision is not required. If it is necessary to enter the calving area, for example to inspect animals and deal with emergencies, it is important for safety reasons to avoid coming between hinds and their calves. Many people only enter calving paddocks in the safety of a robust vehicle and ensure that, if they do get out, they do not get cut off by intervening hinds.

Within handling facilities, it is best if the handlers do not have to enter pens to operate gates and force animal movement – good design is key (see next section, 'Handling systems for deer'). Once deer are well restrained they can be dealt with efficiently and the duration of any proximate negative experiences can be minimized. Thus the use of squeeze crushes/chutes that are appropriate for the size of animal concerned has made a significant contribution to positive handling experiences for both deer and stockpersons. It is important, though, to use only the degree of restraint warranted, and a squeeze crush is not always needed. Some techniques can be undertaken when working in or alongside a pen or a single-file alleyway of red or fallow deer providing the animals are reasonably tightly bunched.

It is good practice to prepare a risk assessment (or review an existing plan) prior to any handling activity. The preparation of suitable risk assessments for any handling procedure allows those involved to think through the likely risks to both humans and deer, to mitigate hazards through facility design and good practice and to have plans in place should problems occur (such as a first aid plan and kit, emergency contact details etc., in relation to handlers and contingencies for dealing with injured or trapped deer). There is not space here to explore this aspect in detail, but it is important to note that all stockpersons should play an active part in this process.

A final aspect of safety recognizes that deer can carry several zoonotic diseases (e.g. yersiniosis, tuberculosis, leptospirosis, tetanus) or harbour ectoparasites such as ticks, which can be the vehicles for disease. Local veterinary and medical advice should be sought as necessary as incidence and risk will vary. In any case, good hygienic practice should always be undertaken when working with deer, especially when working with obviously sick animals or carcasses.

Handling systems for deer

The way in which facilities are designed and operated has a great impact on the welfare of deer. Handling systems impose a variety of challenges on any animal, and deer are no exception. Their flighty reputation (in fallow, chital and white-tailed deer, compared with wapiti, red and rusa deer) and quick reactions mean that the physical construction of the facilities needs to reduce the likely impact of any sudden behaviour and so lessen the chances of injury. Coupled with this requirement is the need for stockpersons to be knowledgeable about deer behaviour and to think ahead, putting themselves in the position of the deer. Preference testing has been used to determine the relative aversiveness of red deer to a number of handling practices (e.g. restraint in a mechanical crush, Pollard *et al*., 1994b; physical restraint and social isolation, Grigor *et al*., 1998a).

Facility design has evolved based on farmer experience and a growing body of technical and scientific findings, but compared with other livestock species, there is far less information available for deer. Any deer farm needs handling facilities that are both appropriate to the activities undertaken and expertly designed with deer behaviour and safety in mind. Facility design should encourage the natural movement of animals through the system, and raceways should be designed as an integral part of the farm set-up (Fig. 20.1). From a disease-control perspective, using common facilities for different groups of animals increases the chance of disease transmission.

Fencing

External fences need to be suitably high to prevent escape attempts and actual escape. Deer fencing for paddocks and initial raceways is usually of high-tensile steel wire mesh and around 2 m in height, even for the larger wapiti, although occasionally deer will jump this. Usually 13 (horizontal)-line wire mesh with vertical stay wires at 150–300 mm intervals is used. Ideally, the horizontal-line wires should be about 180 mm apart near the top, decreasing to about 100 mm near the ground, so that the mesh size is smaller in the lower half of the fence, though even this may be insufficient for very young calves. If the mesh is too big, once a deer pushes its head through it will go to great lengths to get the remainder of its body to follow, leading to entanglement and injury. This is a particular issue for calves, which often show a greater propensity to run at fences. If the situation allows, on external boundaries, it helps to have a visual barrier such as a shelter belt of trees on the outside of the

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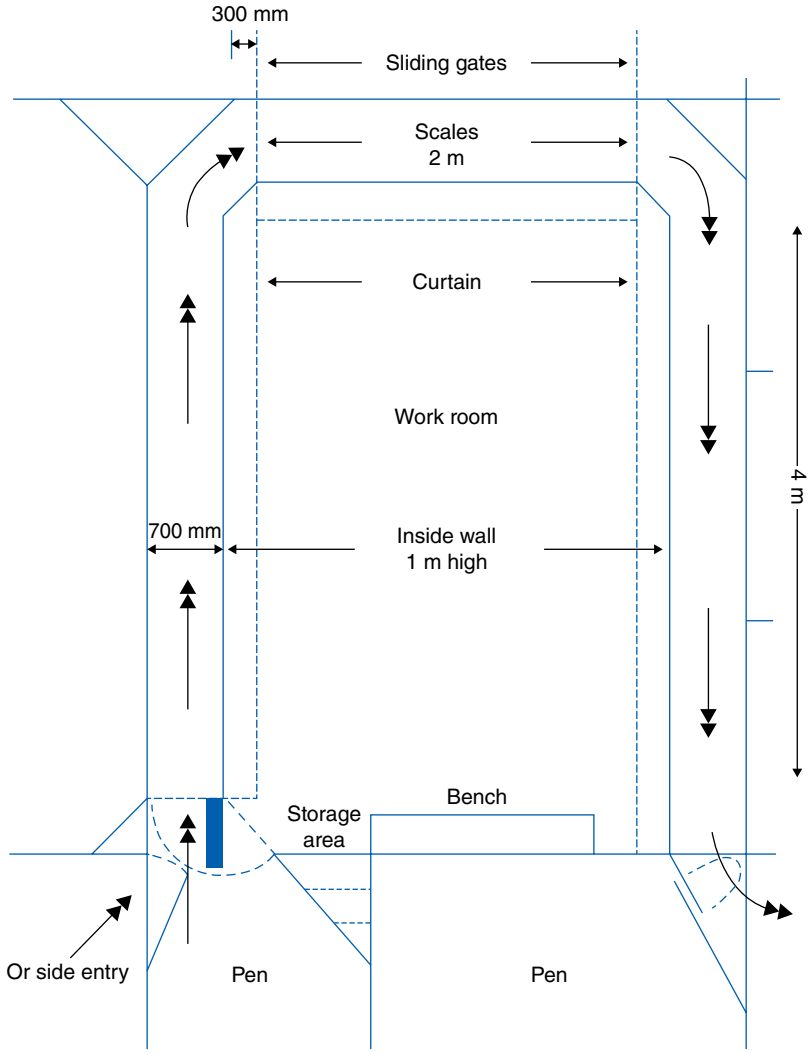


Fig. 20.1. A modern handling facility for use with groups of up to 25 red deer. Additional sliding gates can be positioned along the race to facilitate control of the animals. Drafting (sorting) can be carried out from the race by placing additional gates in the outside wall leading to neighbouring pens.

fence. Alternatively, wooden 'droppers' are added to the upper sections of the netting to provide a visual deterrent.

Suitable electric fencing to around 1.5 m high can be employed for internal divisions (mainly to reduce cost but also to allow pasture reallocation) and electric wires at around 600 mm from the ground can be used to keep deer away from external fences at pressure points ('deer pressure' is the term used to describe the likelihood of deer trying to breach a fence) or when stags are in adjacent paddocks (even when separated by conventional netting fencing), but this is not suitable as the sole external fence. Electric fences are generally not used for antlered stags, which may become entangled. Deer may need some time to adapt to electric fencing, and the inclusion of experienced animals in a group helps.

As indicated above for electric fencing, internal fences may not need to be as high as external

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fences, depending on the class of stock to be separated and the time of the year. Fences of between 1.2 and 1.5 m in height will often suffice when feeding or breeding pressure is minimal. For perimeter deer fencing in very extensive situations, or to protect areas of reforestation or plantations from wild deer, alternative fence designs have been suggested (e.g. for the avoidance of injury to species of conservation interest) (Goddard *et al*., 2001), but not all of these alternatives were found to be 100% effective. Indeed, sustained pressure by numbers of deer can overcome most fences. Within paddocks, deer often develop well-used routes (often there is fence-line tracking, too), thus mimicking a behaviour observed in the wild (Cadman, 1966). Newly released deer are much more likely to attempt to breach a fence. Interestingly, the occasional deer that does escape is generally found not to stray far away.

Raceways

Suitable raceways need to be incorporated into facility design, and as these raceways approach the main handling yards, the specification needs to be increased by using stronger materials and also to present fewer visually apparent opportunities for escape. Stronger intermediate posts, reduced wire spacings and additional visual barriers are required. Equally, the initial lead-in parts of handling systems need to be visually inviting to the deer to encourage natural movement. Lead-in sections are usually 5–10 m wide to allow deer to move as a mob without congestion. If raceways are wider (*c*.20 m) handlers can move past bunched deer without triggering a flight response; equally, with raceways this wide it is easier for deer to turn back. Wider alleyways are advisable if a lot of stag-handling takes place. At the end of raceways, it is good for deer to have to turn through a curve or otherwise have the impression that they are going round a corner and not encountering a dead end, which may cause them to balk.

As the pressure on external fencing increases, it needs to be increasingly visually secure to discourage deer from attempting to escape, but it is best for the appearance not to change abruptly. Where pressure is not excessive, visual barriers to the exterior can be created temporarily by covering mesh fences with hessian or other opaque material, such as plastic windbreak/shade net webbing. Deer should be encouraged to become familiar with raceways by allowing them access at times when they are not in use. This familiarity and resultant reduction in stress is particularly valuable for yearling deer, which can become vulnerable to heat stress during yarding and handling.

Gates from pens and raceways need to be of the same height and grade of construction as the adjacent fencing and must be wide enough to allow a group of deer to pass through together. If the gateways are too narrow, injury can result (especially when hinds with calves at foot are involved) and the flow of animals may be more difficult to achieve; a minimum width of 3.5 m is recommended. Experience confirms that effective, deer-proof and simple-to-operate latches are essential. If the deer pens are on sloping ground it is helpful if the gates to raceways can be placed at the highest points as deer naturally move uphill when feeling threatened. Gates are also best placed in the corners of fields, and strengthening the fencing near gates and making these areas more visually attractive helps to funnel deer out of the field.

There are a number of ways to encourage deer to enter and move along the raceway system, but essentially, they need to enter the first section in such a way that they do not feel threatened and can remain bunched up, as is their natural tendency (Humphries *et al*., 1990). Thus, too small an initial enclosure will not usually work. Deer can often be trained to come to a small feed within this area and, once trained, even the rattling of a feed sack or a whistle may suffice to draw them in. It is usually most effective if the regular stockperson can undertake this first step alone, as the arrival of a number of unfamiliar people at this point can often spook the deer and make the whole process much more difficult. Once in the initial holding area, deer can be encouraged to move into the raceway system, which includes a series of gates that can be closed to prevent the deer from moving backwards. Raceways that are straight and too long (especially without intermediate gates) can lead to deer turning back. In the wider areas, a small number of people carrying a visual barrier, such as a roll of sacking stretched across the width, generally suffices to encourage the deer forwards. As deer tend to cut corners, it is best to avoid designs where tight turns at speed are likely. Otherwise bruising or other injury can result.

Handling pens

Regardless of the main requirement, all farms will need a series of handling yards, pens and shedding

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arrangements, designed to accommodate and move subgroups of animals with ease of natural movement in mind (Fig. 20.1). Overcrowding can lead to stress and injury. All handling activities should be well planned and be undertaken in as short a time as possible. Many pen designs have been implemented, and providing that the simple principles noted above are followed, most seem to work well. Additionally, the system should be designed with ease of working in mind, commensurate with the tasks to be performed, the size of the animals and the number of stockpersons available. There should be suitable escape hatches for humans. As stated before, if the animals can be handled easily and with minimal disturbance, the stockperson can focus attention on the job to be done; this allows maximum attention to be paid to the welfare of the deer.

Raceways/alleyways are needed within handling areas and their design depends on whether they are just used to move small groups or single animals about or are used for close handling of the deer. Grigor *et al.* (1997a) found that deer move more easily as a small group through alleyways at least 1.5 m wide so that they can move two or three abreast, especially if in sight of deer ahead. The same authors also found that deer move more readily into alleyways incorporating curves and move along them more rapidly. Some designs have a series of baffles, lanes or doors to create a zig-zag arrangement. Long, straight alleyway sections are not a helpful design feature and, as noted earlier, enticing features are especially important in getting the lead animal to enter, with the avoidance of dead ends. Wider races are needed for larger groups but for single animals 600–700 mm width is enough (unless antlered stags are involved) as this width makes it harder, but surprisingly not impossible, for deer to turn around. Such narrow alleyways are usually solid-sided, at least part of the way up, and it is helpful for deer to be able to see others ahead.

Unless deer are very tame and show no flight response, forcing gates behind are not usually needed if red deer facilities are well designed, but are considered an essential safety feature for systems handling wapiti, which also tend to move through the system less easily. For wapiti, the dimensions of a facility need to be greater and the structure made much more robust. A series of forcing gates and swinging doors can be designed to move wapiti safely through the facility and provide secure individual handling pens (Thorliefson *et al.*, 1997) (Fig. 20.2). Gateways for wapiti are ideally at least 1.2 m wide to prevent animals from jamming together, thereby stopping the flow and injuring themselves. For all deer, it is considered helpful to have a curve at the end of an alleyway before, for example, entering a restraint device, enclosed yard or weigh crate; Goble (1991) considered a 135° corner helpful.

For close-handling areas, wooden structures are mainly lined with plywood or board and are usually about 2.25 m high (2.6 m for fallow deer and 3 m for wapiti) to be completely deer-proof and to improve visibility of the barriers to the deer. Indeed, many on-farm deer handling facilities are of wooden construction. Even though, from a hygiene perspective, wood is hard to clean and disinfect compared with metal, it does lead to a quieter environment. It is important that there are no sharp protrusions that could result in injury.

Holding pens of similar height are required but, other than in close working areas, internal divisions topped with tight chain mesh or horizontal open boarding (75 mm spaces for red and fallow deer; 150 mm for wapiti) above, about 1.2 m for red deer and wapiti (1 m for fallow deer), seem very successful. These arrangements allow deer to see from pen to pen, which has a quietening influence on them, possibly because they are better able to observe other animals and approaching humans (Pearse, 1992). Some designs have open boarding down to ground level (50 mm gaps), and while these are not ideal when calves are handled, such an arrangement allows the handler to climb out in an emergency. Vertical boarding is avoided because this may lead to a flickering light effect, which may cause moving deer to balk.

Some specialized handling unit designs can incorporate or be based on a narrow, single-deer-width (0.7 m) raceway within the main handling facility, which animals enter from a small group pen. Within the arrangement, sliding gates can control the flow of animals and the handler can work on the deer from within a central handling area. With deer of suitable temperament, the inside wall in this arrangement only needs to be solid to around 1.2 m in height and an offset curtain provides a visual deterrent to escape at the same time as allowing the handler easy access to the animals inside the curtain (Fig. 20.3). If handling wapiti, the curtain can be replaced with horizontal pipe railings, and the ceiling height raised from the 2 m recommended for red deer. This is an example of the many designs

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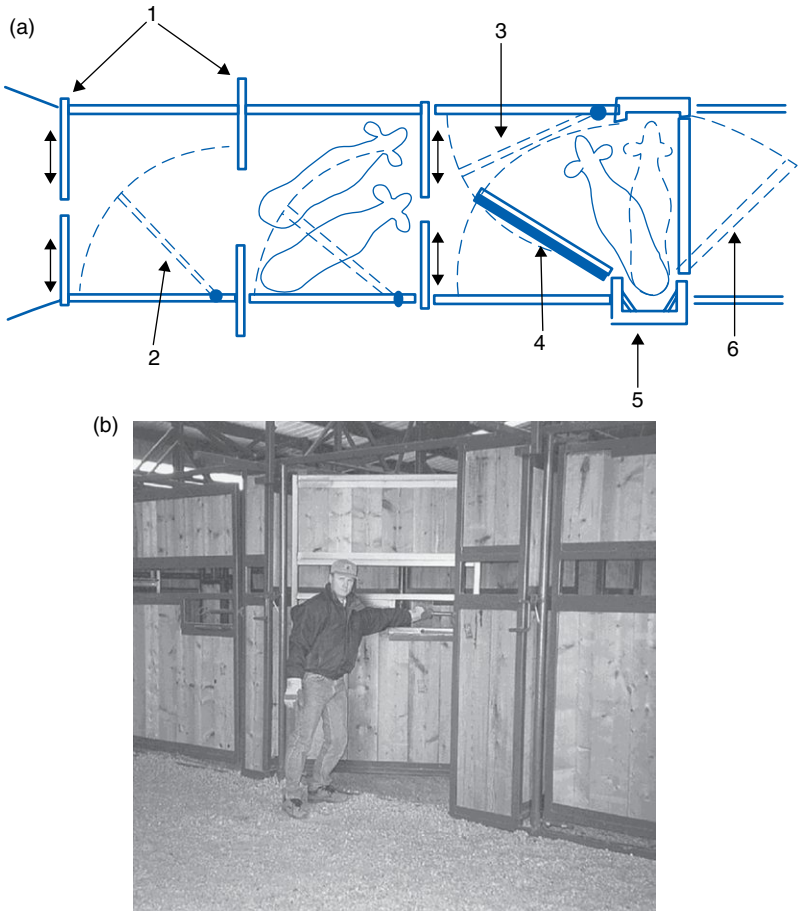


Fig. 20.2. (a) A wapiti (elk) handling facility. On both wapiti and red deer farms in Canada, producers have developed this design, which eliminates the need for a single-file race. Wapiti stay calmer because two animals stand side-by-side as they move through the system. All fences, gates and walls in the facility are solid. Key: 1, biparting sliding gates separate the compartments; 2, a pusher gate is used to move the animals to the next compartment; 3, a pusher gate to urge the animal into the padded stall; 4, side entrance gate on the padded stall; 5, padded stall which holds the animal for palpation, injections and artificial insemination; 6, exit gate from stall. The padded stall shown in this diagram fits snugly but does not squeeze the animal and has numerous small doors on both the side and the rear for access to the animal. (b) Dan Sych in Alberta, Canada, demonstrates the operation of a pusher gate. All handling is carried out from ground level.

that can be implemented satisfactorily based on a good understanding of deer behaviour and past practical experience. Similarly, for fallow deer, a straight race in the form of a tunnel (around 0.9 m in height and 310 mm wide) can be used with a light at the end to attract the deer (Cash, 1987). More details of white-tailed deer handling systems can be found in Haigh (1995).

Deer may be reluctant to leave holding pens if they have previous experience of adverse events in other parts of the facility (Grigor *et al*., 1998a). Behavioural (Pollard *et al*., 1994b; Grigor *et al*., 1998a) and physiological (Pollard *et al*., 1993; Carragher *et al*., 1997; Waas *et al*., 1997) measures suggest that deer can rank the aversion of different experiences; from most to least aversive, the generalized list would be drop-floor crate, transport, social isolation and human proximity. Adverse experiences have less effect on the willingness of deer to move along raceways than does removal

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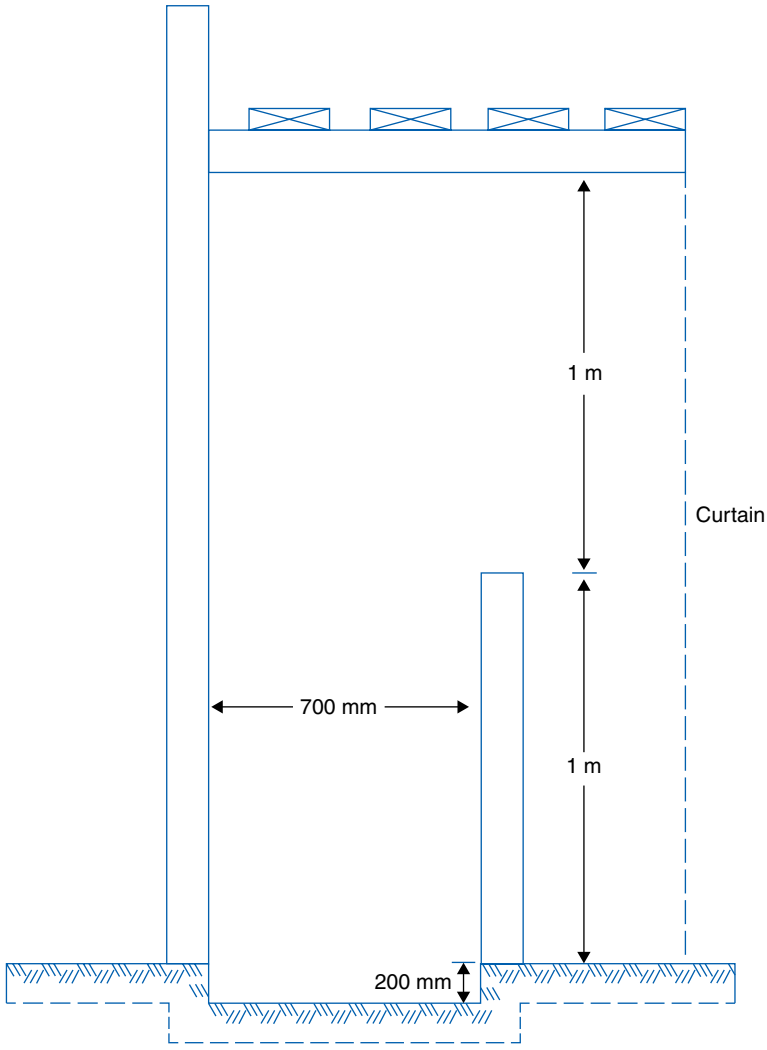


Fig. 20.3. The cross-section and dimensions of a race for red deer. Note that the curtain hangs 300 mm out from the low side wall, thereby allowing the operator easy movement and access when working the deer. If the raceway is not set below the shed floor (as shown) then the shorter side wall needs to be 1.2 m high.

from pens (Matthews *et al.*, 1990; Grigor *et al.*, 1997a). For red deer, the speed of movement along the race is not necessarily influenced by the level of light ahead (Grigor *et al.*, 1997a, 1998b), although some other aspects of lighting may be important. It is also difficult to move animals towards pens or onto transporters if there are bright shafts of light directed towards the deer. Fallow, white-tailed and chital deer are more likely to move from dark to light (Langridge, 1992; Haigh, 1999). Overall movement in the raceway is primarily down to pressure behind the deer (flight response) versus onward attraction.

On a short-term basis, pen size has not been shown to affect deer well-being (Pollard and Littlejohn, 1996). Short-term holding pens for deer need to provide around 2–6 m^2 per animal and groups of around six animals seem to work well. For stags and animals housed for longer periods and overnight, the space may need to be increased. Another way that flightiness can be reduced is to use pens that are not excessively large for the average group of

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animals to be handled and to have low ceilings (around 2 m for red deer and 2.5 m for wapiti), which discourage leaping and boxing. However, for general holding areas, greater pen heights are recommended (e.g. NAWAC, 2007).

Tasks to be undertaken in pens include separation of calves at weaning, dividing hinds into rutting groups, providing veterinary treatments, weighing and condition scoring, removal of antlers from stags, dealing with injuries and loading/unloading. Handling facilities often incorporate a circular forcing pen (rotunda) to facilitate the steady movement of animals, sometimes into a single deer-width raceway system, and it is important that gates and dividers can be operated without the need for the handler to be in the enclosure with the deer. As unexpected noise has been shown to affect deer by increasing the unpredictability of events, handling systems should be built to reduce the noise associated with metal fixtures and fittings.

A suitable deer squeeze crush/chute (which can be of the drop-floor type or operated pneumatically) is almost essential for most deer farms, and allows a number of management activities to be undertaken with the animal securely restrained. These squeeze chutes allow the operator to focus on the task in hand rather than having to worry about the security of restraint. The restrained animal generally adopts a quiet disposition. It should be remembered, though, that deer will rapidly adapt to a handling system and, as a result, they can then be handled with less restraint. For example, most farms will have a weighing crate as part of the main race facility if any form of active nutritional management is practised and deer soon learn to regularly run through this.

To individually sort animals, the handler enters the flight zone to cause movement of deer forwards or backwards depending on whether they are behind or in front of the point of balance at the shoulder. Short lengths of plastic pipe to 'extend' the arms, or wooden shields, can be used to affect the point of balance. A series of lead-out pens, and possibly a loading bay designed to accommodate regular-sized vehicles (and useable in all weathers) (e.g. Yerex and Spiers, 1990), is then required. Decades of practical experience indicate that facilities more similar to those used for handling cattle, without a central drafting (sorting) area, are just as successful for deer. In any case, the design should allow for single stockperson operation which has become the norm. Other than stags, which are handled on their own, deer should be handled individually for the shortest period possible.

The flooring of handling areas should, ideally, be of a solid material that is easily cleaned. Many open-air facilities have earth floors that can become either very dusty or very muddy, making work for the stockpersons more difficult. Indoor facilities also sometimes have earth floors or, often, are made of compacted, freely draining material such as sand or concrete. These provide secure footing for the deer and stockpersons. If deer are to be held in pens for long periods, some bedding is usually supplied (e.g. wood chips) to provide comfort and to absorb urine, along with water and food. Deer may be reluctant to drink or fully meet their hydration requirements in novel situations (Hargreaves and Matthews, 1995).

Handling facilities also need to be designed with specific species or classes of animals in mind. Figure 20.2 shows a specialized facility for handling wapiti. If calves are to be handled, gaps at the side of and underneath gates need to be less than for adults. Fallow and white-tailed deer are less flighty under subdued lighting conditions and thus more easily handled (Kelly *et al.*, 1984), but equally, for safe working by the stockpersons, light must be adequate, especially if zootechnical procedures such as blood sampling are to be performed. In any case, more tractable animals can be handled without difficulty under normal lighting. Red deer, particularly if they are unaccustomed to enclosed handling systems, may benefit initially from subdued lighting (Pollard and Littlejohn, 1994), but this is generally not necessary and, again, good lighting facilitates the stockperson's work and allows him/her to detect early warning of any aggressive signs. Given that animals unfamiliar with the system may be more reactive, it has been suggested (Pollard *et al.*, 1992) that including a tame hind with groups of weaned calves can have a beneficial calming effect. In any case, familiarizing animals with the handling system, including in the provision of supplementary food, is a useful activity and saves time in the long run. Price *et al.* (1993) found that stress levels declined with increasing familiarity with the handling area.

For several reasons, it is desirable if the main working area is covered, but pens can be outdoors with groups of deer drafted into smaller working groups of 12–20 compatible animals when required. For most classes of red deer, drafting can be achieved by cutting animals out by hand as for cattle. Some facilities are designed with elevated walkways

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(particularly in wapiti systems), but generally animals are best handled from ground level rather than from a height as this tends to spook them and make them difficult to control.

Deer squeeze crushes/crates

Deer squeeze crushes/crates are required to provide restraint and a high degree of control in order to undertake certain procedures, such as antler removal, artificial insemination or blood sampling.

In the early years of deer farming, drop-floor crushes/cradles were used (see Fig. 20.4), and these are still found and effectively operated on smaller units). Individuals enter from an elevated race and are held within a padded, V-shaped device, between 2 and 3 m long, depending on the class of stock (most of these devices can be adjusted in size). Once the deer is contained in position, the floor is dropped away, thereby suspending it by its shoulders, chest and hips, so that it is then held up by the padded sides of the crush, which apply pressure across the body. The restrainer therefore needs to be designed so that the deer does not suddenly fall when the floor is dropped, and the best drop-floor restrainers are heavily padded to hold the animal's body securely when this happens. Clearly, deer are more likely to become agitated if they suddenly fall down when the floor is dropped.



Fig. 20.4. A drop-floor cradle for restraining deer.

Securely held in this suspended position with its feet free of the ground, most deer assume a very manageable demeanour (though occasionally the head needs to be held or pressure applied to the withers). Various openings at the front of the crate allow zootechnical activities to be performed, sometimes from an elevated platform. Providing the crush headroom is large enough, deer with antlers can be handled in this way to facilitate antler removal. Units of different sizes (or of flexible set-up) may be required for a complete range of operations. On completion of the task, the sides of the crush are drawn apart, allowing the deer's feet to touch the ground. It can then simply walk away.

With advances in practice and technology, pneumatic or mechanical devices operating on the same principles but without the need for deer to walk up a ramp are now employed (Hutching, 1993). These squeeze chutes simply lift the restrained deer off the ground (without the need to ascend a short gangway) and allow similar management activities to be performed (Fig. 20.5). It helps to encourage deer into a crush if its way out appears unimpeded or if it can see animals ahead. Some units have handlers like this which can accommodate two or three deer at a time. Fallow deer are more readily attracted by light, and this behavioural trait can also be employed to encourage them to enter the crush. Prior exposure to any restraint device before it is used in earnest is well worth the effort and can be accompanied by a food reward (Grandin *et al.*, 1995). Prior to use, the crush should be checked to ensure proper functioning and there should be a way to release deer rapidly in an emergency.

Animals tend to struggle if the pressure is too high or too low or when their shoulders are too far forwards in the squeeze crush. Heavy padding on the deer restrainer applies more even pressure on the animal's body and may help reduce struggling. When pressure is applied evenly, less pressure overall will be required to hold the animal. Struggling can sometimes be reduced by covering the deer's eyes with a blindfold. Wapiti usually remain quite settled in squeeze races where only minimum pressure is applied in a narrow race (Lee, 1992). Particularly

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Fig. 20.5. A mechanically operated deer chute with a stag *in situ*. Note the padded sides and the curtains which are closed while the deer enters. Once animals are within the chute, a mechanical or hydraulic system applies sideways pressure to restrain the deer and elevate its feet from the ground. The operator works alongside the deer – in this case to remove antlers. Longer squeeze chutes can be employed that accommodate more than one animal, though not usually for de-antlering. (Ali Loader)

flighty species such as fallow and chital deer need greater restraint for close handling. However, close handling can also be achieved by restraint in narrow stalls or U-shaped races with movable sections so that required parts of the animal can be accessed; numerous designs based on experience and knowledge of deer behaviour can be successful.

On-farm activities

General management

For most of the year, farmed deer are kept as single-sex groups: a small group of breeding stags; weaned calves (often segregated by sex); yearling stock destined for prime venison; and hinds, either pregnant or with calves at foot. If velvet production is undertaken, there will be groups of adult males. Castration is rarely practised, but if undertaken before the antler pedicle bud begins to grow, antler development will not occur. Disbudding of male calves has been tried (Hamilton *et al*., 1993) but, while feasible, it is rarely undertaken. Neither confers a significant benefit to the enterprise as most youngstock will be sold before reproductive maturity (and associated behavioural changes in males), and although the development of spiker antlers in yearling males can prove a danger, the effort in handling large numbers of hinds with their calves in order to prevent spike development is not thought to be warranted. Given the native habitat of deer, it is desirable to avoid featureless paddocks that provide no visual shelter or shade. Visual shelter can be provided by tree belts, or the use of plastic webbing within or outside of the paddock can reduce disturbance (Herrmann, 1995).

Housing is not usually deemed necessary for adult stock and may even be counter-productive. Where conditions dictate, housing of weaned calves over their first winter can be beneficial, especially if there is insufficient natural shelter outside, and will maximize survival (unless diseases such as yersiniosis occur). Bullying is the principal problem that can occur in housed stock and among calves. The problem can be reduced by having groups of weight-matched individuals and providing adequate feed trough space (unless feed is supplied ad libitum). However, smaller space allowances for animals kept indoors for long periods may provide for improved welfare (Hanlon *et al*., 1994). After the turn of the year, the hair coat of the deer becomes looser and the impact of kicking and biting by dominant individuals – common features of bullying – is considerable hair loss (particularly along the back) in the recipient. Dominant deer often prevent subordinate animals from accessing feed resources. Adult stags are rarely housed together and, if necessary, mature stags over three years of age should be penned individually.

The natural desire for calving hinds to seek isolation and some degree of protection can be met by providing shelters within the grazing area. These can be permanent structures, such as small windbreaks made from corrugated iron, or structures of a more temporary nature made with straw bales. In the absence of either, hinds often find small clumps of weeds or hollows in the ground. As has been shown with other species, calving and maternal behaviour differ with experience (Waas *et al*., 2003); for example, yearling hinds showed a longer interval than adult hinds between birth and suckling. Calves are strong enough to stand and suck within an hour, but, even if able to follow the hind at a slow pace, are often left hidden by the hind until strong enough to run with the herd. Initial sucking by the calf is around 12 times/day, falling to 3–4 times/day by three months of age.

Weaning can be a very stressful time for deer calves, and newly weaned calves need to be handled

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gently. The weaning process is generally abrupt, but other methods such as gradually withdrawing hinds (interval weaning) or including a quiet adult hind in a group of weaned calves (Pollard *et al*., 1992) have been suggested. Continued fence-line contact with dams has been shown to reduce distress in weaned calves (Haigh *et al*., 1997). It is sometimes difficult to handle calves in a large barn or shed as they tend to rush to the part most distant from the handler. It is preferable to work with a tight group of calves in a small pen; in this way the majority of required management techniques can be undertaken. It is also best not to work on and release calves one by one as, at the end of the operation, the pen will be too large for the group and isolated individuals will be determined to escape. Some farms have small deer chutes designed specifically for calves.

Moving/gathering (mustering)

When moving deer, knowledge of underlying behaviour, previously described, can be put to good use. Deer are best handled in familiar groups. For tamer deer, the options are whether to drive the deer or to use an attractant. Deer can be habituated to the provision of supplementary feed delivered by a familiar stockperson, and this training can be started soon after weaning. Auditory cues can also be used. Hand-reared calves can also be trained in this way. Deer will subsequently be attracted to the stimuli that have previously been used and can often be led rather than driven, particularly when the lead deer comes to the front. When using these means, a familiar stockperson is often better able to move deer through a gathering system than a larger number of unfamiliar people. As noted earlier, if gates to alleyways and handling areas can be left open when not in use, deer will become accustomed to them (deer are generally curious animals) and subsequently move more easily. If time allows, this principle can also be applied to moving deer between paddocks – simply leaving gates open to desired areas may be sufficient and deer will often be found to have moved overnight. As deer tend to move to higher ground when they perceive a threat, if fields or paddocks slope, it can be convenient to site gateways on the uphill aspects. Deer also exhibit a high degree of grouping when disturbed and, in addition, show leader–follower tendencies.

To drive deer, the handler needs to adopt the best balance of pressure at the edge of the flight zone to achieve the objective. If the deer are unfamiliar with their environment they are more difficult to move and the handler also needs to be aware that deer have excellent all-round vision and, depending on their degree of habituation, can have a large flight distance. Slowly walking behind a mob of deer, applying gentle pressure, usually achieves the best results. As the handler approaches the deer, natural anti-predator responses cause the deer to bunch together with their eyes and ears directed towards the intruder. As the handler gets closer to the boundary of the flight zone some animals will turn and face away, and then as the handler gets even closer, and eventually penetrates the flight zone, the leaders begin to move and, due to the leader–follower response, the rest of the group follows. The handler can achieve co-ordinated and steady movement by balancing his/her position at the edge of the flight zone. If the lead deer balks for any reason, the herd will stop and possibly circle round, so the handler will need to be particularly aware of the movement of the lead animal. Once the handler recognizes that the lead animal is at the front again, pressure can be applied once more.

Flight distance tends to be less in smaller enclosures, but here the speed at which deer change their direction increases and handlers need to be very observant. As with the attractant approach, driving works better with familiar handlers and as few people as possible. If the process is undertaken too rapidly, deer can panic and initially disperse in all directions. Such panic responses are more likely in young animals and with animals that are unused to handling when groups have been newly formed, or if there are novel aspects to the handling process (Hodgetts *et al*., 1998). Arm-waving and shouting are decidedly unhelpful. If the group to be moved becomes too agitated, it is advisable to postpone the process for at least several hours. Older, experienced deer in a group of youngstock can usefully act as leaders (Pollard *et al*., 1992).

Previous negative handling experiences can make subsequent handling more difficult. Deer penned near to handling facilities were found to exhibit more stress-related behaviour than those at a greater distance (Diverio *et al*., 1993, 1996). Aversive experiences are likely to arise from a combination of visual isolation, physical restraint, other handling practices and proximity to humans (Matthews and Cook, 1991; Pollard *et al*., 1993; Price *et al*., 1993; Grigor *et al*., 1998a). As noted earlier, balancing aversive experiences with the provision of a coupled food reward may counteract some of the negative effects.

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In situations where a handler has become isolated ahead of a group of deer running towards him/her, it is important to remember that often deer will generally choose to move closer to the fence line, so it may be safer to remain in the open away from the chosen fence line if other escape is not possible. While it is generally unwise to try to prevent a single determined deer from running back past a handler, it seems that eye contact between the handler and a deer can sometimes be used to turn animals back (and eye contact can sometimes also be used in the process of drafting animals in a yard situation). Individual deer that become isolated will often injure themselves through attempts to breach fences or other handling facilities.

Many people consider that the use of dogs to herd wapiti is not effective and generally counterproductive, though on some units well-trained dogs are used to help move red deer. Deer can be accustomed to being driven ahead of a stockperson on a four-wheel-drive motorbike. On some units, deer can be moved by the handler mounted on horseback, but animals need to be accustomed to this approach.

Attempts to shed off individual animals or small groups in relatively unconfined conditions are difficult. Individual deer so isolated will often panic and may well injure themselves in attempts to rejoin the main herd. Moving hinds with calves at foot can be difficult if calves do not keep up or become separated, so enough time must be allowed if this cannot be avoided. In any case, groups of calves need to be given sufficient time to move, especially when the routines are unfamiliar. If they get cut off from their mothers, calves use a lot of energy running in search of them, which also leads to general disruption of the whole mob.

Mixing animals

The mixing of unfamiliar deer is a highly stressful event and frequent changes in group structure should be avoided (Hanlon *et al*., 1995). Mixing unfamiliar animals causes behavioural and physiological responses, and leads to negative immunological effects (Hanlon *et al*., 1994; Jago *et al*., 1997). Introducing animals into established groups is generally inadvisable. Pollard *et al*. (1993) also showed that mixing of unfamiliar red deer stags was stressful to the deer, based on both physiological measures and behavioural measures that included aggressive interactions and a decrease in grooming behaviour. It helps if mixed mobs have a large space allowance. If animals do need to be mixed, it is preferable for them to be well matched for weight. Recently mixed deer should be closely observed for signs of continued aggression so that remedial action can be taken. When red deer are pastured with other species, such as sheep or cattle, the animals must never be crowded; paddocks with only 67 m^2/animal resulted in lower performance than those with 267 m^2/per animal (Blanc *et al*., 1999). Due to the risk of malignant catarrhal fever (MCF), a sometimes fatal viral disease, which can be carried by sheep, some producers prefer not to mix sheep and deer (adult stags seem at a higher risk). Veterinary advice should be sought about risk management in this case.

Abattoir slaughter

Deer for slaughter are sent either to a suitable (often specially designed) abattoir facility or are shot in the field by a trained marksman, following ante-mortem inspection on their rearing premises. The process of abattoir slaughter imposes a series of potential stressors on deer as on other livestock species, because of mustering, loading, transport, unloading, lairage and moving to the stunning area. In most countries, there are codes of conduct for the abattoir slaughter of livestock, and some of these include deer (NAWAC, 2016a). Such codes advocate the following basic principles:

- pre-slaughter handling facilities and procedures that minimize stress;
- the use of competent, well-trained, caring personnel;
- the use of minimum force necessary to encourage movement;
- appropriate equipment that is fit for purpose;
- an effective process that induces immediate insensibility, or an induction to a period of insensibility, without distress;
- a guarantee of non-recovery from that process until death ensues.

In the UK, MAFF (1988) produced a code of practice concerning abattoir slaughter of deer, and although somewhat dated, many of the principles therein in relation to handling still apply. Ultimate muscle pH is used industry-wide to evaluate meat-keeping quality and can also be used to provide a retrospective assessment of pre-slaughter conditions (Lawrie, 1985). Typical pH values for deer are

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within the range considered to represent good-quality meat (Jago *et al*., 1993, 1997; Grigor *et al*., 1997b; Pollard *et al*., 1999). Under several codes of practice, personnel should receive animal welfare training in the handling and management of deer from arrival through to, and including, slaughter. Stags presented for slaughter should have had their antlers removed on the farm of origin. (If this is done, it is best undertaken in advance to allow any possible bruising associated with handling to resolve.)

Abattoir processes, including lairage

Poor handling during transport and immediately preceding slaughter can have detrimental effects on meat quality, particularly wastage due to bruising and reduced keeping characteristics. In turn, these effects have been used in a number of studies from which to infer poor welfare conditions during these events. Forceful methods of capture can be highly stressful. A Swedish study showed that roping reindeer and shooting them with a captive bolt in the field was less stressful than catching them and loading them on to a truck for shipment to slaughter (Wiklund *et al*., 2001). When wild reindeer were captured for ethological studies, longer periods of capture and restraint increased body temperature, and other stress indicators were elevated, but there was no effect on summer calving (Omsjoe *et al*., 2009). As the deer in this study were captured during late winter, stress during early pregnancy when the embryo is most vulnerable was avoided.

During the lairage period, meat hygiene requirements may dictate the degree of ante-mortem inspection required. The purposes of lairage include permitting a smooth flow of animals to the slaughter line and allowing animals to recover from the rigours of transport: for example, to recover biochemically from journeys that may have led to metabolic stress. However, this has to be set against the psychological conditions related to a range of novel stimuli, which may suggest that slaughter should take place as soon after arrival as possible. The handling principles outlined earlier also apply to deer during lairage, where they are likely to be disturbed by various aspects of novelty. This applies particularly if they are exposed to other species or to unfamiliar deer (Abeyesinghe *et al*., 1997; Abeyesinghe and Goddard, 1998), when deer show avoidance behaviour, higher levels of aggression and increased heart rates.

Overnight lairage was found to increase the rate of bruising in males during winter (Jago *et al*., 1996), but generally had little other adverse physiological effect. Similarly, Grigor *et al*. (1997b) found no evidence of dehydration, depletion of muscle glycogen or increase in ultimate pH following up to 18 hours of lairage. A number of studies have shown that lairage may allow some degree of recovery from the physiological effects of transport (Jago *et al*., 1993; Grigor *et al*., 1997b), although observations of behaviour indicate that longer periods of lairage may not be ideal; agonistic encounters increased with time in lairage (Grigor *et al*., 1997b; Pollard *et al*., 1999). Using biochemical measures to infer significant physiological change that may be detrimental to animal well-being is always difficult, but Jago *et al*. (1997) reported on increases in plasma concentrations of cortisol and glucose following transport and pre-slaughter handling and showed that these changes were consistent with those seen in other livestock species. Plasma cortisol concentrations in deer have been shown to become elevated within 15–60 minutes of exposure to a stressor and return to baseline within two to three hours if the stressor is removed (Matthews *et al*., 1994).

Feed and water may be provided, depending on the duration of lairage. Deer may exhibit neophobia of the feedstuff and may be reluctant to drink, possibly as a result of the novelty of the container or system, or the position of the drinker in the pen. In some deer lairages, animals are subjected to fine mist spraying to settle and cool them.

Multi-species facilities

Where possible, deer should be slaughtered in purpose-built facilities that, as best as possible, meet the behavioural needs of deer. In New Zealand, all commercial deer are slaughtered in purpose-built facilities. Elsewhere, even though dedicated facilities exist, deer are also slaughtered in some multi-species facilities, so these need to have adaptations to ensure that the lairage, restraint and stunning arrangements are suitable for deer. In all cases, it is important that different species are not mixed and that exposure to other species is minimized, as deer have physiological and behavioural responses which indicate that such exposure is aversive (Abeyesinghe *et al*., 1997).

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Stunning

As for other handling areas, the design of the raceway leading to the stunning box needs to encourage free movement of deer. Visual contact with the preceding deer is beneficial. Swinging doors and suitably curved raceways can be helpful and electric goads should not be used; they are not considered to be needed if the design of the facility is correct. A suitable corridor width and ceiling height discourages turning or rearing attempts. For fallow deer, appropriate lighting ahead encourages movement. In the interests of animal welfare, the process of movement to the stunning pen and the time left in the stunning pen before stunning should be as short as possible (Grigor *et al*., 1999). In some facilities, and for deer of appropriate temperament, a small group of deer can be stunned in a small pen, avoiding the need to move to a dedicated stunning crate. Following stunning, deer must be rapidly bled out to prevent them from regaining consciousness. Other general principles of livestock slaughter also apply to deer (see also NAWAC, 2016a).

Field slaughter

Depending on local meat hygiene regulations, field slaughter of farmed deer using a rifle represents a high-welfare method of killing as this can be done by a familiar stockperson while deer perform their normal daily behaviour (Smith and Dobson, 1990). A number of individuals can be head-shot at relatively close range on any one occasion, a practice facilitated through offering some supplementary feed. The usual practice is a head shot, but as the distance from the marksman to the deer increases, accuracy may be compromised and, on some occasions, a high neck shot is used; this may lead to less rapid death and also to the waste of some useful meat. Nevertheless, such field slaughter offers the possibility of eliminating any stress associated with abattoir slaughter processes and avoids the risk of any carcass quality loss associated with transport and handling. Indeed, much farmed venison has been produced this way in Scotland. Field slaughter, naturally, has to be done safely (e.g. in relation to bystanders) and only a limited number of animals can be processed at any one time (the limitations of a small associated abattoir often also dictate the throughput). To align with meat hygiene requirements, field-slaughtered farmed deer require ante-mortem inspection and rapid bleeding out.

Wild deer capture methods

Capture of free living deer (rather than shooting individuals) may be required for several reasons, but often because a group is causing localized environmental damage. Usually, these activities focus on hinds. One option is to build a series of progressively smaller enclosures, if possible using the topography of the area to make the enclosures blend in with the surroundings. Deer can be tempted into the first, largest enclosure by providing a preferred feed source – maize, hay, feed cobs or root vegetables. A temporary gate can then be closed behind them, ideally when the deer are quiet at night. For such a system to work, the pens would need to be built in an area regularly used by hinds and allow small numbers of animals to be captured on each occasion. It would be generally much more dangerous to deal with stags in such systems, and if stag removal was required, they would be best shot rather than attempting to run them through a novel handling set-up (which would necessarily need to be sufficiently robust).

Alternatives include capture by a net dropped from a helicopter, but in one study of white-tailed deer, it was noted that a number of deer might die some days later as a result of the stress caused by this operation (Beringer *et al*., 1996). It has been suggested that group capture approaches, with deer assessed and humanely dispatched at the point of capture and subject to approved hygiene inspection, represent a sustainable offtake option, especially for locations where there is a perceived overpopulation issue.

If wild deer are to be transported (to a new location for example), the use of neuroleptic drugs to encourage the maintenance of more normal behaviour patterns may be appropriate as these facilitate adaptation to new conditions (Diverio *et al*., 1996). However, meat hygiene regulations are likely to prohibit subsequent human consumption of meat from animals so treated. Individual deer can also be tranquilized using a dart gun to deliver a range of agents.

Capture myopathy (CM) (McAllum, 1985) is a stress-related condition that was reported in the early days of deer farming (particularly with wild capture), but is less common today as deer handling systems and procedures applied to farmed stock are better tailored to the deer. CM is essentially a degeneration and necrosis of the skeletal and cardiac muscles as a result of a complex of biochemical events. The clinical signs include respiratory distress, muscular weakness (the deer may

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collapse) and hyperthermia. CM is often fatal, but death may not be immediate and can follow some days later. The condition can still be seen as a result of wild capture and translocation activities.

Transport

Deer are transported for a variety of reasons, from simple relocation on individual premises to moving from the finishing unit to an abattoir. In addition, in Scotland, for example, weaned deer calves from store calf producers in the uplands are moved to finishers on lower ground where pastures are better, just as occurs in some other livestock industries. Red deer and wapiti travel well given the right conditions. For the most part, they can be transported safely in small groups in conventional livestock vehicles, providing that pen divisions are high enough to prevent deer jumping over them. A number of behavioural and physiological studies have suggested that the process of transportation is a relatively mild stressor when compared, for example, with physical restraint (e.g. Carragher *et al.*, 1997; Waas *et al.*, 1997; Grigor *et al.*, 1998a). So by following best practice deer well-being can be protected during transport. Animals should be segregated into groups of the same size and sex, and with previous familiarity. Stags in hard antler need to be penned individually.

Given the large numbers of deer transported in many countries, guidelines, regulations or quality-management programmes exist to protect their welfare (e.g. MAFF, 1989; NAWAC, 2016b). These include the stipulation of journey distance/duration, transport conditions in relation to food, water and rest, and the duties incumbent upon drivers, including knowledge of how to deal with the need for emergency slaughter. In particular, the transport of deer in velvet is usually prohibited owing to the risk of injury. Deer transport has been the subject of considerable research, and an indication of some general requirements is given in Table 20.1, although specific national legislation and local regulations should always be consulted.

The transport conditions, from pre-loading mustering and handling right up to the point of slaughter have a major impact on deer welfare and on carcass quality. The novel experiences to which deer are exposed include some or all of the following: removal from the familiar home environment, loading, unloading, confinement, exposure to or mixing with unfamiliar animals, food and water deprivation, novelty, temperature extremes, motion and vibration.

As deer welfare and carcass quality are linked, there should be an economic incentive for best practice to be implemented. Carcass-quality aspects include yield-associated downgrading (such as bruising), keeping quality and microbiological status (MacDougall *et al.*, 1979; Jago, 1994). In the study of Jago (1994), which involved a deer slaughter plant survey, 6.5% of carcasses were downgraded in one year as a result of wounds and bruises. In a study reported four years earlier, Selwyn and Hathaway (1990) noted an average loss in carcass value due to downgrading to be almost 27%. In an industry survey, Jago *et al.* (1996) found more evidence of bruising in animals transported for more than 200 km, in smaller or less-fat deer and in males transported in the breeding season. Other studies have found that as the distance travelled increases, injuries such as bruising and muscle damage are more commonly found (Jago *et al.*, 1997), and stress increases (Waas *et al.*, 1999). However, the magnitude of these increases is small. Grigor *et al.* (1997c, 1998c) and Jago *et al.* (1997) found little effect on dehydration with journeys up to six hours long. When specifically considering dehydration, Hargreaves and Matthews (1995) and Waas *et al.* (1999) showed that biochemical signs became apparent only after 11–20 hours following water withdrawal. More obvious external injuries and even death are recorded in all transported livestock species.

Over the intervening years since these reports, there has been a huge economic incentive to reduce these avoidable losses as much as possible, an action that has been accompanied by a significant improvement in deer welfare. As for other species, ergonomically designed loading and unloading areas and the avoidance of off-putting vehicle interiors facilitate easy movement of deer and a better working situation for stockpersons. Because of the high risk of injury to growing antlers and the serious consequences if this occurs, transport of stags in velvet is not usually permitted. Other classes of stock subject to similar restrictions are hinds in late pregnancy and newly calved hinds with calves at foot.

In some countries, journey conditions are prescribed either in general livestock transport requirements or with specific regulations for deer. These also include general assessment of fitness to be transported, which includes assessment of lameness and the presence of any pre-existing injuries or

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Table 20.1. Some generic requirements when transporting deer.

A journey plan, including a contingency for delays or accidents
Vehicles and livestock compartments fit for purpose and designed to avoid injury
Adequate floor space and height allowance – ideally to allow deer to lie down and stand without restriction and have sufficient space above their heads
Assurance that deer are fit to travel. Overriding exclusions generally relate to animals that are lame or otherwise ill or injured, or unable to undertake the journey without unreasonable suffering or unnecessary pain or distress. Some classes of deer are not considered fit to travel: deer in velvet antler or with velvet recently removed; pregnant deer soon to give birth (e.g. in the next 21 days); entire males during the rut; unweaned deer and deer weaned for less than, e.g., 10 days
Handling of the deer only by competent stockpersons (usually including the driver); personal responsibilities to be assigned
Appropriate provision of feed and water (depending on journey duration/weather conditions)
Encouraging driving styles that are appropriate and take cognizance of the impact on deer welfare
Planning of rest periods depending on journey length
If possible, a way for the driver to observe deer during the journey (or sufficient halts to allow this)

disease. In the European Union, general transport conditions are detailed in Council Regulation (EC) No. 1/2005 (Defra, 2006) which, among other things, states that no animal shall be transported unless it is fit for the intended journey and that all animals shall be transported in conditions guaranteed not to cause them unnecessary suffering. All personnel handling deer during transport need to be adequately knowledgeable and competent and be in a position to take corrective actions if situations dictate.

Adult stags during the rut are not usually transported owing to their heightened aggression. When transporting other than trophy stags, it is advisable to first remove the antlers. Stags are recommended to be transported in individual pens, especially if in antler. If stags for slaughter are de-antlered too close to the time of slaughter, residual bruising may lead to downgrading of the carcass.

Mustering and loading/unloading

Well-designed loading and unloading areas should be available and designed to encourage deer to move while avoiding injury (i.e. there should be no sharp projections and fences should be secure and of adequate height). Deer are generally loaded out of buildings with some gentle pressure behind them. It is essential that there are no possibilities for them to escape between the loading pen and the vehicle ramp, so the walls of loading ramps should be high enough to prevent them from attempting to jump out. The flooring material and design should afford a good grip.

Before transport, it is helpful if deer can be familiarized with the loading race. The loading operation should be performed as quietly as possible in order to avoid deer starting their journey in an excited state, which could lead to more serious sequelae, such as dehydration, or the chain of events that results in the CM syndrome described earlier, though this is seldom seen today. Deer can be loaded more easily if the raceway is wide enough to allow them to move as a group rather than singly (Grigor *et al*., 1997a, 1998b), and so openings need to be sufficiently wide. Deer tend to move more readily up ramps than down, especially if the slope is no more than 20°, but there have been no systematic studies done to support this proposition. Waas *et al*. (1997) suggested that if there is a choice, deer should be penned closer to the front of the transport vehicle where vehicular motion is reduced; on the middle and at the rear of transporters, heart rates and plasma lactate concentrations were greater than for those at the front.

When the deer are unloaded into unfamiliar facilities, it is important to ensure there are no opportunities for injury, as they may be inclined to run into fences or pen divisions. Deer generally unload readily from a vehicle, especially if the way ahead is clear and ramps are as wide as the exit of the vehicle. It is the loading that can be more of a problem.

Vehicle design, driving quality and effects of transport on deer

Livestock compartments need to be designed to avoid injury and, therefore, be free of projections or

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openings in which a leg could become trapped; as for handling pens, any openings should be less than 50 mm in width or height, unless they are sufficiently high up (i.e. greater than 1.2 m above the floor). The effect of the space allowed in livestock compartments and the number of animals loaded have been investigated, particularly in relation to falls or losses of balance. The proximity of adjacent animals to provide support reduces the need to adjust posture to avoid loss of balance, but on long journeys, a greater space allowance is recommended to allow animals to lie down if they so choose (without being stood upon) and, importantly, to have the freedom to stand up again – something that may be difficult or impossible at a low space allowance (e.g. SCAW, 1991). Accordingly, it is recommended that densities should be reduced on long journeys to permit lying down (Jago *et al*., 1997). Overcrowding can lead to problems ranging from hyperthermia to aggression, but excessive space can lead to a greater incidence of unstable animals being thrown about during the journey. For this reason, it helps if vehicle pen size is adjustable and can be set at the start of the journey.

When transported in groups, deer of similar size should be penned together (Jago *et al*., 1997). Practical experience has led to groups of around six animals of about 100 kg usually being penned together, and a study by Grigor *et al*. (1998d) supports this, finding that smaller groups (five animals) were less disturbed than larger groups (ten animals) during a journey. Agonistic interactions were found by Jago *et al*. (1997) to be more common between recently mixed animals and those of differing bodyweight, so correct batching and familiarization are important for deer welfare.

Increasing the space allowance is not always beneficial. Jago *et al*. (1993) found that aggression between males was more prevalent at a higher space allowance, especially on short journeys. Hence, tailoring the stocking density to journey length may be a good idea, but this needs substantiation (Jago *et al*., 1997).

Several studies have shown that deer choose to orientate in a preferred way when transported, given sufficient space (e.g. Jago *et al*., 1997; Grigor *et al*., 1998d). At low stocking densities, deer tend to align themselves in parallel with vehicle sides, avoiding diagonal orientations, regardless of whether the vehicle is moving. So based on a motivational preference, denying them the ability to choose a preferred orientation would be considered poor, from a welfare perspective. It is worth noting, though, that when deer cannot orientate in preferred directions they are still able to maintain balance.

Floor-space allowance, along with the height between the floor and roof, may be specified in local regulations, which should be consulted. The floor space allowance may depend on the journey length. The minimum figures suggested by MAFF (1989) for the UK are given in Table 20.2, and these still seem a reasonable guide. However, more recent codes focus on outcome measures, such as animals being able to travel in a natural posture. In future, there is also likely to be more reliance on developing allometric stocking density recommendations.

The height of the trailer should be sufficient for animals to stand with ears erect but low enough to discourage aggressive behaviour and rearing. For stags in antler, these too should be able to stand erect. For other red deer, in the UK, MAFF (1989) recommended that a height of 1.53 m be provided for animals of 75–100 kg, a height of 1.22 m for animals of 45–75 kg and a height of 1.00 m for animals less than 45 kg.

The temperature within the livestock compartment is likely to be greater than ambient. Harcourt (1995) suggested that this would be 5°C higher when the vehicle was moving and much higher when stationary. It was, therefore, recommended that ventilation openings be provided around the sides of livestock containers: around 100 mm wide at a height of 1.4–1.6 m above the floor, with a gap of 250 mm between pen divisions and the roof to allow air circulation. Openings near the floor need to be of such size or protected so that feet do not become entrapped. During hot and humid periods, it is advisable to schedule transport at night or in the early part of the day. Vehicles should not be

Table 20.2. Suggested minimum space allowances – modified from MAFF, 1989.

Class of animal	Floor space per animal (m^2)
Red deer	
Calves to 3 months	0.30
Calves to 6 months	0.35
Calves 3 months to yearling hinds	0.30–0.50
Adult females	0.50–0.60
Adult males	1.00
Fallow deer	
Adult females	0.35
Adult males	0.50

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parked in direct sunlight. Deer suffering from heat stress may benefit from spraying with water.

Whenever communal facilities such as vehicles are used, adequate measures must be implemented to ensure biosecurity. In particular, when using vehicles that have been used to transport other species, consideration needs to be given to disease transmission. For example, if vehicles have been used to transport sheep, there could be a risk of transmission of MCF to deer; this risk should be assessed professionally, especially as some deer species seem more susceptible to MCF than others. In some countries, there is a major problem with chronic wasting disease (CWD), and the movement of deer (and of deer-related implements and trophies, for example) from potentially infected areas to areas believed to be unaffected is usually controlled. CWD is a particular problem as the infectious agent, a prion, is extremely resistant to normal disinfection processes.

Driving 'quality' is a key determinant of the welfare of deer during transport, particularly the avoidance of high-speed cornering or braking. Deer are more likely to lose their footing in the early stages of a journey (Jago *et al*., 1997) and on steep or winding roads (Jago *et al*., 1997; Grigor *et al*., 1998c). Thus drivers need to be particularly careful at these times. Using video observations to monitor the behaviour of the deer has provided valuable information to reinforce the message that routes should be planned that, as far as possible, allow the maintenance of a constant speed and avoidance of an excessive number of bends. Providing in-cab video images of transported animals is an excellent way for drivers to be aware of the effect of their driving style. Indeed, recorded images have been used as part of driver-training packages. An example is a driver-training DVD (*Careful Driving and Animal Welfare: The Effects of Driver Behaviour on the Behaviour of Livestock in Transit*) for livestock transporters in the UK, produced by Edinburgh University as a result of a project funded by the UK Department for Environment Food and Rural Affairs (Defra) in 2005–2007 (Edinburgh University, 2006). As already noted, with sufficient space, many deer will lie down following the initial stages of the journey (Jago *et al*., 1997).

Jago *et al*. (1997), in their study of transported hinds, reported that biting accounted for 95% of the agonistic behaviour observed, with heavier animals generally directing this toward smaller animals. While distance travelled caused a proportionate increase in the plasma concentration of some muscle-related enzymes (creatine kinase (CK) and some lactate dehydrogenase (LDH) isoenzymes, which tend to 'leak' into the circulation as cell membranes lose their integrity), increasing distance had no additional effects on behaviour or on muscle ultimate pH (a measure of pre-slaughter glycogen depletion). Bruising tends to increase with distance transported, and may do so significantly at certain muscle sites (e.g. Jago *et al*., 1997). A number of other studies have also provided information about the response of deer to transportation (Jago *et al*., 1993; Waas *et al*., 1997; Grigor *et al*., 1998d) at deer densities of 0.4–1.2 m^2/100 kg of animal. In all of these studies, some degree of stress response was recorded (e.g. increases in plasma cortisol concentration), regardless of variations in space allowance. Heart rate increased significantly during loading and the initial stages of the journey, but declined thereafter, suggesting that some acclimatization to the experience occurs (Grigor *et al*., 1998d).

Some drivers recommend leaving vehicle engines running during brief stops because the deer will have become accustomed to this noise.

Feed, water and bedding in the transporter

Some authorities recommend the withdrawal of food for a minimum of four hours, but for a maximum of 12 hours, before transport (NAWAC, 2007). Depending on the journey length, feed and water may need to be provided en route. Requirements for the provision of feed and water are often stipulated in national transport regulations, but the provision of water in unfamiliar receptacles or of unfamiliar feedstuffs may be a deterrent to their use. Many people have found that giving root vegetables is a good way to provide hydration during a journey; deer should be accustomed to these in advance. Following unloading, it is usual to provide feed and water. Excessive provision of concentrates is undesirable, as deer will be likely to overindulge (which may lead to acidosis); experience suggests that they will also feed before drinking, even when potentially dehydrated. Journey breaks, especially if deer are unloaded into a novel environment, may not always facilitate rest or feeding or drinking. Bedding in the vehicle can be provided; straw, sand, sawdust or wood chippings allow comfortable resting, prevent slipping and absorption of moisture. Hay is sometimes used, which the deer also eat.

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Effect of handling and transport on disease

In other farmed species, it has been shown that handling (and particularly transport and mixing) has an impact on disease prevalence, for two main reasons. Firstly, the bringing together of large numbers of animals in a restricted area provides increased opportunity for pre-existing disease to spread by contact. Secondly, the stress associated with handling and transport can have a negative impact on immune mechanisms and disease resistance. Even in the wild, the congregation of deer around feeding stations has been shown to increase disease transmission and incidence (Miller *et al.*, 2003).

Translocation of wild deer for management and conservation

Deer may need to be moved for management or conservation purposes. For example, a small group of European red deer was successfully introduced into the foothills of the Andes in Patagonia in the early 1920s, and the estimated population size is now around 100,000 animals (Flueck and Smith-Flueck, 2011). Specialist advice should be obtained for such an operation.

Handling for Zootechnical Work

Handling systems need to allow for optimal (i.e. sufficient but not excessive) restraint for procedures such as dosing, vaccination, tagging for identification, hind insemination, ultrasonography to determine pregnancy, and de-antlering or velveting, depending on the farm's needs. Some of these procedures, such as individual treatments, can be performed with the stockperson working quietly among a group of individuals in a small pen but increasingly this is done from outside of the pen or race over a low division, which is much safer for the stockperson. Sick or injured deer may show exaggerated or unusual reactions and handlers need to be suitably alert. Like other livestock, sometimes deer go down in awkward places and it is sensible for a basic set of tools to be readily available to deal with facility deconstruction tasks. Facilities should be designed with the possible need to handle casualty animals in mind. While sick or injured deer may choose a darkened environment, there always needs to be sufficient lighting available to allow adequate examination.

Antler/velvet removal

Male deer (and female reindeer, too) grow antlers that are first seen in yearling calves and develop annually from anatomically specialized regions of the skull called pedicles. Velvet (growing) antler contains an abundant nerve and blood supply and has skin covered by soft hair; it is easily damaged. Before the rut, velvet antlers become calcified, nerves are no longer functional, and the skin is lost. The resultant hard, devitalized antlers are cast in the late winter, with regrowth beginning in the spring. Over a number of years, antler architecture becomes more complex.

Velvet antlers are very sensitive, and their surgical removal without adequate anaesthesia will cause pain and distress to the deer. Other than in emergency situations, removal is prohibited or regulated in many countries. It is beyond the scope of this chapter on handling and transport to have a complete discussion of best surgical procedures and pain relief. Suffice to say that anaesthetics are required when antlers are in the soft velvet stage, but when they have hardened, the ability to feel pain from the antler is lost.

The presence of hard antlers in the farm situation is undesirable as it makes male deer difficult and potentially more dangerous to handle so, for safety reasons, hard antler is often removed. Yearling deer often develop single antler spikes (tines) up to about a metre long and these can be particularly dangerous to other deer (especially in situations where space is limited or handling is pressurized) and to handlers. Within a group of spiker deer, severe penetrating injuries to internal organs are sometimes seen. Antler removal does not always render animals significantly less dangerous and it remains necessary to practise extreme caution at rutting time. Nevertheless, the removal of hard antler is generally undertaken for the safety of handlers and ease of management in both yearlings and adults. With the animal suitably restrained, the process simply requires sawing through the devitalized and ossified antler a small distance above the growth line on the pedicle, using a bone saw or embryotomy wire or a power tool. Occasionally, chemical sedation may be required as stags at this stage of antler development are often aggressive and difficult to handle.

Emergency slaughter

Any livestock farming enterprise needs to have a plan for the dispatch of animals. This applies to

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some cases of injury, or to situations in which treatment is not an option and slaughter is necessary to prevent further suffering or distress to the animal. It may also not be permitted or desirable to move the animal from the premises if this would increase pain or distress, so slaughter would again be necessary. Readers are referred to the general principles and comments about deer outlined in HSA (2013).

Bison

In North America, a considerable number of units running bison have been established over recent years, primarily for meat and hide production, although most American bison are raised to produce meat for human consumption. This short overview provides only superficial coverage of bison handling and transport; interested readers should consult the information provided in the references and further reading sections, along with other industry sources. Note that the term 'buffalo' is also used for the bison, but this is taxonomically incorrect.

Bison present a considerable handling challenge but, like deer, with experience and appropriate facilities they can be handled in a safe way which avoids injury and also safeguards their welfare. Given their size and strength, facilities need to be proportionately bigger and stronger than those described for deer and wapiti. Handling needs to reflect the natural behavioural characteristics of bison, which have yet changed little from those in the wild and are those of prey animals. Bison, as prey species, show marked flight behaviour when threatened, but if escape is not an option they may turn and fight. When attempting to escape, bison tend to circle, and this characteristic can be exploited in handling operations. Isolated animals will always attempt to rejoin a group, often regardless of obstacles. In unfamiliar places, bison will also attempt to return to familiar ground. Undisturbed behaviours focus on grazing and resting. The flight zone and point of balance for bison are similar to those of other livestock, except that the flight zone tends to be greater, especially with more nervous animals, and more so when exposed to novel conditions. Bison move best as a group and when worked from one side. When agitated, the flight zone is also greater and handling is more difficult overall; if bison show signs of impending panic, the handling pressure must be reduced. Thus, handling should be as calm and quiet as possible, completed as rapidly as possible, and if animals become very agitated, stoppage of work and rescheduling of the operation should be considered. Early signs of fear include agitation, increased restlessness, balking and self-licking, and as pressure increases, sitting or lying down. As with deer, open-mouthed panting may be seen in some individuals. As fear increases thereafter, some animals may become aggressive: warning signs include shaking their head in the direction of a threat, pawing the ground, holding their head high and elevating their tail before charging or otherwise attempting escape. Handlers should be responsive to these signs and adjust their behaviour accordingly (NFACC, 2017). Handlers should always have an escape route available in case bison charge. Since bison are susceptible to heat stress, handling should not be undertaken on very hot days (>30°C).

In handling areas, bison will move from poorly lit to better-lit areas, and so lighting can be used to encourage movement around the facility and, for example, movement into chutes or squeeze crates. Entrances to raceways or pens need to be wide enough to allow bison to enter freely and have sufficient gates to encourage the flow of animals. It is helpful to cut larger groups into smaller ones and, if possible, to separate dominant individuals such as bulls and older females from larger groups, as these animals tend to be aggressive to others in confined areas. In large groups, calves are at greater risk of injury.

Specialized squeezes/crushes for bison are like those used for cattle, except for their increased size. There is a need for a closure/crash gate at the front that is closed when the bison enters and before the head gate/yolk is applied around the neck (Fig. 20.6). Just relying on the yolk to catch and stop animals is difficult given the size of the head and horns. Extra restraint can be obtained by using a rope around the horns. Facilities need to have squeezes to allow for routine procedures such as disease testing for brucellosis and tuberculosis, foot care, semen collection etc. Handlers need to be aware that bison often exit the squeeze at a considerable pace.

As for the handling systems described earlier, a number of designs can work effectively but all will need a series of pens to allow for the bison to be moved to a crowding raceway before entering a handling chute, weighbridge or series of lead-out or loading pens. Bison, like other livestock, can balk in response to shadows inside buildings, and in response to contrasting surfaces: a continuous colour eases animal movement. Bison can also balk if they catch glimpses of handlers ahead of them – for

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Fig. 20.6. Large bison squeeze chute mounted on a concrete base with crash gate lifted up at the front. (Photo: Murray Woodbury)

example through pen slats – or if the handlers make sudden movements without giving animals time to adjust and react calmly. These principles also apply to loading into and out of livestock vehicles, which should be well lit to facilitate entry. Given the desire of individual bison to rejoin the group, facility design and operation should minimize periods when individuals are isolated (except perhaps when mature bulls are concerned). As bison do not like to be on their own for long periods, all single-file raceways should be short; having a long row of single bison standing in a single-file raceway can cause them to become agitated. It is not recommended to mix unfamiliar animals in a confined space such as the handling facility, because dangerous fighting may result. Attempts to use electric prods can be counter-productive as they make the animals more frightened and difficult to handle. If animals are to be held in handling facilities for any length of time, provision should be made for feeding and watering, though it is a general phenomenon that neophobia may make animals reluctant to feed and drink.

Bison do not appear to like to run up the tailgate of a trailer, so it is best to build a proper loading ramp within the facility if this type of vehicle is being used. Unloading to a level surface is also helpful. Transport is likely to be stressful to bison and adequate preparation prior to the journey and adherence to national animal transport requirements are essential. Any bison to be transported must be deemed fit to travel. During transport the main problems animals face are due to rough handling and being given insufficient space on the trailer.

The general handling principles previously described for deer apply to bison, but with several additional practical and human safety points to be borne in mind. People involved in handling procedures must be conversant with the use of the facilities and briefed effectively on what is to be done. Both sexes of bison have horns and may lash out with these horns and behave aggressively towards other animals and handlers when crowded or stressed. For this reason, some stockpersons dehorn bison to reduce the risk of injury, but good facilities and knowledgeable handing have made this a less-common practice; more often the tips of the horns are removed to reduce damage to conspecifics. Given the size and strength of bison, it is essential to have an escape route and never to work with them inside a pen unless safety provisions exist. These could be provided by safety exits and toe slots or grab rails in pens or raceways (Fig. 20.7). Handling systems should be designed so that gates etc. can be operated without the need to be in the pen with the bison. In a paddock situation, or in large pens, it is important to construct refuges or safety islands. It is always good, through facility design, to have ways

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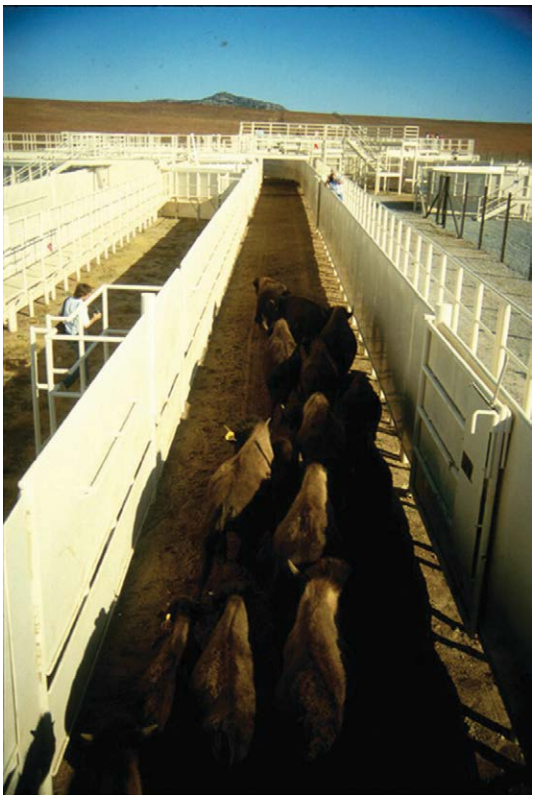


Fig. 20.7. Solid fence for a bison handling facility with a toe slot and grab rail so that handlers can easily climb out and escape.

to remove difficult or distressed stock from handling areas. In pens, self-catching gate latches mean that handlers do not need to enter small pens but can allow closure from the outside. As for deer, bottle-raised bison of either sex can be a danger as they are unpredictable and show less fear of humans.

Unlike the red deer facilities described earlier, the initial capture pen for bison will need to be larger because animals are generally brought in from the range. However, if the pen is too large, it will be difficult to move the animals on to the next component of the system. The entrance to this next part of the system needs to be inviting. By feeding or watering the animals in this area when they are not being brought in, they will become familiar in an unthreatening situation. On those occasions when handling of animals is required, it is then a simple matter of closing the gate behind them; it is much easier to entice them (for example with feed or a mineral lick) than to drive them.

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21 Poultry Handling and Transport

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Summary

The Food and Agriculture Organization of the United Nations (FAO) has estimated that 87% of transported poultry is broiler chickens. Broiler death losses during transport average 0.2% but can vary greatly. In layers, poor feather cover is associated with more mortalities, and in broilers, poor health increases transport losses. It is difficult to remove hens from furnished/enriched cages and this can result in more injuries. Design innovations are needed. Mechanical catching of broilers reduces stress during container loading. It may be slower than manual catching and may result in more heat-stress mortalities during hot weather unless two machines are used. In hot temperatures, stocking rates should be reduced and trucks need to be kept moving to prevent heat stress, unless the vehicle has active climate control. In cold winter temperatures, chickens can be exposed to both heat stress or cold stress in different parts of a vehicle with closed curtains unless mechanical ventilation is used. Death losses tend to increase with both longer transit times and more time waiting at the abattoir unless mitigation strategies are employed.

Keywords: broiler chickens, hens, mechanical catching, transport mortality

Introduction

The numbers of poultry handled, transported and slaughtered are greater than those for any other livestock. The FAO estimated all types of poultry meat production for 2012 to be 106 million tonnes, 87% of which was from some 50 billion broilers. More recent statistics show that poultry production is expected to grow by 24% by 2025 (Watt Ag Net, 2015), and the OECD-FAO agricultural outlook for 2018–2027 predicts a 15.6% increase in worldwide poultry meat production (stats.oecd.org). Another major trend is growing export markets from Brazil and other countries (USDA/FAS, 2018). Market projections for 2019 are 97.8 million tons of broiler chicken meat (USDA/FAS, 2018). The three top exporters of poultry meat are Brazil, the EU and Thailand (USDA/FAS, 2018). Laying hen numbers are about 6400 million (WATT, 2011). It is common for production sites to place hundreds of thousands of chicks or pullets within two to three days and to depopulate to slaughter equally swiftly. All birds are handled and transported at least twice unless hatched on the farm. There is a need for this to be carried out both efficiently and with due regard for the welfare of the individual birds. Both legislation and retailer codes cover many issues related to poultry, including the welfare of animals in transit. Furthermore, improving welfare may well benefit meat quality and performance. There have been developments in automated handling systems and gas stunning is now more widely used, thus eliminating the need for live bird shackling. Colony (furnished) cage and multi-tier housing systems pose challenges for catching hens at depopulation. The importance of training humans to handle birds more efficiently and humanely is also widely recognized (Pilecco *et al*., 2013). A variety of factors ranging from the thermal environment on the

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vehicle, fitness for transport, catching methods, and distance travelled can all contribute to broiler chicken mortality (Cockram and Dulal, 2018).

Poultry Fitness for Transport

Research has indicated that the husbandry system and management can affect the resilience and fitness of birds for catching, handling and transport at the end of production. For example, Weeks *et al.* (2012a) found that an increased risk of dead on arrival (DOA) birds for end-of-lay hens was positively associated ($P < 0.001$) with poor feather cover, poor health, lower bodyweight and cumulative mortality of the flock, with flocks in non-cage systems having significantly greater average on-farm mortality rates than those kept in cages. Similarly, Lupo *et al.* (2010) found that the risk factors for turkeys of condemnation at the slaughter plant were locomotor disorders and high cumulative mortality on farm in the final two weeks, plus clinical signs of ill health observed by ante-mortem veterinary inspection at the plant. If a farm has a strict culling programme, this may result in a fitter flock to be transported and fewer DOA birds (Jacobs *et al.*, 2017c,d).

A Norwegian study showed that 75.5% of the broiler chickens that were DOA had lung lesions (Kittelsen *et al.*, 2017). Birds that have greater production-related physical defects will be more stressed during transport (Jacobs *et al.*, 2017d). An innovative system being developed in Brazil is to use carcass data from federal meat inspection to track both injuries and health problems that would have a detrimental effect on poultry welfare (Souza *et al.*, 2018). The quality of delivered chicks and pullets can affect their lifetime health and performance (Decuypere *et al.*, 2001; Jacobs *et al.*, 2016; Valros *et al.*, 2008), and the transfer process to the production site is an important component of this.

Jacobs *et al.* (2017b, d), Tuyttens *et al.* (2018) and Tuyttens (2017) have developed simple, easy-to-use animal-based measures for assessing fitness for transport and welfare assessment and benchmarking during the pre-slaughter period (http://survey.ilvo.vlaanderen.be:3838/WQ/).

Chicks

Careful handling and transport of both hatching eggs and newly hatched chicks are important for subsequent performance (Meijerhof, 1997; Mitchell, 2009; EFSA, 2011; de Lange, 2012). Major causes of losses in transit and post-transport mortality and morbidity are dehydration and under-nutrition (Xin and Lee, 1997). Transporting chicks in the dark may reduce the rate of utilization of yolk reserves (Tanaka and Xin, 1997). Control of humidity as well as temperature is particularly important for eggs.

Newly hatched chicks are usually tipped from incubator trays onto a series of conveyors, creating accelerations of up to 882 m/s, with several drops of 7–55 cm in height (Knowles *et al.*, 2004). At the end of the process they pass through automatic counters and are dropped into the lightweight, disposable containers perforated with ventilation holes that are used for their transport (Figs 21.1 and 21.2). These authors also found that in passing from one conveyor to another, if the belt speeds differed by more than 0.4 m/s, few chicks were able to remain standing. Careful maintenance of automated chick



Fig. 21.1. Automated chick handling. (Photo: Andrew Butterworth)

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Fig. 21.2. Automated chick counting into a transport crate. (Photo: Andrew Butterworth)

handling equipment is essential. Signs of injury to chicks are blood on the equipment or very weak chicks that have been repeatedly tumbled (T. Grandin, personal communication).

There is a time window of 24–48 hours between first and last hatched chicks, depending on the eggs (e.g. size) and parental flocks (Bautil *et al*., 2015). Therefore, the so-called 'day-old chicks' can, in reality, be up to three days old when they are transported (reviewed by Jacobs, 2016). Chicks are believed to survive 72 hours after hatch without feed or water by using yolk sac reserves. However, it is assumed that modern genetic lines may deplete their reserves more quickly due to the higher metabolic rates associated with faster growth (EFSA, 2011).

The yolk sac reserves can enable chicks to be transported for up to 48 hours from hatch with low mortality, but water (via hydration gels) and feed should be available in transit for longer journeys (Mitchell, 2009), and modern strains of fast-growing poultry may use up their reserves more rapidly. Some day-old chicks are transported long distances. Khosravina (2015) and Jacobs *et al*. (2017a) have studied chicks transported 11 hours or 800–1000 km. Increasing distance increased physiological stress irrespective of whether chicks were from young or old breeders. Chick containers are transported by either truck or aircraft, generally in controlled environments to maintain uniformly warm yet well-ventilated conditions. In Belgium, chick transportation reportedly takes, on average, 1.5 hours, but can take up to 11 hours (Jacobs, 2016). This wide range is because chicks for different farms are transported in the same truck, resulting in long transportation durations for chicks that are transported to the farms furthest away. The optimum temperature for chicks at normal stocking density in transport containers was reported to be 24–26°C with relative humidity in the range of 60–63% (Meijerhof, 1997; Mitchell, 2009). However, Xin and Harmon (1996) found that 30–32°C was optimal at humidities below 40%, while de Lange (2012) suggested that 32–35°C maintains chicks in their thermoneutral zone and, importantly, ensures that yolk sac protein reserves are conserved for the development of the immune and digestive systems. Clearly, air temperature is just one factor determining the heat balance of chicks, with the humidity and air movement, and design and stocking rate of containers, plus radiative exchanges, all being important. More research is needed to determine the optimal specifications for different circumstances. Stocking rates are generally 21–25 cm^2/chick, although 19 cm^2 has been proposed to prevent chilling in extreme situations. There has been no research on the handling of chicks on arrival, when they may either be gently tipped out or removed manually from the transport containers. For broilers, in-house hatching may obviate many of the welfare issues associated with transport and handling of chicks after hatching (see Fig 21.3). It is beneficial to chicks to feed them immediately after hatching (Careghi *et al*., 2005).

Pullets

Laying hens may be reared in cages or on litter and will usually undergo transportation at 15–18 weeks of age when they approach point of lay and are taken to the egg production farm. Perforated plastic crates, usually with solid floors, are widely used for transport, particularly when the rearer is responsible for delivery and may be using general purpose vehicles. Narrow, modular systems that can be loaded and unloaded directly into cages and wheeled onto the transporter are favoured by professionals using dedicated vehicles. These predominate in the USA and, with reducing labour availability, are increasing in popularity in Europe. A labour-intensive but thermally more comfortable system comprises crates built as permanent fixtures on the bed of the lorry with a central ventilation channel. Hinged openings to the outside are used to load and unload the birds, which therefore have to be carried out of the crates and into their housing. They may also be passed in handfuls from person to person.

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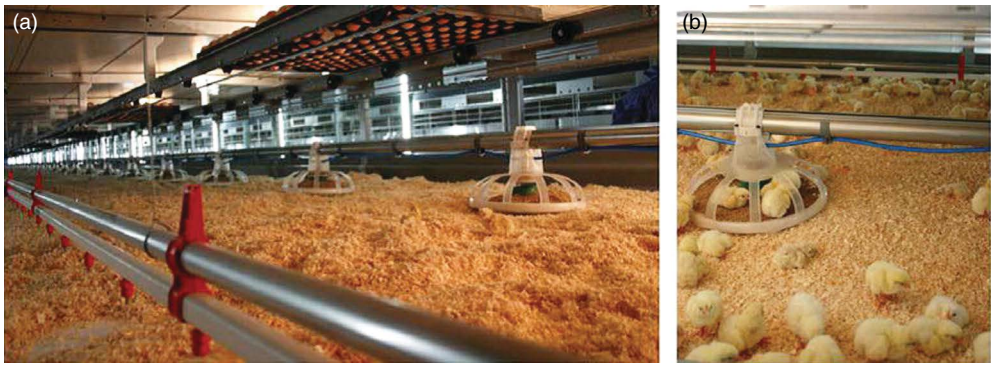


Fig. 21.3. Hatching eggs are placed above a rearing belt in the 'patio' multi-tier housing system for broilers. (Photo: Vencomatic)

Pullets are relatively valuable birds with good plumage (insulation) and are resilient to transport and handling stressors. Egg producers require them to arrive in good condition, so they tend to be handled and loaded carefully. The vehicles are usually generously ventilated with air gaps above the floor and below the roof, air inlets in the headboard and either roof fans or a central ventilation channel the length of the trailer, including a slot in the roof.

Broilers, turkeys and ducks

Most poultry intensively reared for meat are placed in mixed or single-sex groups of up to 60,000 birds in environmentally controlled houses. There is a trend to install windows providing natural light to enhance the typically low levels of under 20 lux. Birds live at stocking densities of up to 45 kg/m^2 at slaughter age on a deep litter of wood shavings, straw or similar material, with automated provision of food and water. The European Broiler Welfare Directive (European Council, 2007) limits stocking densities to a maximum of 42 kg/m^2, with lower rates (33 kg/m^2) for broilers housed in less well managed and equipped accommodation. Animal welfare groups and some voluntary codes of practice recommend 30 kg/m^2. A recent study showed that birds stocked at 30–32 kg/m^2 had fewer dermatitis lesions than at 34–36 kg/m^2 (Bailie *et al.*, 2018). In hot climates and free-range or organic systems, birds may be grown more slowly in naturally ventilated and lit pole barns or with access to the outside. Catching birds in such systems is invariably harder because they are more active and have more space; in this case, portable pens are often used to confine birds for catching.

A patio system (http://www.vencomatic.com) of growing broilers has been developed in the Netherlands, which comprises multi-tier units the length of the house. Each level has belts covered with litter on which the birds are raised (the production layer), with another belt (the hatching shelf) above them onto which eggs (on trays) that are close to hatch are automatically placed from one end (Fig. 21.3a). After hatching, the chicks jump down onto their production layer (Fig. 21.3b) and the eggshells are removed from the other end of the hatching shelf.

At the end of production, birds can be loaded into module drawers via several moving belts without the need for any human catching and handling. The potential welfare advantages provided by reduced live-bird transport and handling are offset by the difficulties of inspection of the higher tiers during production. This system may be difficult for people in developing countries to maintain and manage. Welfare auditors employed by a large buyer observed serious problems in a poorly managed system in a developing country.

Most poultry meat is grown on contract or as part of an integrated system, so processors usually own and are responsible for the transport system. They provide specialist catching teams to depopulate the poultry houses. Birds are calmer and less affected by the catching process if they are handled in darkness (Duncan, 1989), so catching in the early hours or evening/night in very dim light is common. Blue lights are useful with turkeys (Siegel, personal communication). Broilers are caught by one leg, inverted and carried in bunches of three or four per hand to the waiting crates or modules (Gerrits *et al.*, 1985).

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Inversion may cause fear, as indicated by prolonged tonic immobility (TI) responses (Zulkifli *et al*., 2000). To avoid dislocated hips and other injuries, handling by two legs is preferable, as is maintaining the bird upright (Gerrits *et al*., 1985; Parry, 1989). Appropriate handling techniques for all species are given in Anderson and Edney (1991). Broilers may be caught by one leg, but if they have to be carried their bodies have to be supported (Animal Transport Guides, EU 2017).

Methods of catching were reviewed by Mitchell and Kettlewell (2004). More recent research has shown that wing breakage occurs most often at catching (Jacobs *et al*., 2017b). Kittelson *et al*. (2018) reported that catching and holding birds upright had 0.2% wing fractures and it was superior to catching by two legs. Another study showed no statistical differences between one-leg versus two-leg catching (Langkabel *et al*., 2015). In the USA, one-leg catching of heavy broilers is routine. The average percentage of birds with broken wings for 36 poultry plants was 1.67%. The best plant had 0.2% and the worst was 3.80% (Grandin, 2015). Jacobs *et al*. (2017b) reported a prevalence of 1.9% in Belgium and Kitttelsen *et al*. (2018) reported only 0.8%. Particularly with heavier birds, loose crate systems are laborious and thus are decreasing in popularity. A change to modular systems, comprising a unit of compartments or sliding drawers, which can be moved by forklift on and off the transport vehicle and right into the poultry house or lairage, may reduce numbers of birds DOA to about a third of previous levels (Aitken, 1985; Stuart, 1985). Nijdam *et al*. (2004) found catching team and breed, as well as the type of handling system, influenced broiler DOA. In modular systems, care needs to be exercised when lifting birds up into the top-most drawers, particularly with heavy poultry. To avoid injury to birds that are already loaded, it is very important to load drawers from the top down.

Manual catching is exhausting, repetitive and dirty for those employed in the work (Bayliss and Hinton, 1990). Up to 1500 broilers may be caught per person hour in shifts of five hours (Metheringham, 1996). Data from Belgium indicates that an average of 1842 broilers could be caught per person per hour (Jacobs *et al*., 2017c). Significant welfare benefits, such as reduced heart rates and catching damage, were recorded for turkeys that could be driven into a modular system when this was compared with three other systems in which they were manually caught and loaded (Prescott *et al*., 2000). In many countries, dump module systems are used. To unload the broilers at the processing plant, the module is tipped and the chickens slide down the chute onto a wide conveyor belt. These systems work well for lightweight broilers, but give increased levels of broken wings when used with heavy broilers. Unpublished industry data from Australia showed that in heavy birds, 1% had broken wings from the dumping process. This did not occur in the small roaster chickens. Another interesting finding was that 74% of the birds with broken wings were females. The greatest numbers of broken wings were found in birds with the longest slides from the top decks of the modules. New systems where an entire dump module can be anaesthetized can eliminate dumping of live chickens (Midway Machine, 2017).

Skeletal defects are a serious welfare issue and cause substantial economic losses in broilers, broiler breeders, ducks and turkeys (reviewed by Mench, 2004). The most common defect is lameness, which results in significant changes to behaviour; in particular, the number of visits to the feeders is reduced in proportion to the degree of walking disability (Weeks *et al*., 2000). This implies a cost to the bird of lameness, which may be painful (McGeown *et al*., 1999; Danbury *et al*., 2000). Thus, most catching and handling procedures could cause pain, especially inverting and carrying birds by the leg(s) and shackling. European legislation (European Council, 2005) clearly defines birds that are unfit for travel if they are unable to walk unassisted or have severe open wounds. Canadian transport guidelines have very clear guidelines and photos of birds that are not fit for transport. Conditions that make a bird unfit for transport are: unable to walk, dislocated or exposed bones; bloody/prolapsed vents; and other listed conditions (Poultry Service Association, 2017). While severely lame birds are unfit to travel, EU Regulations consider animals fit to travel if they are 'slightly injured or ill and transport would not cause additional suffering' (European Council, 2005). Severe clinical lameness following the transport of male breeding turkeys with dyschondroplasia has been reported (Wyers *et al*., 1991). This indicates the potential for transport to exacerbate underlying conditions.

Ducks

The husbandry and welfare of ducks in European systems was considered by Rodenburg *et al*. (2005). Over 2000 million ducks and 500 million geese are

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being slaughtered annually, worldwide. Ducks are often caught and handled by their necks, and care needs to be taken to avoid damage to their neck vertebrae; heavier birds should be carried with support under the breast. A large Czech study of Peking ducks showed that the highest death losses occurred during the summer or on longer trips of 101–200 km (Voslarova *et al*., 2016).

Hens

The majority of laying hens are still kept in cages, which, particularly in Europe, are now of the larger furnished/enriched type, accommodating up to 80 birds. Numbers in alternative production systems, such as aviaries, barns and free-range systems, have increased, especially in northern Europe and Australia. After a production year, hens are caught and transported to the slaughterhouse. End-of-lay hens are generally purchased 'off farm'. This has improved the care taken in handling them and the investment in transport systems in some countries. Gradually, the modular systems such as Anglia Autoflow and gas or controlled-atmosphere stunning are replacing loose-crate handling and water-bath stunning. Many types of vehicles are used for transport, but dedicated trucks with side curtains are increasingly common.

Hens are removed from cages either individually or in groups of two or three by pulling them out by one leg, despite recommendations to handle poultry by two legs (e.g. the UK Codes of Recommendation). During removal, they may be struck against the cage entrance or food trough, and in furnished cages the perches and nest boxes may form an obstruction. Hens may also hit cages or roof supports as they are carried down the narrow aisles of a battery house (Knowles, 1991). Depopulation is very labour-intensive, with bunches of inverted hens commonly being passed along a human chain. In enriched colony cages, depopulating is especially difficult as the depth of the cages from front to back is about double that of a conventional (battery) cage, so most catching teams have people at the far side (back) of the cage to help drive the hens towards the grasp of the catchers. The operation becomes hazardous and time-consuming as catchers not only have to climb up to nine tiers high but also to walk the full length of very large houses carrying the birds. There is a need for research into methods of improving the depopulation process, as well as a need for designers and builders to at least incorporate doors at both ends of, and halfway down, the houses. Kristensen *et al*. (2001) evaluated a modular system for depopulating battery cages and found a significant reduction in the time each bird was handled – from 64.5 to 4.5 seconds. Compared with manual handling, there was no difference in the proportion of damaged birds in the small trial, but the catchers preferred the modular system.

More recently, Elson and Weeks (2017) undertook a trial using trolleys to load hens directly from their (furnished) cage into one of four transport drawers, which were then wheeled to the house for loading onto the lorry after transfer into the module framework. This system was preferred by the handlers, was less tiring and potentially quicker than manual handling. The slaughter plant reported fewer rejects than control loads. The trolley system was developed to overcome the problem of very narrow aisles (often 90 cm) found in houses converted from conventional cage systems whilst also using the drawers designed to fit the handling system at the abattoir. In a new build and with additional capital investment for handling equipment, an ideal system would be similar to the Belgian Samyn one (https://www.youtube.com/watch?v=H_Ne02LQR-8),[1] which avoids the need to transfer drawers between modules before loading.

In some countries, such as the Netherlands, where crates are still used, these may be placed onto dollies and wheeled into the aviary house for loading (Fig. 21.4). However, litter needs to be moved from the floor or tracks laid down. That preparation would also be needed for trolleys carrying module drawers as there is seldom sufficient space in layer housing to take a whole module into the house.

Hens in many aviary systems are difficult to catch, tending to crowd and pile up at the end of aisles, thereby creating a potential for suffocation, or to flap and fly with the risk of injury to the catchers. In some systems, the back of a tier is beyond arms' reach, resulting in birds having to be goaded or driven out, which is both time-consuming and hazardous (L.J. Wilkins, 1992 personal communication). Furthermore, some slatted areas are not built or maintained to carry the weight of several human catchers and a stack of crates, so accidents can occur, particularly as depopulation is invariably carried out at night in semi-darkness. Many catching teams drive birds into temporary pens for catching and move these around the house as necessary. It is particularly important that producers cull unfit birds before the

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Fig. 21.4. Wheeled dolly can be rolled into the house close to where the birds are caught to move a stack of individual coops or crates, which are then rolled to the transport vehicle. (Photo: Thea Fiks van Niekerk)

catching process commences (Weeks *et al*., 2012b; see also Table 21.1).

A direct comparison of different catching and carrying methods for end-of-lay hens showed that plasma corticosterone concentrations were significantly higher when they were removed from their cages three at a time and carried in an inverted position from the house than when they were removed singly and crated before removal from the house (Knowles and Broom, 1993). However, all hens in experimental handling treatments had high concentrations of corticosterone in comparison with control birds that were removed individually and gently from their cages in an upright position (Knowles and Broom, 1993). Scott and Moran (1993) found that the fear levels of laying hens carried for 20 m on a flat-belt conveyor were lower than those of hens carried the same distance in an inverted position by hand or on a processing shackle. In the absence of a non-inverted control in this study, it is difficult to know whether the reduced fear was a consequence of upright conveyance or some other fear-reducing property of the flat-bed conveyor. As with broilers, well-designed automated handling devices would seem to have the potential to reduce trauma and fear.

Table 21.1. Simplified, user-friendly protocol for monitoring and benchmarking broiler chicken welfare. (From Jacobs *et al*., 2017b, c; Tuyttens *et al*., 2017, 2018; de Jong *et al*., 2016)

Indicators for assessment of fitness for transport	Pre-slaughter welfare indicators assessed at the slaughter plant
Lameness (gait score)	Wing/leg fractures[1]
Illness (body temperature)	Bruising of breast, wings, legs[1]
Foot pad dermatitis[1]	Thermal stress – panting (hot) huddling (cold)[1]
	Splayed legs[2]
Hock burn	Crowding (stocking density)[3]
Skin lesions (includes breast blisters)	Supine birds[3]
Physical defects	Stuck body parts in transport containers[3]
Plumage cleanliness	Mortalities (DOA)
Cachexia (wasting syndrome)	Carcass rejections

[1]Adapted from Welfare Quality (2009)
[2]EFSA (2011)
[3]Adapted from Visser *et al*. (2014)
The indicators of food pad dermatitis, hock burn and skin lesions can be easily assessed at the slaughter plant to locate producers who may be sending birds unfit for transport.

Automated catching and handling systems

Automated catching and handling systems have great potential for reducing injury and distress for birds and humans alike (Lacy and Czarick, 1998; Knierim and Gocke, 2003), and several are commercially available for broiler chickens (Mitchell and Kettlewell, 2004). Uptake by the industry is increasing as the systems become more reliable and the difficulty of recruiting human bird catchers increases in some countries.

An early study revealed that the heart rate of broilers caught by an automatic combine returned to base levels more quickly than the heart rate of broilers caught manually (Duncan *et al*., 1986), and Delezie *et al*. (2005, 2006) have reported a quicker

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decline in levels of corticosterone and of TI following mechanical, rather than manual, catching. A possible explanation for the lowered stress is that the birds remain upright during mechanical catching – they are not inverted. Scott and Moran (1992) found significant increases in loss of balance, wing flapping and alarm calls by hens conveyed up or down slopes rather than horizontally. Drops from one conveyor belt to another need to be avoided as they tend to cause injuries and wing flapping. Ekstrand (1998) did not observe the experimental birds during catching, but this is the probable cause of differences found in the carcasses examined after slaughter, in which twice as many wing fractures and significantly more bruising, mainly of the wings, were seen on mechanically, rather than manually, caught birds. Nonetheless, there were insignificant differences in DOA birds between the two methods of catching. In a study in the Netherlands, Nijdam *et al.* (2005a), in paired comparisons of commercial depopulation by hand or mechanically on eight farms, found few differences in DOA and none in the proportion of bruising, in meat quality or in biochemical indices of stress, such as corticosterone levels. In the USA, improvements in catching-machine technology during 2005 and 2006 have reduced the occurrence of broken wings. Moreover, unpublished industry data from a large integrated poultry company indicate that machine-caught and hand-caught birds have similar levels of broken wings. They compared data from entire houses that were either machine- or hand-caught. There are many factors that could have influenced this result such as operator expertise and catching-machine design.

Recently, there have been major advances in mechanized broiler catching that may have solved some of the problems shown in the earlier studies. Two videos show the more advanced chicken-catching machines (CrossMindReklamebureausAs, 2013) and CMC Industries (2016); see video references at end of chapter).

Gracey (1986) noted that DOA averaged 0.2% for mechanically caught flocks compared with 0.3–0.6% for manually caught broilers. Other surveys have recorded similar levels of DOA for mechanically harvested broilers compared with manually caught birds, or higher levels in the spring (Knierim and Gocke, 2003; Nijdam *et al.*, 2005a). In the USA, where there are extremely hot temperatures (38°C), mechanical catching gave higher DOA levels because it took longer than manual catching. One innovative company solved this problem by using two catching machines. It is likely that in both these studies the increased mortality was due to heat stress: Knierim and Gocke (2003) noted uneven stocking rates for machine-filled compartments, and Nijdam *et al.* (2005a) suggested that particular climatic conditions were associated with the higher losses. It is possible that this could explain the increased risk of DOA for mechanical versus manual handling modelled by Chauvin *et al.* (2011), as climatic factors also increased the risk of loss.

Compared with almost 88,000 manually caught broilers, Knierim and Gocke (2003) recorded significantly reduced injuries (3.1% versus 4.4% of birds) in over 108,000 mechanically caught broilers, particularly in respect of leg injuries, thus confirming the results of an earlier study by Lacy and Czarick (1998), and the results of field trials of the Easyload system that found a halving of catching damage, from 4–6% in a manual system, to 1–3% using the machine (Poultry International, 1998). However, in a field study at a commercial slaughterhouse in 2001, Nijdam *et al.* (2005a) found no differences in the percentages of bruises, meat quality or corticosterone levels between the two catching methods, indicating similar levels of stress. It therefore appears that with experience and careful management, mechanical and automated systems can perform at least as well, and generally better, than manual handling. Indeed, during the year of their broiler survey, Knierim and Gocke (2003) noted a reduction in loading time by a third, and significantly decreased rates of injury, which might, in part, be attributed to a reduction in speed of the conveyor from 1.4–1.6 m/s to 0.8–1.0 m/s.

Figure 21.5 shows a portable pen layout loading system for turkeys in which the birds are herded in groups of 25–30 through a bugle-shaped yard onto a 1.2 m-wide loading conveyor that loads the transport containers.

Transport Practices

Transportation is an extremely stressful process for commercial poultry. Having lived in relatively uniform environments, they are suddenly exposed to multiple changes that include being handled, as discussed above, and the withdrawal of food and water. They experience stimuli that may be novel – such as motion with vibration and impacts – or of greater intensity and more varied than previously – such as daylight, noise, overcrowding and temperature

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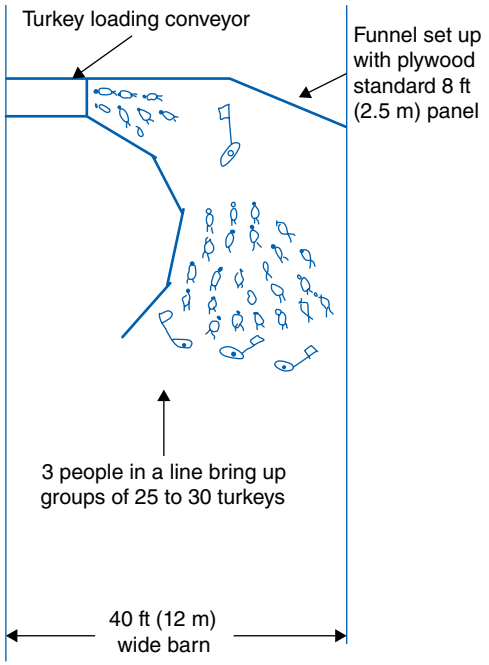


Fig. 21.5. Portable pen layout for herding turkeys onto a conveyor that loads the transport containers.

extremes. EU regulations stipulate a maximum transport time of 12 hours (EU Council Regulation 1/2005) (European Council, 2005).

New genetic techniques are now being used to study the combined acute stressors associated with food withdrawal, catching and transport. Sherlock *et al.* (2012) compared global hepatic gene expression between control broilers and those exposed to commercial handling and transport using 20K chicken oligonucleotide microarrays for transcriptome analyses. Hundreds of hepatic genes associated with energy metabolism, and with the exhaustion of stored hepatic and pectoral muscle glycogen, were expressed in response to commercial transport, together with significant differential expression of genes associated with cellular control and immune function. Such studies have the potential to inform breeding and husbandry practices to improve welfare and meat quality. The potentially adverse consequences of transportation include physical, physiological and behavioural changes, and the greater the duration of exposure to stressors, the greater the integrated stress for the bird. The resistance of birds to handling (Zulkifli *et al.*, 2000) and to transportation stressors (Kolb and Seehawer, 2001) may be enhanced by the addition of ascorbic acid (vitamin C) to the drinking water.

Irrespective of the catching method, catching and crating are stressful (Beuving, 1980). In a small study, Bedánová *et al.* (2006) reported significantly elevated haemoglobin and reduced erythrocyte counts in heavy (3 kg) broilers crated at 105 cm^2/kg compared with those crated at 115 cm^2/kg and non-crated controls; they also found increased heterophil:lymphocyte ratios at the 105 cm^2/kg density compared with the control and 115 cm^2/kg values. Thus, high stocking rates can increase levels of stress (as witnessed by the results from the 115 cm^2/kg stocking rate), possibly as a result of heat stress. Immediate elevations of plasma corticosterone following catching and crating may persist for over two hours (Voslarova *et al.*, 2011), without the additional stress of transport. Compared with uncrated controls, these authors found that lactate dehydrogenase levels rose steadily from 30 to 120 minutes after crating, and there were also changes in other biochemical indices. Further physiological changes are associated with moving poultry after they have been caught. Increased glucagon and plasma corticosterone (Freeman *et al.*, 1984) and increased heterophil:lymphocyte ratios (Mitchell *et al.*, 1992) were found in broilers transported for two or three hours.

Factors associated with mortality in transit (DOA)

Death is the most obvious and easily recorded indicator of intolerable stress. Global figures for DOA poultry are unknown. A survey of 59 million broilers at one UK plant had average DOAs of 0.13% (Warriss *et al.*, 2005), and a fairly similar mean of 0.18% (range 0–1.4%) was found by Chauvin *et al.* (2011) for 404 broiler flocks processed in France during 2005. In the Czech Republic, a survey carried out by Vecerek *et al.* (2006) from 1997 to 2004 found that broiler DOAs were 0.25%. An updated survey by Vecerek *et al.* (2016) reported that the greatest mortality (0.55%) occurred during the winter and deaths were lower during the summer (0.30%). In the Czech Republic long-term trends over two decades show that mortalities may be increasing (Vecerek *et al.*, 2016). In the hot tropical climate of Brazil, death losses for broilers ranged from 0.12% for trips averaging 25–50 km to 0.41% for very short trips and trips over 51 km (Viera *et al.*, 2010). New data from Belgium

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reported mean DOAs of 0.3% with a median of 0.19% and a range of 0.04–3.34% (Jacobs *et al.*, 2017c). The short-transit birds benefited from a longer time in a fan-cooled lairage, which allowed the body temperatures of the birds to normalize. A second survey of all poultry species transported in the Czech Republic from 1997 to 2006 revealed the highest DOA figure to be for end-of-lay hens and cockerels (averaging 1.01% p.a.) followed by turkeys (0.27%), broilers (0.25%), ducks (0.10%) and geese (0.06%) (Voslarova *et al.*, 2007). A large survey over five years in Italy (Petracci *et al.*, 2006) found that the average mortality for 1266 million broilers was 0.35%, for 118 million turkeys it was 0.38% and for 54 million end-of lay-hens it was 1.22%. For 13.3 million end-of-lay hens transported to five UK plants during 2009, DOAs averaged 0.27% (Weeks *et al.*, 2012a).

To illustrate the global scale of these losses, a conservative estimate of 0.2% DOA, based on the surveys mentioned above, represents some 100 million broilers alone dying annually between farm and factory, with associated impacts on profit, food security, the environment and bird welfare.

Several surveys in several countries have found a significant (risk of) increased mortality rate for all species with increased transport distance and marketing time (Warriss *et al.*, 1992a; Vecerek *et al.*, 2006; Voslářova *et al.*, 2007; Weeks *et al.*, 2012a; Machavcova *et al.*, 2016). These surveys would have been conducted in non-climate-controlled vehicles. While longer journeys may increase the risk of DOA, this is not inevitable (e.g. Jacobs *et al.*, 2017c). Varied levels of mortality were recorded for end-of-lay hens transported in 2009 in the UK at all lengths of journey up to 500 km (Weeks *et al.*, 2012a), though in 7% of loads no losses were sustained. This is partly due to commercial implementation of science-based mitigation strategies such as altering stocking rates according to bird condition, weather and journey distance.

If some birds are sufficiently stressed to die, many more will be stressed close to their capacity to survive and have compromised welfare. Typical times in transit are unreported in most countries, but vary considerably. A survey of four UK broiler-processing plants by Warriss *et al.* (1990) found that average time from loading to unloading was 3.6 hours, with a maximum of 12.8 hours. Unpublished figures from the USA are similar. In the UK, the time in transit for 90% of turkeys was under five hours with a maximum of 10.2 hours (Warriss and Brown, 1996). A small study of 24 commercial end-of-lay hen journeys, also in the UK, found mean marketing time to range from 5.4 to 17.6 hours (Richards *et al.*, 2012). In the USA and Canada, a review of DOAs by Newberry *et al.* (1999) found a substantial increase in hen mortality with marketing time from (for example) 0.7% (under 12 h) to 9.9% (over 24 h). In Hungary, during 2005–2006, mean time from first bird loaded to first bird unloaded averaged 7.2 hours at one plant, with mortalities of 0.74% for broilers with longer marketing time significantly greater than for those experiencing shorter periods, where average losses were 0.40% (Miklos, 2008). Transit times in Belgium are short. A survey of 81 loads of commercial broiler chickens indicated a mean transit time of 1.9 hours (Jacobs *et al.*, 2017c).

Thermal stress

In countries with hot summers, heat stress is thought to be the major contributor to both deaths (attributed to 40% of DOAs by Bayliss and Hinton, 1990) and overall transit stress. Petracci *et al.* (2006), in a large survey in Italy, found significantly increased DOAs for all poultry in the summer, indicating heat stress to be a likely cause of mortality during hot weather. Gregory and Devine (1999) associated high mortality rates of 11% in two out of nine flocks of end-of-lay hens in New Zealand (overall mean DOA 2.5%) with either hyperthermia or hypothermia, but they did not report journey times or conditions. The UK survey of 59 million broilers by Warriss *et al.* (2005) indicated that mortality increased when ambient temperature rose above 17°C, with DOAs almost seven times greater when air temperatures were over 23°C.

Broilers may also be subject to cold stress. Vosmerova *et al.* (2010), after sequentially measuring the biochemical indices of broilers transported over different distances throughout the year, concluded that transport in winter, when ambient temperatures were around zero (±5°C) and internal load temperature averaged 18.5°C, was the most stressful. Cyanosis damage in turkeys in Canada was found to be associated with prolonged journey times (>8 h) and sub-zero ambient temperatures (Mallia *et al.*, 2000). Risk factors for DOA hens in the UK included the slaughter plant, distance travelled and external air temperature, with longer journeys and low external air temperatures increasing the risk (Weeks *et al.*, 2012a). In broiler transport, an

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increased risk of mortality was also associated with high (>15 °C) or low (≤5 °C) ambient temperature, daytime rather than night-time transport, larger flock size, heavier mean bodyweight, and an interaction between ambient temperature and transport time (Nijdam *et al*., 2004). Vecerek *et al*. (2006) also noted significantly higher losses in hot summer weather or cold winter weather. Rain and wind were associated ($P < 0.05$) with an increased risk of broiler DOA in a model by Chauvin *et al*. (2011). Thus, the degree of thermal stress experienced by birds in transit depends on the duration and intensity of both heat and cold stressors. The more recent studies have continued to confirm that both extremely hot and cold ambient temperatures increase mortality (Machavcova *et al*., 2016; Caffrey *et al*., 2017). In extremely cold weather, stocking broiler chickens or hens too loosely can increase death losses because it is more difficult for them to stay warm.

Side curtains are used as protection against precipitation, wind and solar radiation, as well as to hide the birds from public view. However, even in winter, these often restrict ventilation too much and excessive heat and moisture levels can build up around the birds (Mitchell *et al*., 1992; Webster *et al*., 1992; Kettlewell *et al*., 1993; Burlinguette *et al*., 2012). The risk of increased DOA tends to be associated with high environmental temperatures and the stationary parts of the transportation process (i.e. loading, unloading, traffic jams and waiting at the factory; Ritz *et al*., 2005).

Several studies in the temperate UK climate have measured the thermal environment in different parts of the loads of pullets, hens and broilers during winter and summer conditions and on stationary and moving vehicles of varying design (Webster *et al*., 1992; Kettlewell *et al*., 1993; Weeks *et al*., 1997; Richards *et al*., 2012). These have shown that most vehicles used for transporting poultry, which are naturally ventilated, do not provide a uniform thermal environment. Studies of the aerodynamics of full-size and scale models of one design of vehicle, including a trailer, have shown that, when moving, air predominantly enters at the lower rear of the vehicle and moves forward to exit at the front of the vehicle (Baker *et al*., 1996; Hoxey *et al*., 1996).

Barbosa Filho *et al*. (2008), using data-loggers within loads of broilers in Brazil, found that the summer season produced the worst thermal conditions for the birds and that the combination of afternoon and summer ranked as critical and lethal in most areas of the load. Studies in Canada using similar methods (Burlinguette *et al*., 2012) have observed that during milder ambient conditions (9.8°C), trailer roof vents and side curtains were kept open, resulting in a more even distribution of air and an on-board temperature range of 10.3–16.7°C. As external temperatures dropped, the side curtains and some of the roof vents were closed. This resulted in increasingly variable and more extreme thermal conditions, with heat and moisture accumulated along the midline of the load near the front of the lead trailer and near the back of the rear trailer. At an ambient temperature of –22.1°C, temperatures within the trailer varied widely, from –20.7 to 21.7°C, with an estimated 58.6% of the load volume being exposed to temperatures below 0°C. In addition, in the trailer, the humidity ratio rose to 14.0 g/kg above ambient, and the relative humidity (RH) approached saturation (>80%) in 55.2% of the load volume. Measurements of broiler rectal temperatures showed that during winter weather in Canada, when the trailer is closed up and tarped, both hypothermia and hyperthermia occurred within the same trailer (Knezacek *et al*., 2010).

With a reliance on natural ventilation, different parts of a load of poultry are over- or under-ventilated, and birds at the main inlet point are also susceptible to becoming wet and chilled unless they are protected. In certain positions, there is virtually no air movement to dissipate the body heat produced by the birds. Weeks *et al*. (1997) calculated that the average air speeds immediately surrounding the birds in moving vehicles varied between 0.9 and 2.4 m/s with maxima of 6.0 m/s. There are also large differences between the conditions on moving and on stationary vehicles, again primarily due to ventilation and to the speed of air movement. Ritz *et al*. (2005) reported an increased level of mortality in broilers during loading, unloading and lairage, but not during the journey. Richards *et al*. (2012) modelled data from loggers in eight positions within loads of end-of-lay hens transported in modules and confirmed that both when travelling and in lairage, some parts of the load tracked outside air temperatures whereas others were dominated by bird heat. Conditions also varied within modules, with the upper and central drawers (unsurprisingly) being warmer. Thermal 'hot' or 'cold' spots within loads are frequently detrimental to welfare and may lead to deaths associated with

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climatic conditions and excessive or inadequate ventilation (Hunter *et al*., 1997).

This knowledge of thermal conditions experienced by live birds in road transit and the physiological consequences of these (Mitchell and Kettlewell, 1994; Vosmerova *et al*., 2010) leads to the inescapable conclusion that, to achieve thermal comfort for all birds in transit, controlled and uniform ventilation is essential (Weeks *et al*., 1997; Mitchell and Kettlewell, 1998; Kettlewell *et al*., 2000; Burlinguette *et al*., 2012). Heat losses from model (artificial) chickens among live birds in vehicles fitted with both side curtains and roof-mounted inlet fans were generally in the comfortable range, with little variation between areas of the load (Weeks *et al*., 1997). These authors suggested that air speeds within bird crates or modules should be maintained between 0.3 and 1.0 m/s except in extremely hot weather. The ventilation requirement is between 100 and 600 m^3/h for typical commercial loads. Kettlewell *et al*. (2000) proposed that for each kilogram of chickens in uniformly ventilated loads under temperate conditions (up to 20°C), an air flow of 2.2 m^3/h was sufficient.

It is strongly recommended that all vehicles be fitted with several temperature probes placed in close proximity to the birds. Temperatures should be both recorded and linked to an in-cab monitoring and alarm system. As a guide, which should be modified according to individual loads and vehicle designs, Weeks *et al*. (1997) indicated that broilers and pullets transported at 10–15°C and poorly feathered end-of-lay birds at 22–28°C were likely to be thermally comfortable at the usual high stocking densities. The European Food Safety Authority (EFSA, 2011) recommended that specific thermal limits should be defined for broilers and end-of-lay hens, giving an upper limit in transport containers for broilers of 24–25°C, assuming an RH of 70% or higher. In hot weather, the direct and indirect heating effects of solar radiation should be avoided by transporting at night or early in the day, and parking in the shade.

Commercially operated, fan-ventilated, temperature-controlled vehicles with sensors within the load have been developed similar to the Concept 2000 vehicle (a mechanically ventilated broiler transport vehicle with automated control; see Mitchell and Kettlewell, 2004), but are not widely used. More relevant than this could be the adoption of management strategies during the loading and unloading of vehicles to minimize thermal impact. For example, loading alternate stacks of modules from the rear of the vehicle in hot weather and either not using curtains or drawing them just before the journey commences. In winter, it is especially important to minimize wind chill by the use of curtains, and by parking in the lea of buildings or trees and to avoid birds becoming wet. Canadian research has shown that when cold –5 °C air was blown through chickens in a standard transport drawer, they moved away from the front of the drawer to avoid the draught (Strawford *et al*., 2011).

Clearly the proximity of other birds has a large impact on their ability to dissipate heat. The ceiling height of the crate may also influence heat stress. Turkeys transported in 55 cm-high crates panted less than birds transported in 40 cm-high crates (Wichman *et al*., 2012). The disadvantage of providing more headroom was more scratched backs. At high stocking densities, individual birds have a reduced surface area from which to lose heat and also gain heat via conduction from close contact with other birds. This could be advantageous in extremely cold weather but, as indicated above, often leads to heat stress during transit. There needs to be more research on optimum stocking rates during transit, and it is important that a representative sample of birds is weighed before transport so that appropriate stocking rates can be planned. In practice, broilers and hens are frequently loaded by the handful (i.e. in multiples of 3 per drawer), so guidelines should take this into account. Based on recent research by the author's team (Richards *et al*., 2012), she feels that there is a strong argument for using different stocking rates in different areas of the load (in particular for reduced numbers of birds in the drawers at the top, front of the load), if this could be achieved in practice.

Space allowances are dependent on bird age and condition, weather and vehicle design, and, to a lesser extent, on journey duration, and should be adjusted accordingly. Delezie *et al*. (2007) considered that stocking density during transit may have a greater influence on levels of stress than feed withdrawal or transportation. In Hungary, Miklos (2008) reported that space allowances for broilers and hens of less than 207 cm^2/kg led to higher mortality from traumatic injuries (0.60%) in journeys of up to eight hours duration than did a more generous space allowance, which reduced levels to 0.49% (which is still high). Nijdam *et al*. (2004),

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Table 21.2. Guideline space allowances for poultry in transit (European Council, 2005; EU, 2017).

Age/weight of poultry (kg)	Space allowance (cm^2/kg)
Chicks (day-old)	21–25 cm^2/chick
<1.6	180–200
1.6–3.0	160
3.0–5.0	115
> 5.0	105

in modelling data from Dutch and German broiler flocks, concluded that reducing the stocking density of broilers would significantly reduce mortality and enhance welfare. This finding was confirmed by Chauvin *et al.* (2011) for French broilers. The stocking densities recommended by European legislation (European Council, 2005) may be used as a guide that needs adjusting according to weather, bird condition and journey duration (see Table 21.2).

Trauma

Osteoporosis in laying hens is ubiquitous, and a survey in the UK by Sandilands *et al.* (2005) found that 26–55% of laying hens had sustained fractures during production and 4–25% during depopulation, depending on the housing system. Another UK survey of prevalent housing systems has confirmed high levels of keel damage, with mean prevalence least for flocks housed in furnished cages (36%), despite also having significantly weaker bones. Hens in systems equipped with multi-level perches showed the highest levels of damage (over 80%) and the highest severity scores (Wilkins *et al.*, 2004, 2011). Previously, the problem of weak bones was thought to be primarily confined to caged birds (Gregory *et al.*, 1990; Knowles and Broom, 1990; Keutgen *et al.*, 1999). Two-leg handling substantially reduces bone breakage as compared to one-leg handling (Gregory and Wilkins, 1992). Thus, hens in all systems need to be handled with great care to avoid creating new fractures. Unhealed old breaks are likely to be painful during handling. Although the overall incidence of leg fractures in DOA birds was low, Weeks *et al.* (2012b) found, in a small study of 24 loads, that levels were ten times greater for hens depopulated from the new furnished cages (which is now the only legal caged system within the EU) than from free-range systems. The depth of colony cages (from front opening to the rear) means that it is hard to catch the hens at depopulation.

Injuries to broilers from careless handling and catching include bruising to the breast, wings and legs, as well as fractures and dislocations, especially of the legs of heavier birds carried by a single leg (see reviews by Nicol and Scott, 1990; Knowles and Broom, 1990). Post-slaughter rejection rates due to trauma damage range from 5 to 30% (Jepersen, 1982; Gerrits *et al.*, 1985; Kettlewell and Turner, 1985). Newer data shows lower levels of bruised legs at 1.38% and bruised wings/breast at 3.65% (Jacobs *et al.*, 2017b). In a survey of downgrading at a turkey abattoir, McEwen and Barbut (1992) found substantial levels of bruised drums, but fewer leg and breast scratches were seen where birds had clipped toenails, and spur clipping reduced back scratches. These authors found no effect on injuries of truck design or stocking density, but increased half-wing trim and bruising of drums was associated with length of time spent on the truck. In their model, Nijdam *et al.* (2004) found that low ambient temperatures (<5 °C) increased the risk of bruising, as did transport during the day and in the summer.

Damage to muscle cells results in an increase in the concentration of creatine kinase (CK) in blood plasma, so it may be possible to use CK concentrations as a quantitative index of injury (Mitchell *et al.*, 1992). Apart from muscle damage, broilers also sustain a worrying number of broken bones and dislocations during the catching and transportation process. Jacobs *et al.* (2017b) reported 1.95% wing fractures and 0.35% leg fractures. Gregory and Wilkins (1990) found that 3% of broilers had complete fractures before stunning at the processing plant, and 4.5% had dislocated femurs. The dislocated femurs were probably caused by swinging the birds by one leg before placing them in the crate, as the chance of a broiler suffering a dislocation of this type increases with its bodyweight. The incidence of dislocations recorded in live birds before stunning may not be a true reflection of the problem, as many dislocations result in fatal haemorrhaging. Indeed, when 1324 DOA broilers from six UK plants were examined, it was found that 27% had dislocated femurs (Gregory and Wilkins, 1992). These data indicate that the physical injury that occurs during manual catching and loading is a severe welfare problem for all poultry, which should accelerate the search for more humane alternative methods.

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Fatigue

Many birds arrive at the slaughterhouse in an apparently exhausted state. It has been argued that the dehydration and depletion of body glycogen stores that occurs when broilers are subjected to food deprivation and simulated commercial transport (Warriss *et al*., 1988) may produce a sensation of fatigue in birds (Warriss *et al*., 1993). However, progressive immobility is also a correlate of increasing fearfulness (Jones, 1996), and a response to painful (nociceptive) stimulation. This immobility may be related to learned helplessness, and could be an important 'cut-off' response in transported poultry.

Sherwin *et al*. (1993) investigated the effects of fasting and transportation on measures of fear and fatigue in broilers. Broilers subjected to either food deprivation for 10 hours or a journey of 6 hours, or both, were compared with control birds that were neither fasted nor transported. When the behaviour of birds was monitored in their home pens after the treatments had ended, it was found that both fasted and transported birds were more active than controls, and showed less lying behaviour for at least 12 hours, suggesting that they were not particularly fatigued.

Hunger and thirst

With the exception of in-house hatching systems, newly hatched chicks are not provided with food and water until they reach the rearing unit. During transportation, which may last up to two days on international journeys, chicks are thus completely reliant on yolk sac metabolism. Warriss *et al*. (1992b) found that chicks deprived in this way for 48 hours weighed 16.5 g less than control chicks which had access to food and water within 6 hours of hatching; the deprived chicks showed both physiological and behavioural signs of dehydration and thirst.

The fasting regime imposed on broilers before transportation to the slaughterhouse may have important implications for welfare. At the very least, it affects the amount of weight lost, which, after four to six hours of fasting, occurs at a rate of 0.2–0.5% per hour as birds begin to metabolize body tissue (Veerkamp, 1986). Jacobs *et al*. (2017b) reported 5.3% decrease of bodyweight during the pre-slaughter phase and an average loss of 0.68g bodyweight per minute spent in transportation. Initial weight loss is most likely due to defecation, while further weight loss can be attributed to fasting and dehydration. Fasting is also aversive (Nicol and Scott, 1990) and may increase stress, too (see below). Broilers transported for two, four or six hours after feed withdrawal for one to ten hours had similar live and carcass weights to those of non-transported controls (Warriss *et al*., 1993), although transport significantly reduced liver weight and liver glycogen concentration. Chickens should not be fasted over six hours (Cockram *et al*., 2018). Glycogen depletion of the biceps muscle increased progressively with journey time, which could have reflected the muscular effort involved in maintaining balance in a moving vehicle. There was also evidence from this study that transported broilers were becoming dehydrated.

Withdrawal of food, or both food and water, for 24 hours resulted in a 10% drop in live weight (0.43%/h), of which 41% was loss in carcass weight (Knowles *et al*., 1995). There was no evidence of significant dehydration in this study, nor in a survey of 800 broilers at two plants in the UK (Knowles *et al*., 1996). A more recent study (Nijdam *et al*., 2005b) also noted significantly reduced bodyweight (0.42%/h) at slaughter in broilers that had feed withdrawn for ten hours before three hours of transport plus one hour of lairage, compared with those that had access to feed until transported, which had minimal weight loss. Changes in blood metabolites indicated stress and negative energy balance. There are both welfare and commercial advantages to minimizing the duration of feed and water withdrawal.

Fear and aversion

Cashman *et al*. (1989) assessed the TI duration of nearly 700 broilers on arrival at four commercial processing plants. The overall mean TI duration was 12.6 minutes, a level comparable to that reported after exposure to high-intensity electric shock (Gallup, 1973). Journey duration had the most significant effect on duration of TI. A strong positive linear relationship indicated that the birds' fear levels were increased by transportation and not just determined by the catching and loading procedures. When a similar study was conducted with 300 laying hens, there was no evidence of a positive linear relationship between journey duration and the duration of TI (Mills and Nicol, 1990), though the TI durations of laying hens undergoing short journeys were higher than those found for

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broilers (Mills and Nicol, 1990). Differences in catching procedures for broilers and caged hens are a possible explanation. Fear or stress reactions can be modified by changes in handling procedures. Jones (1992) found that the TI response of both broilers and hens was reduced by gentle handling. Kannan and Mench (1997) confirmed this result in broiler chickens that were subjected to a two-minute handling treatment and then returned to their home pens, where plasma corticosterone was sampled at hourly intervals for the next four hours. Birds that received upright handling had lower plasma corticosterone concentrations than birds that were inverted either individually or in groups of three. However, the effects of handling treatment were masked when the broilers were crated after the two-minute handling period, suggesting that crating was stressful.

Transportation involves simultaneous exposure to many factors, including noise, motion, heat and crowding. The birds' experience of some of these separate factors has been examined by tests of preference and aversion. Mean sound levels on animal transportation lorries typically fall within the range 95–103 dB(A). The response of poultry to the specific noise encountered during transportation has not been assessed, but it is generally thought that vibration is likely to be more aversive than noise.

Vibration

The fundamental frequency of most trucks used for poultry transport is 1–2 Hz, with a secondary peak at 10 Hz that coincides with the resonance frequency of poultry viscera (Scott, 1994). More detailed measurements by Randall *et al.* (1996) found that resonant frequencies of broilers were around 15 Hz when sitting and 4 Hz when standing. Experimentally, passive avoidance procedures have been used to examine responses to vibration. For example, Randall *et al.* (1997) used a wide range of horizontal and vertical vibrations, imposed for a two-hour period. They showed that both vertical and horizontal vibrations were aversive to broiler chickens, but that there was a greater sensitivity to vertical vibration by a factor of between 1.3 and 2.5, which was found at all acceleration levels. Aversion tended to increase with acceleration magnitude (0–5 m/s) and to decrease with increasing frequency (0–10 Hz) of the motion. As chickens find vibration below 5 Hz particularly aversive, Randall *et al.* (1997) concluded that the resonant frequencies of 1–5 Hz found on transporters are undesirable. Although animals can reduce the effects of vibration by moving, and by skeletal muscle tone, the scope for this in broilers with leg problems at high stocking density is very limited. Thus, evidence suggests that vibration does adversely affect the birds and should be reduced, for example by using air suspension. Appropriate methodology to compare aversiveness of concurrent stressors during transport is being developed, initially using thermal and vibrational stressors (e.g. MacCaluim *et al.*, 2003). There is a recent review of vibration research in Donofre (2014).

Post-transport Handling and Environment

Thermal conditions at the end of the journey must be considered as it can take two to three hours to manually unload pullets. Broilers and spent hens may also have to wait at the processing plant (Warriss *et al.*, 1990), either on the vehicle or unloaded in modules or stacks of crates. In both instances, a well-designed lairage is preferable to remaining outside, exposed to the elements. It is important that the birds themselves receive adequate ventilation; measurements in two lairages found air movements around the stacks of modules of greater than 1 m/s, but less than 0.1 m/s adjacent to the broilers (Quinn *et al.*, 1998). Temperatures and humidities among the birds consequently rose rapidly to give rise to conditions of heat stress within an hour, in both winter and summer. Average body temperatures rose by 0.3°C in the first hour of lairage and by 0.1°C per hour thereafter for the four hours of measurement undertaken (Warriss *et al.*, 1999). The model birds used by Webster *et al.* (1992) and Weeks *et al.* (1997) indicated that conditions of substantial heat and cold stress were frequently experienced by hens and broilers in lairage during loading and unloading. Hence, the duration of such times needs to be kept to a minimum of preferably less than one hour. This recommendation is often exceeded (Jacobs *et al.*, 2017c).

A controlled environment providing adequate ventilation while avoiding excessive wind and air movement (except in hot weather) onto the birds is highly desirable. There should also be sufficient space around each module or stack for effective air exchange and flow. Monitoring of the condition of birds and their environment in lairage is as necessary as during the journey. In practical terms, birds

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observed to be panting will become progressively dehydrated and increasingly heat stressed. In some cases, the stress of transport may lead to PSE (pale, soft, exudative) meat in broilers similar to that in pigs. Showering heat-stressed broilers with water appears to be effective in reducing PSE and improving breast meat quality (Guarnieri *et al*., 2004). Vieira *et al*. (2011) found that lairage in a controlled environment reduced the mortality of broilers transported in the summer in a subtropical climate.

Following arrival at the processing plant, most broiler chickens and end-of-lay hens are manually removed from containers. Where electrical stunning is used, live birds are suspended by their legs from shackles for conveyance to the bath. Many birds react to this potentially painful procedure by struggling, flapping their wings and attempting to right themselves. Bedanova *et al*. (2007) reported that shackling chickens by their legs is stressful. To reduce the stress of hanging birds in shackles, Lines *et al*. (2011) found that struggling was reduced through the use of a breast support conveyor, though this can lead to injury and also reduces the chance that the bird will be effectively stunned prior to slaughter. Jones and Satterlee (1997) reported that covering broilers' heads with a hood immediately before shackling reduced struggling in comparison with non-hooded controls. A smaller reduction in struggling was also obtained when the birds were fitted with transparent hoods, leading Jones *et al*. (1998a) to suggest that the effect was due both to the tactile properties of the hoods and to their ability to impair patterned vision. When poultry are stunned in the newest controlled-atmosphere stunning systems, they remain in the transport containers. This would eliminate shackling stress.

Observations in US plants show that providing a breast rub made from strips of smooth conveyor belting will also reduce struggling and flapping. Reducing ambient light intensity reduced struggling in broilers shackled in groups of three (Jones *et al*., 1998b) but not in broilers shackled individually (Jones *et al*., 1998a). The authors argue that the welfare benefits of reduced injury would outweigh any possible increases in fear suggested by the increased immobility observed when hoods are fitted. Fitting birds with hoods would not be practical on most commercial processing lines, but it may be possible to design a system for a slaughterhouse based on the principles of reduced light intensity, mild tactile contact and interference with clear vision.

Bird welfare is greatly improved when the labour-intensive, stressful and often painful procedure of removing them from the containers and hanging them on shackles is eliminated. Controlled atmosphere (gas) stunning of chickens and turkeys is now the commercial norm in some countries, with welfare and meat quality benefits, such as reduced breast muscle haemorrhaging and bone breaks (Raj *et al*., 1997; Hoen and Lankhaar, 1999). It may also be used for ducks, which can be difficult to electrically stun (Raj *et al*., 1998). Automation of shackling has been investigated (e.g. Lee, 2001; Tinker *et al*., 2005) and is easier with gas-stunned birds than with conscious ones that may flap, struggle and experience pain when shackled (Sparrey and Kettlewell, 1994).

Training

The benefits for animal welfare of training stock people and handlers is increasingly recognized (Hester, 2005), with specific benefits from altering attitudes (Hemsworth, 2003), and in handling and transport (Broom, 2005). The poultry industry is beginning to be proactive in implementing training – for example, the Poultry Handling and Transportation Manual and Education Program developed by the Canadian Poultry Service Association (PSA, 2017). Incentive programmes are also effective in reducing damage to birds. Providing incentive pay to employees will greatly reduce broken wings during the catching of broilers. In US plants, broken wings averaged 5–6%, but the implementation of both incentive pay and auditing by restaurant company customers reduced broken wings to 1% or less in lightweight birds and to less than 3% in large 3 kg birds.

Conclusions

Systems of housing, catching, handling, transport and lairage that are more humane both for poultry and for workers need further development but adoption of current best practices would have both commercial and welfare advantages. In many cases, mechanization is less stressful and more efficient. Improved techniques for depopulating laying hen houses need to be developed, especially for large colony cage and multi-tier systems, and should be considered as part of the design and planning process. Machine harvesting of broilers is increasingly more reliable and should be more widely adopted.

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Improved designs of vehicles are becoming commercially available, and it is now possible to monitor bird behaviour and thermal conditions in transit in real time by accessing onboard data recording. The ability to access such information is a prerequisite for the sensible enforcement of welfare legislation or farm assurance standards, and can even be monitored remotely alongside vehicle tracking by GPS.

Scientific evidence shows increasing stress and mortality in all classes of poultry as transportation time, holding time and feed and water deprivation time increase. Both hot and cold thermal stress is a major component of overall stress. Control of ventilation during transit should be provided to reduce this, as well as minimizing the duration of all stages of transportation and adjusting stocking rates, using curtains and adopting management practices according to weather and the condition of the birds. It is feasible, by applying existing knowledge and best practice, to reduce losses in transit by at least half of the current mean levels, and doing so would have substantial positive impacts on profit, food security, pollution and bird welfare.

Note

[1] The link may not work in some countries. To find the video, type 'video Belgian Samyn Poultry' into a search engine.

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22 Transport of Cattle, Sheep and Other Livestock by Sea and Air

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Summary

Large numbers of sheep and cattle are sent around the world for either growing, slaughter or breeding by ship, and occasionally by air. The majority of air shipments are of expensive breeding animals. Transportation by ship mainly occurs to the Middle East for Halal slaughter, much associated with religious festivals. Some of the major welfare concerns on ships are: heat, stress, exposure to high levels of ammonia, standing in wet manure, and crowded conditions. Heat-stress problems are greatest when ships are in port and not moving and when aircraft filled with livestock are sitting on the ground. Some of these problems can be reduced by minimizing time spent stationary in port or by improving ship ventilation systems. Aircraft transporting livestock should take off promptly after loading because heat will build up rapidly. When a jet airliner is flying at normal cruising altitude, it can be kept cool with cold external air.

Introduction

Over the last 25 million years, ruminants co-evolved with the savannahs and grasslands of the world's continental interiors in a mutual symbiosis. This allowed a unique ecosystem to develop in these arid regions, which are characterized by large circannual and annual variations in temperature. Very much more recently, about 10,000 years ago, humans learnt to utilize the cattle and sheep from these grasslands in agriculture, primarily for the production of food and clothing, which enabled the populations of both humans and ruminant livestock to expand. The transition of human habitation into cities, for the trading of goods, led to a necessity to transport ruminant livestock from the grasslands to the cities. For the most part, animals were transported alive because they could remain 'fresh', delaying the spoilage of meat that starts when the animal dies, and they could move themselves on droving roads and, more recently, on and off vehicles. Even more recently, in the 16th to the 19th centuries, livestock were transported by ship to accompany world colonizers, ostensibly for breeding stock, but many were consumed before they fulfilled this role.

Nowadays most cattle and sheep are transported as fresh or frozen meat because only about one half of the live weight is used for consumption, and automation has enabled processed animals to be transported easily in bulk. Local abattoirs mean that most cattle only travel short distances to slaughter (e.g. 80% in Australia travel less than 400 km). About 16% of this global beef production is traded internationally, in a market dominated by Australia, India, the US and Brazil (ACCC, 2017). One of the major exporters, Australia, exports 70% (about one million tonnes) of its production (MLA, 2018).

There remains, however, a substantial trade in live animals over long distances, which is usually by sea and occasionally by air. This method is used often to transport animals to developing countries, where refrigerated storage is not in widespread use. Even though a refrigerator is one of the first assets that a low-income household acquires, when possible, there remain parts of the world where ownership is rare, e.g. in India it is only 24% (Anon, 2014). Developing regions that have rapidly urbanized are increasing refrigerator ownership most rapidly,

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e.g. in China it has increased from 24% to 88% in just 20 years (1994–2014) (Anon, 2014).

Another reason that a live animal trade persists is to support religious festivals, which require the ritual slaughter of an animal as a devotional activity. The carcass is often divided between the owner, the owner's neighbours and the poor in the community. This is particularly common in the Muslim and Jewish faiths and may be seen as a relic of hunting activities that humans engaged in prior to the development of agriculture (Berkert, 1983), co-evolving with the development of religion. Some Muslim countries utilize purchased meat to distribute rather than live animals at the festival times, for practical reasons, so a live animal trade is not essential. One of the biggest Muslim festival gatherings is the Eid al-Addha (Festival of Sacrifice), which celebrates Abraham's offering of a lamb to spare his son. About 6 million sheep and goats are slaughtered, mostly imported from Australia and the Horn of Africa (Abbas *et al*., 2014). The Eid festival is currently in late August, advancing by 11 days each year. The sheep coming from Australia have a particularly high mortality when transported into the northern hemisphere summer, typically 1.1% of sheep compared with 0.6 % for sheep exported in the spring (Richards *et al*., 1989; Zhang *et al*., 2018). This is due to the transition from cold temperatures in Australia to hot conditions in the Persian Gulf. Not only is the Eid festival coming closer to mid-summer each year, temperatures in the Gulf are forecast to increase considerably over this century with global warming (Pal and Eltahir, 2016). The other major source of sheep and goats, the Horn of Africa, contains some of the world's poorest farmers. The international funding to support their trade in livestock (FAO, 2016) creates an ethical dilemma of whether to support human welfare at the expense of that of the livestock that they tend. Both the Horn of Africa and Australia are increasingly facing prolonged droughts that threaten the supply of livestock.

A third reason for long-distance transport of live animals by sea and air is because of the developments in freight opportunities. An expanded freight capacity, relaxation of trade restrictions under the World Trade Organization and a sustained period of relatively harmonious international relations have all facilitated the live animal trade. This has been supported by an increasing number of free-trade agreements, which relax tariffs to facilitate trade, often in agricultural goods. The carrying capacity of the world's container ship fleet expanded by a factor of 6 between 1990 and 2014, with an approximate doubling of ship numbers to about 40,000 large merchant ships, and trebling of ship size (Langewiesche, 2010; Tran and Haasis, 2015). Larger ships that can carry more cargo have increased total profits but have reduced profit per cargo unit, in this case the individual animal. Air freight has also increased, though not as rapidly, to 49 million tons of goods worldwide in 2012, up 71% from 2001 (Worldwatch Institute, 2013). However, very recently, air freight has been increasing faster than shipping (Reyhan, 2017).

A final reason that a live trade persists is because of geographical variation in feed availability and prices of livestock. The live export from Australia, for example, is dependent on the major differential between prices for livestock in Australia, where prices are relatively low, and those in the Middle East and Asia, where they are high. These differentials exist because of variation in the supply and demand relationships around the world. Regions with a large, affluent population, but little production capacity, are likely to be paying higher prices for livestock than those with small populations but with large production capacity. Other regions may have ample space and low-quality grasslands for breeding of livestock, e.g. Patagonia in southern Chile, but insufficient high-quality feed to grow cattle to slaughter weight; therefore they are shipped to areas where high-quality feed is available.

Despite these many factors potentially favouring some trade in live animals, the live export industry has been troubled by opposition from the public, who are particularly concerned about the welfare of livestock on long-distance ship voyages and after disembarkation in developing countries (Sinclair *et al*., 2018). Another factor mitigating against the long-term viability of the trade is its fickle profitability, affected by the high costs of the transport, some significant mortality events, and the variable price of livestock in drought-prone regions.

Regulatory Control of Livestock Export by Ship and Air

Export by ship

There are no internationally regulated standards for the transport of livestock by sea. Cargo ships are largely unregulated, flying under 'flags of convenience' from minor world powers, e.g. Panama,

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Liberia. However, the World Animal Health Organisation (OIE), a reference organization of the World Trade Organization, has developed standards for sea and air transport (OIE, 2018a,b), which may be implemented by any of the 182 member countries. These ship transport standards have specific requirements for each sector of the voyage: preparation of the animals on land, loading, travelling and unloading.

Australia has the most comprehensive Standards for the Export of Livestock by sea, issued by the federal government (ASEL, 2011). These address sourcing and on-farm preparation of livestock, land transport of livestock, management of livestock in the pre-embarkation facilities, vessel preparation and loading, and finally on-board management. The Australian Maritime Safety Authority also has some specifications for livestock pen design to promote safety at sea (AMSA, 2018). As part of its attempt to manage welfare during and after the voyage, the Australian government has issued both these standards and an Exporter Supply Chain Assurance Scheme, which aims to guarantee that OIE standards are upheld throughout the supply chain, including in the importing country, and that exporters have independently verified control of Australian animals in the supply chain. The Australian government also requires a veterinarian to accompany long-haul voyages and for them to complete a daily report, which is discussed with the captain. This records mortality and thermal conditions on each deck, the respiratory and faecal characteristics of the livestock and the animals hospitalized. Wet and dry bulb temperatures are recorded, but consideration needs to be given to the inaccuracy of a single or two-point measurement on each deck, often in a well-ventilated doorway (Zhang *et al*., 2017). The lack of adequate environmental measurement and control on ships contrasts with the much more detailed control on aircraft described later. A final, more detailed, end-of-voyage report by the veterinarian and stockperson covers all aspects of the voyage up until discharge, with a focus on health and welfare of the stock.

Failure to maintain adequate standards can result in an export licence being rescinded. Investigations take place if mortality is more than the normal mortality of transported stock to try to identify the cause. Mortality is the main welfare indictor used, although the Australian federal government is considering reductions in the maximum permitted stocking density during hot periods. Currently the live export industry uses a Heat Stress Risk Assessment Model to attempt to predict high-mortality voyages during the northern hemisphere summer. Stocking densities are relaxed by about 25% on such voyages, but given the high ambient temperature in the Persian Gulf in summer (Pal and Eltahir, 2016), it is unlikely that this will reduce the temperatures in the sheep pens to any great extent. No such control operates for the cattle trade, which is mainly from northern Australia to south-east and east China, because voyages are shorter and the mortality rate is much less.

The European Union has prepared standards for the transport of livestock by ship, rather less comprehensive than the Australian standards but nevertheless sufficiently specific on the key issues, such as stocking density for animals of different weights, ventilation requirements and necessary documentation (EC, 2005).

Other exporters of livestock by sea generally do not have the regulatory control that Australia and the European Union have put in place over the last 15 years, largely in response to continued lack of support for the trade by the public. Like the Australian government, the Brazilian government has the suspension of export licences at their disposal, a tactic used several times by the Australian government. The export of cattle from Brazil was temporarily suspended in 2018, which affected about 600,000 cattle. Suspensions of the live export trade are also being considered in the UK. About half a million sheep are currently exported annually from the UK to continental Europe, a relatively short journey for which the animals remain in trucks. Nineteenth-century UK legislation mandates the free passage of livestock through ports, including about half a million pigs and 20 million chicks imported to the UK from the EU annually.

As well as the live export of animals for finishing, there is a growing importation of breeding animals, such as dairy heifers imported into China. Disease status is more important here; in particular, it is important to determine whether the exporting countries are free of Johne's disease, bovine viral diarrhoea and enzootic bovine leucosis.

Export by air

The International Air Transport Association (IATA) has produced comprehensive standards for the transport of livestock and other animals by air (IATA, 2018). These are established as the international

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standards to be utilized worldwide, covering government and carrier regulations, responsibilities of the carrier and shipper, animal behaviour and maximum stocking densities, documentation, container requirements, marking and labelling, and handling procedures. IATA is formed from 290 airlines from 117 countries, and as well as providing standards, it provides training for personnel involved in the handling and transport of live animals by air. The standards have been legally adopted in many countries as well as by the major airline carriers. The EU requires compliance with the IATA standards, as well as requiring compliance with additional standards of their own (EC, 2005). The IATA standards largely pertain to specification of facilities and do not, for example, specify maximum time off feed and water, preferring general statements like: '…water must be provided…. if climatic conditions, species and class of livestock and total journey time warrant'. The IATA standards do, however, specify the size of all species of animals likely to be transported by air, so that suitable containers can be constructed. Pregnant animals can only be accepted if there is veterinary certification that there is no risk of birth, and animals that have given birth within the previous 48 hours cannot be accepted. As with the ship transport standards of the OIE, animals transported by air must be able to stand, turn around and lie down naturally.

IATA requires that all shipments of livestock are accompanied by:

- A shipper's certificate, which specifies the departure and destination airports, the number of containers, the species and number of animals and the authorized shipping agent.
- An air waybill, which is an agreement between the shipper and the carrier, prepared by the shipper, and contains details of the consignment, including charges if necessary, its carrier, contact details and the departure and destination airports; it is either electronic or has multiple copies for all involved in the process.
- A load plan, which notifies the captain of the exact location of all containers and the number of stock within each one, the stocking density and, in some jurisdictions, the space requirements and necessary headroom of the stock according to national legislation, and a full itinerary including details of transport before arrival at the airport.
- Health and vaccination certification prepared in advance by the relevant veterinary authorities.

There are also World Animal Health Organisation standards for transport of livestock by air (OIE, 2018b), which are more specific in regard to animal requirements. Thus, water must be provided 'during transportation of longer than six hours duration'. The Australian Standards for the Export of Livestock also cover export by air, as well as by sea (ASEL, 2011). These specify that an export permit from government must be obtained before export occurs.

Description of the Trade

Transport by ship

The live export trade by ship has mostly built up over the last 30 years, with the expanded freight opportunities described above. Much of the large-scale shipments travel the long distances between the livestock-rearing regions of the southern hemisphere and the regions of high demand in the northern hemisphere. This naturally follows from the lower population density and labour costs in the southern, compared with the northern, hemisphere. The growth of the trade in Australia was at the expense of the meat processing trade at home; in the 1990s, all of the northern abattoirs closed because the live cattle trade was more lucrative. Regions of high demand in the northern hemisphere include the Middle East where livestock production is limited by the hot, arid landscape and where there is a preference for live animals for religious slaughter (largely supplied by shipments from Brazil, Paraguay and Australia); China, where increasing affluence has led to a rapidly increased demand for animal products and the development of an intensive dairy industry (supplied mainly by Australia, New Zealand and, more recently, Chile); and Europe, where the high population density and relative affluence has sustained a high demand and limited livestock production potential per capita of the population. An increasing number of dairy heifers are exported from the established dairy industries in New Zealand, Chile and Australia to China (15,000 in 2008, 62,000 in 2013) (MLA, 2013), Russia, Malaysia, the Philippines, Pakistan, Indonesia, Thailand and Vietnam.

Smaller-scale shipments bring livestock from small islands to centres of population where there are abattoirs and a demand for animal products. For example, cattle and sheep travel from the Scottish islands to Aberdeen on the mainland in containers and trucks (roll on–roll off) and across the English Channel and Irish Sea bound for the continent of Europe. Concerns

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about the short journey from England have led to some sailing from Scotland to Ireland and then on to France, a much longer journey.

Elsewhere in the world, several million livestock travel from Africa to the Middle East each year for the sacrificial festivals, most through the Horn of Africa and mostly sheep, goats and camels. A typical journey from Berbara, Somaliland, to Jeddah, Saudi Arabia, takes four days. But many originate in Ethiopia and arrive at the departure ports after being driven on foot or trucked to the ports, with trucked animals often overstocked, injured and heat-stressed. Several Middle East countries, most notably Saudi Arabia, banned the livestock trade from Somalia at the beginning of this century for a decade because of concerns about biosecurity. Since then the Food and Agriculture Organization and the European Union has supported the commercial development of the livestock trade through mass vaccination programmes and investment in slaughterhouses and markets. Livestock are quarantined at the port for testing for diseases and vaccination to meet the import requirements of Middle Eastern countries. These are predominantly Muslim countries, a religion that places great importance on excellent health status of imported animals. Sheep and goats board the ships by a gangway but camels are winched up and then individually tethered on the ship.

In Indonesia many cattle are transported between the islands in small ships. Variations in sea height as a result of tides means that cattle are often winched onto the ships rather than walking up a gangplank, which can cause neck injuries, particularly if they are winched in small groups with ropes around their necks.

Some countries transport livestock by ship because there are no suitable roads for this purpose. Cattle and sheep produced in the Patagonian grasslands of southern Chile journey north to the centre of this long narrow country by ship for precisely this reason (Fig. 22.1). The journey of 1700 km takes three days, which brings problems of supplying sufficient feed and water to all the stock in the heavily stocked trucks. Some stock do not have such provision and leave the ship dehydrated and, inevitably, hungry.

Transport by air

The transport of livestock by air has the advantage of being very quick, thereby avoiding the long



Fig. 22.1. Transport of cattle in trucks from the south of Chile to central Chile, a three-day journey. (Photo: Grisel Navarro)

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journeys that cause many welfare problems. However, the high cost of air compared to ship travel means that only high-value animals (e.g. dairy cows, specialist breeds of cattle, like Wagyu) and livestock that would not cope well with a sea voyage (e.g. feral goats, young calves and day-old chicks) are transported. Feral goats are not allowed to be sent by ship from Australia, because of high mortality; approximately 50,000 goats are flown annually to Malaysia and surrounding countries with very low mortality (0.02%). Overall, only about 3% of sheep and 0.5% of cattle exported from Australia travel by air, i.e. about 60,000 and 6000 animals, respectively. The number of animals that can be transported by air is usually much smaller than by ship, typically just 50–100 tonnes of livestock by air. On a per-shipment basis, the mortality of both sheep and cattle in air transport from Australia is lower (0.2% and 0.1%, respectively) than by sea transport (1.0% and 0.3%, respectively) (mean values 2008–2016; Norman, 2017); however, it is, on average, increased on a per-day basis. In addition, there have been four high mortality air shipments with mortalities of 7–39%.

Standard Practices

Ship

The selection of livestock to travel on the vessels often starts several days before embarkation, on the extensive, rangeland farms that produce large numbers of cattle and sheep for export. They are mustered by helicopter, aeroplane, vehicles, motorbike and riders on horseback. They are then driven to yards, slowly if the weather is hot, and remain there to cool down and relax for several hours, often overnight. The following day they are typically loaded onto a truck and transported to a pre-embarkation assembly depot, a journey which can take anything up to 50 hours. At the pre-embarkation depot they should remain for several days, preferably a week, to get used to the new environment and other unfamiliar animals that will accompany them on the shipment. Sheep and goats need a few days to adapt to the pelleted feed they will receive on the ship, especially if they have only been on pasture previously. Any that are not adapting can be removed and returned or sold locally.

Minimizing the pathogen challenge during this stressful period is important, as it protects the animals during the voyage. Keeping the animals on slatted floors to remove contact with faeces helps. Before the journey to the ship, a veterinarian should inspect the sheep, and again at the port, to ensure that over-fat, over-thin, lame or otherwise sick animals do not travel. Ship transport is stressful and the weaker animals quickly succumb.

Moving large numbers of animals to the ship by truck requires considerable co-ordination, first of all with the ship's captain to make sure the tides are at the right height for the gangplank to provide a suitable slope for loading; also with the quarantine and inspection services; and with the exporter to ensure that the arrival of animals at the port is timed to minimize waiting time in trucks. Large numbers of livestock that have been driven long distances in the Horn of Africa will amass at the ports, leading to considerable stress and increasing the risk of disease acquisition.

Injuries are most likely to happen, particularly to cattle, as they move up into the ship (Fig. 22.2). Most ships have a number of decks, up to about ten, with some above the waterline and some below. Decks above water level may be both naturally and artificially ventilated, or all decks are artificially ventilated. Decks just above the waterline may be fitted with covers for the open sides that must be erected before high seas create a risk of ingress of seawater onto the decks. Animals are directed up or down from the arrival deck to reach their final place for the voyage. Once livestock are on the right deck, they are placed in pens at approximately the prescribed stocking density. This may be adjusted later, in particular after some animals have been discharged and there is space to relax the stocking density. Some ships only carry stock in the hold of a container vessel, which may have poor ventilation characteristics. Multi-deck vessels have air inlet ports on the top deck and outlets at multiple points on each deck. It is important that exhaust air from the ship is not allowed to enter the inlet ports. Characteristics of efficient modern ship ventilation systems are described in Schultz-Altmann (2008).

Ships must carry sufficient crew to care for the stock during their voyage. At the very least livestock should be inspected twice per day. Sick animals should be removed to hospital pens, if they exist, and given more space, more attention and more easily accessible food and water. Long-distance voyages from Australia also carry a veterinarian and trained stockperson, and more recently an independent observer to comment on conditions for the animals. The veterinarian should continually

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Fig. 22.2. Loading Friesian cows onto a ship at Fremantle, Australia, for transport to the Middle East.

monitor the welfare of the stock, deal with any disease problems in conjunction with the crew, and liaise with the captain daily about the animals' welfare. Given that crew, officers, veterinarian and stockperson may all be of different nationalities, the ship's captain plays an important role in ensuring cordial relationships onboard ship.

On voyages less than three to four days, livestock may remain in trucks on the vessel, in which case they are only offered limited feed and water. However, on most voyages over one day, livestock leave the truck and are penned in sufficiently small groups to prevent stampedes and bunching occurring. This could be up to 100 sheep and five to ten cattle.

Feed offered onboard has to be stowed beforehand. This is usually pelleted and either comes onboard in bags or is augured into the ship's hold. If it is piped around the ship before delivering to troughs at the front of the pens, it needs to be sufficiently robust to remain in the pellets and not broken into dust during the process. Dust in the atmosphere contributes to respiratory disease and conjunctivitis in the eyes of the animals. Chaff or other dried herbage may also be offered to encourage sheep to start eating, as inappetence is a major cause of mortality. This is particularly in the fat sheep that are not as hungry as thin ones and less likely to push their way through to the feed troughs. Troughs should be checked daily for possible bridging of the feed leaving the pipes. Similarly, water should always be available, but reports from recent shipments leaving Australia in the winter to arrive in hot conditions in the Middle East summer suggest that insufficient water is available in the final stages. Insufficient feed and water is a common problem, as noted above in relation to the ship transport of cattle from Patagonia in Chile.

Sheep are not usually provided with bedding, and depending on the length of the journey, nor are cattle. Excreta falls onto the solid floor and is gradually dried by the high ventilation rates on the ships, creating a friable product about 10 cm deep that the animals lie on (Pines and Phillips, 2011). Sometimes, if the humidity is high, the excreta turns to a slurry, in which sheep can die.

Disembarkation requires just as much co-ordination and good facilities as embarkation, often more if the animals are hot and tired after a long journey.

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Unfortunately, many countries export to the developing countries in the Middle East, where offloading facilities are not always at a high standard. Crew, captains, veterinarian and stockpersons have a primary duty to ensure the offloading runs smoothly before disembarking themselves. If there are multiple ports at which livestock are disembarked, the remaining stock can be given more space, especially if conditions are hot.

Following disembarkation, livestock may be taken in trucks to a feedlot to continue growing. Vietnam has established a major feedlot industry for cattle coming from Australia, many of which will be sent to surrounding countries when they are of sufficient weight. Indonesia has stopped taking Australian cattle over 250 kg, preferring to take young cattle that can be finished in Indonesia. This may require the importation of high-quality feed for the cattle. Some livestock will be used for breeding, particularly dairy cows. Other livestock will be sold at markets, often for the slaughter festivals. Families buy animals, usually a sheep or goat in the Middle East, but more often cattle in south-east Asia. Transport for these animals to the wet market at which they are slaughtered may not be of high standard, with animals placed in car boots, on roof racks and other precarious practices. Another cause for concern is when the standards for slaughtering the animals are not as strict as those in the exporting countries. This has particularly been a problem for livestock exported from Australia, with most animals travelling to the Middle East and south-east Asia. Slaughter facilities are usually worse than in Australia, with no stunning of the animals to render them unconscious before slaughter, for either religious or economic reasons (Tiplady *et al*., 2012, 2015). In 2011, this led to the trade in cattle to Indonesia being temporarily suspended.

The entire process for livestock coming from rangelands may last several weeks until they are finally slaughtered in their country of destination, with the risk of cumulative stress on the livestock. The key stakeholders are the exporters, the carrier, the vessel owner, the crew, the veterinarian, the stockperson, the quarantine officer, the truck drivers and, of course, the animals themselves.

Air

Livestock are generally flown in small numbers in containers made of plywood, metal or plastic (Hogan and Willis, 2009). They are brought to the airport's freight depot by the shippers and loaded into the containers. The larger the animals, the bigger the containers. Sheep crates are normally stacked three high. Typical crates for one-year-old cattle are 3000 mm long by 2250 mm wide and 1600 mm high (Fig. 22.3). These are designed to retain excreta by having a plastic sheet on the floor and up the walls. Bedding may be provided but some recipient countries do not allow this. Ventilation is provided by 5 cm holes drilled in the solid sides and through the open top of the crate, which should together total 33% of the floor area. Each container sits on a pallet on a metal tray (unit load device) that is fork-lifted up into the cargo hold of the aeroplane, often a Boeing 747. A net is used to cover the crate, excluding the door. After transfer of the cattle from the truck to the containers, these are screwed shut. The crates are rolled onto a weighing platform and the weight recorded with a unique code on the pallet base, then the crates are stored prior to loading, either in a freight shed or on the apron outside. At this point the responsibility transfers from the exporter to the carrier. Once loaded by airfreight



Fig. 22.3. Cattle crate in the hold of an aircraft. (Photo: CMTP; https://www.cmtp.com.au/product/livestock-crates/)

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handlers, with a 'loadmaster', using the plan provided by the exporter under the direction of the services division, containers are secured to the decks, in case of turbulence.

On the aircraft, the maintenance of a comfortable thermal environment is very important, particularly because a full plane of cattle generates a lot of heat and moisture. Environmental control is automatic, with temperature set at 12–18°C by the captain, but this is not necessarily the actual temperature in the hold. As well as temperature, humidity, noxious gases and air pressure are controlled automatically. The cargo holds are usually pressurized to an altitude equivalent to approximately 2500 m. During the flight, cold air from outside is bled from each engine and passes through a moisture separator and filter before being mixed with recirculated air. The temperature is regulated by passing the air over heat exchangers. Cool air is supplied by a series of ports running the length of the hold and any deviance should be detected by the aircraft's central maintenance computer.

Livestock are loaded just prior to take-off to minimize the stress caused by being on the plane. Loading may be at night if days have hot temperatures. On most cargo planes there are two decks, and the load plan will specify the contents of 13 pairs of containers on the upper deck, 10 pairs on the lower deck and four single containers in the nose and tail. Reduced airspace on the lower deck and/or the presence of horned animals requires a 10% relaxation of maximum stocking density, according to the ASEL (2011) standards. Refuelling stops or partial disembarkation stops must be accompanied by sufficient ventilation whilst on the runway, which may require an auxiliary power supply, either the plane's own supply or an external supply provided by the airport, organized by the ground engineers. Inspection is not usually possible in the lower hold during the journey, even though an animal attendant usually accompanies the cargo on the upper deck. Cattle emit large volumes of water vapour, which can interfere with the aircraft sensors, occasionally causing emergency landings.

Welfare Problems

Mortality is the best indicator of the welfare of livestock, even recognizing that some welfare problems, such as ammonia, will not kill the animals (Pines *et al.*, 2007). However, mortality is easily measured and has a clear relationship to welfare, whereas environmental measures such as temperature may not have such a clear relationship. Usually, mortality is higher, on a daily basis, during travel by ship and air, compared with land (e.g. for sheep, 0.1% by ship, 0.2% by air, versus 0.007% by land; Phillips, 2015).

Specific problems at sea

Stocking density

By most standards, livestock only have slightly more space on ships than they do on trucks, and this is substantially less space than they have in feedlots. They should have room to stand up, lie down, turn around and move to feed and water. The best way to calculate space requirements is to use an allometric equation relating to the weight of the animal to the power 0.66 (space availability is a two-dimensional measure, weight is three-dimensional) (Petherick and Phillips, 2009).

Overstocking of ships (Fig. 22.4) is common as a result of the high cost of the transport. It has been reported that for ships travelling from Patagonia to



Fig. 22.4. An overstocked cattle truck on a ferry from Kangaroo Island to mainland Australia.

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central Chile (Gallo and Tadich, 2008), sheep lie down less in the early stages of the voyage at high stocking densities (Ferguson and Lea, 2013). Studies using simulated ship conditions on land suggest that highly stocked livestock push other animals more and are more aggressive towards them, causing them stress (Navarro *et al*., 2018). Highly stocked livestock also excrete more urine and faeces per unit area, leading to dirty conditions, increased ammonia and the generation of more heat (see below).

Heat stress

Cattle and sheep, as ruminant livestock, are both species that are particularly at risk of heat, rather than cold, stress, because of the large amount of heat they generate in their digestive processes. Over a period of about ten days, in August, sheep may go from 0°C in Australia to 40°C in the Middle East. Many exported Australian sheep travel for the Festival of Sacrifice, Eid al-Adha, which is advancing towards the Australian mid-winter period. On voyages from Australia to the Middle East, mortality can increase rapidly in the final stages as the temperature and humidity rises rapidly, and cross-ventilation decreases in the narrow confines of the Persian Gulf. Major problems begin if the wet bulb temperature exceeds 30°C. Sheep attempt to lose heat by panting, which may increase respiration rate from 30 to 300 breaths per minute, and in extreme cases sheep hang their tongues out of their mouths (Black *et al*., 1994). There is uncertainty about exactly when sheep begin to feel stressed, i.e. when rising temperatures have an impact on the sheep's welfare (Phillips, 2016). Observing respiratory rate alone will not provide a sufficient indicator because sheep change to a deep, heavy panting at very high temperatures, at around 160 breaths per minute, presumably because very rapid respiration itself generates heat in the animal. This is accompanied by drooling or, in the case of cattle, foam around the mouth. Another factor that exacerbates the stress of high temperatures onboard livestock vessels is that temperature is relatively constant around the clock, unlike on land where low night-time temperatures allow animals to reduce their core body temperature. The greatest risk is to livestock in naturally ventilated pens, on the upper decks, if there are no cross-winds or the ship is in port. High stocking densities will in theory also increase heat-stress risk, because of increased heat output from the animals, but this factor depends on how important this source of heat is compared to radiant heat from the ship's exterior and convection heat from the engines.

Wool length is a critical factor influencing the sheep's ability to resist heat stress (Grandin, 1983). The Australian Bureau of Animal Health export standards require a maximum fleece length of 25 mm; however, shearing sheep too close to the sheep departure date may increase stress (Hutchinson and McRae, 1969). Skin temperature is reduced in shorn sheep by about 2°C and respiration rates increase less in response to heat stress (Austin and Young, 1977). Thus shearing reduces heat stress in hot, humid environments (Lee, 1950; Klemm, 1962).

Sheep often suffer from a combination of heat stress and a persistent inappetence, salmonellosis inanition (PSI) condition. These conditions are likely to be synergistic and related to the stress that the sheep are experiencing, as evidenced by increased stress hormone production in both conditions (PSI: Higgs *et al*., 1993; heat: Cwynar *et al*., 2014). This may lead to multi-organ failure at high temperatures. Crucial in the moderation of heat stress is the provision of adequate drinking water; however, this in itself may be very hot in Middle East summer conditions. Increased drinking increases urination and air humidity, which increases heat stress and creates a vicious circle. Stock congregating around water troughs may prevent others from drinking, and aggressive plunging behaviour to get to the troughs has been observed in sheep as a result (Taylor, 1983; Black *et al*., 1994).

Diseases

The major disease conditions in the Australia-Asia trade, i.e. those that have triggered disease investigations, experienced by cattle, sheep and goats on ships, are heat stress, pneumonia and traumatic injuries (MLA/Livecorp, n.d.). Additional major diseases experienced by sheep and goats are inappetence and salmonellosis. Heat stress and inappetence are here described separately from other diseases.

Pneumonia is a pulmonary viral or bacterial infection, also connected with the stresses associated with the export process. The disease is associated with oronasal and ocular discharge, coughing, lethargy and laboured breathing. It may occur when livestock are chilled by the high wind speed around ventilation shafts on vessels with automatic ventilation.

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Salmonellosis is often accompanied by inappetence, and the combination may be confused with heat stress (Phillips, 2016). The bacterial infection is typically acquired at the pre-embarkation assembly depots, when sheep are brought together from a number of different sources and suffer social and environmental stress. The continued stress at sea predisposes sheep to an outbreak of the disease, aggravated by persistent exposure because the faeces are not removed from the pens. Affected animals present with enteritis, fever, a listless appearance and diarrhoea, sometimes with blood.

Another infectious disease that is common, but not usually fatal, is keratoconjunctivitis, known in cattle as pinkeye. This bacterial infection affects both cattle and sheep, inflaming the conjunctiva and cornea of the eye and potentially rendering the animal blind in one or both eyes. A prevalence of 1.6% has been recorded on one sheep shipment, higher when the sheep were in high-ammonia conditions (Pines and Phillips, 2013). Usually, the condition requires both irritation of the eye and the acquisition of a bacterial infection at the site. Irritation may be caused by dust particles that circulate in the ship's artificially ventilated decks, when the feed is moved around the ship. Feed pellets of poor quality may crumble under load, liberating dust. Changing to higher-quality pellets, however, would increase intake, excretion and exacerbate the heat-stress problems that exist on many shipments. This disease is a painful condition that renders the animal temporarily blind.

Ammonia

Ammonia is liberated into the atmosphere by the volatilization of nitrogenous compounds in livestock excreta. The failure to remove the excreta from the cattle and sheep pens on ships increases ammonia concentrations, as do the high temperatures and humidity on board. Ammonia on one live export shipment accumulated quickly on closed decks, but on decks open at the side, ammonia is also potentially high when the ship is in port, rather than on the open water (Pines and Phillips, 2011). Maximum levels of 30 ppm are suggested for livestock shipments (Phillips *et al*., 2010, 2012). The position of the livestock will determine the ammonia concentration in naturally ventilated decks, those at the centre, furthest from natural ventilation, experiencing the highest concentration, as well as those near the hot engine block (Pines and Phillips, 2011). Sheep in ship pens with high ammonia eat and ruminate less (Pines and Phillips, 2013) and chew their feed less during both feeding and ruminating (Zhang *et al*., 2018), suggesting that the inappetence known to be a major cause of mortality in sheep may be partly due to ammonia. It has been suggested (Zhang *et al*., 2018) that these effects are due to inflammation of the buccal cavity. The coughing, sneezing and lacrimating that are observed in livestock in ammonia concentrations typical of ships are also indicative of inflammation of the mucosal surfaces of the mouth, eyes and nose (Phillips *et al*., 2010, 2012).

Slipping, falling and motion sickness

Sheep and cattle on ships are subjected to a variety of movements, which vary depending on how far they are from the metacentre of the ship. Heave, roll and pitch, in declining order of severity, have the biggest effects on sheep. Sheep at the sides of the ship will be subjected to significant heave movements, causing behavioural and physiological stress (Santurtun *et al*., 2015). Heave is the movement primarily responsible for motion sickness and is a movement that ship-borne livestock will never have experienced. There is no definitive evidence that livestock suffer from motion sickness during ship travel, but they do have better balance if provided with an anti-emetic in simulated ship motion (Santurtun, 2014). In high seas, the wave motion can also produce slamming forces, waves that shunt the ship sideways and are likely to severely stress the animals. Mortality increases during high seas, partly because livestock slip and potentially fall, but also because the ship may take on water on decks just above sea level.

Inappetence

Early research identified that inappetence, or an anorexia-like reluctance to eat, was a primary cause of mortality in Australia's shipment of sheep to the Middle East (Richards *et al*., 1989). It is probably caused partly by sheep not mobilizing fat tissue adequately, relying on endogenous protein for their energy supply (Higgs *et al*., 1991) and partly by sheep not being used to eating pellets on the ships, having come off pasture. Research in the 1970s and early 1980s suggested best management practice was to train sheep to eat the ship's pelleted feed (Grandin, 1983). To reduce problems with

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refusal to eat pelleted feed, the sheep should be acclimatized to eating it before departure (Arnold and Mallor, 1974; Fels, 1973, 1976a,b, 1982; Fels and Malcolm, 1973). In addition sheep may have difficulty gaining access to the feed troughs, since the high stocking density prevents them moving around the pen (Pines and Phillips, 2013). In other shipments, it is simply because inadequate fodder is provided, which is most likely if livestock are left in trucks in voyages that last more than one day. Treatment is relatively simple but rare, not only ensuring that adequate palatable fodder is provided but also the space for the stock to get to it.

Specific problems in air transport

Livestock may react violently to take-off, which submits them to G-forces, heave and noise never experienced before. Shipments of cattle have occasionally been found to have significant mortality in some containers on arrival, this being due to suffocation, probably after stampeding during the terror induced by take-off. There have also been at least two incidents of the cargo deck fire alarms being triggered during descent of the plane, probably due to emissions from the livestock.

Apart from these isolated events, high mortality on cattle and sheep shipments is nearly always due to poor ventilation, sometimes caused by failure of auxiliary power units during stopovers, but often without explanation. This suggests that stocking densities are too high, especially if stopovers occur in airports with hot, humid conditions. In addition, the crates that livestock are confined in rarely have good ventilation characteristics, particularly if small animals are transported that cannot benefit from the ventilation ports at the top of the crates.

Future of Ship and Air Transport of Livestock

With its relatively short history and attention to passenger safety, the airline industry has developed careful management procedures to safeguard the welfare of livestock in transit, which is reflected in the low mortality rates per shipment (but not per day). This is despite the fact that the process is clearly stressful, albeit for a shorter time than transport by ship. By contrast, ship transport has relatively high mortality per shipment. When the industry has been heavily criticized by the public in Australia, government has introduced many stipulations. New Zealand has stringent licensing restrictions that have effectively stopped any trade in growing livestock, although they continue to export breeding stock – dairy heifers mostly – to Asian countries. These often await a very difficult transition to Asian conditions, with inadequate feed and an expectation of high milk yields and regular calf production that they are unable to fulfil.

Little has been done to address the major welfare issues on ships, in particular that of heat stress. No air cooling has been introduced, no waste management, and the heat-stress risk-assessment model used to reduce stocking rates for high-risk voyages appears to do little to reduce the risk. Other strategies could be investigated, such as heat exchange with the ocean, but all attempts to mitigate heat stress have a time and/or fuel cost associated with implementation. The Australian government has assisted with research funding, but increasingly high livestock prices and low profits for exporting companies have prevented implementation of most strategies to improve welfare. This does not suggest a good future for the industry, which is coupled with major public concern in many developed countries and now increasingly in developing countries, such as Brazil. The public have particular concern about sending livestock from a developed country to one in which welfare standards are, at best, variable and not regulated by national or international law. One of the main reasons has been the traditional sale in wet markets in Asia, but in China, for example, this is expected to have declined from about two thirds to one third between 2010 and 2020 (Motton, 2014). This rapid transition is coupled with the rise in supermarket sales, from about 3% to 42% for beef and mutton over the same time period. These are both species that the large-scale suppliers, such as Australia and New Zealand, might think of sending by sea if public opinion supported it.

Conclusions

With a transition from wet-market supermarket sales happening around much of Asia, and production within Asia intensifying and concentrating more on chicken and pork, the demand for large numbers of live cattle and sheep to be sent long distances around the world is likely to diminish in the future. Air freight is growing rapidly, but high costs and the expected future growth in self-sufficiency in Asia for meat production means

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that this is likely to remain confined to very high-value animals. Concerns about animal welfare put the industry under constant pressure, and it seems likely that there will some phasing out in key exporting countries – Australia, New Zealand, the UK and Ireland, in particular. There will remain major short-distance trade from Africa to Asia, and within Asia, in livestock to support the Muslim religious festivals for the foreseeable future.

Photo credits

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23 Principles of Biosecurity during Transport, Handling and Slaughter of Animals

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Summary

Use of proper biosecurity practices will help to reduce the spread of disease. To prevent disease introduction onto a farm, all incoming animals should be isolated and, when possible, tested for disease before they are added to the herd. An important biosecurity principle is the biosecurity sequence, which details different groups of animals within a production chain; procedures need to be strictest at the beginning of the sequence and less strict at the end of the sequence. The sequence is: (i) foundation herds and flocks; (ii) newborn animals and commercial multiplier herds; (iii) commercial livestock used for breeding and production; (iv) feedlots, grow out and production operations with no breeding; and (v) areas of high contamination and commingling, such as livestock markets, wet markets, slaughter plants and rendering plants. If a severe disease outbreak occurs, immediate closing of markets may help to reduce its spread. This chapter also reviews methods to reduce *Escherichia coli* and *Salmonella* contamination of beef and pork. Lists also are included of select agents and toxins as defined according to the US Select Toxins Regulations, and of diseases that require the World Organisation for Animal Health (OIE) to be notified by member nations.

Keywords: animal health, biosecurity, slaughter, transport

Introduction

In the modern era of global trade and travel, multinational corporations, intensive livestock-raising practices, terrorism and persistent threats to animal and public health from foreign animal diseases and emerging food-borne pathogens have elevated the importance of implementing sound biosecurity measures during livestock production. Economic consequences alone, as a result of an animal health crisis (caused either by zoonotic or other animal diseases), in the livestock and meat industry merit serious effort towards their prevention. However, the ramifications to the industry are vastly escalated when the biosecurity threat also affects food safety and public health.

People who handle and transport animals must understand the importance of preventing the spread of animal disease and food safety threats as they are in a unique position to help control transmission of such agents. More training is needed for transporters and truck drivers. In a study in Kansas, for instance, only 38% of the trucking companies were training their employees to recognize foreign animal diseases when present (Fike and Spire, 2006).

Basic Disease Control Principles on the Farm for All Species of Animals

1. All new breeding stock arriving at a farm should be isolated in a separate area away from other

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animals; this is known as quarantine. Consult with local veterinary authorities for the recommended isolation time. Unfortunately, a study in England showed that the majority of cattle producers failed to isolate incoming stock (Brennen and Christley, 2012).

2. When purchasing breeding stock, the animals need to be tested for diseases that are a problem in the geographical area concerned. Consult with local veterinary authorities.

3. Rendering and dead-stock trucks should not be allowed to enter the farm. Dead stock should be brought to the outer perimeter of the farm for picking up. If dead stock is buried on site, precautions as to not reintroduce pathogens from the dead stock into the environment should be taken (Pratt and Fonstad, 2017).

4. Livestock trucks should be kept clean and all visitors and drivers should have clean footwear. This is especially important if a visitor or vehicle is arriving from an area where many different animals have commingled, such as auction markets and slaughter plants.

5. The biosecurity sequence should be observed for all species. Most veterinarians recommend that sanitation and biosecurity measures need to be stricter for newborn animals and valuable breeding stock than for animals being raised for meat. Below is a list of five phases, from those that should be the least contaminated to those that are likely to be the most contaminated. Some veterinarians call this the biosecurity pyramid. Seaman and Fangman (2001) and Levis and Baker (2011) both provide a good description of the implementation of such a sequence. Phase (i), Foundation herds and flocks, is at the top, where measures to prevent the introduction of disease should be the strictest.

- (i) Foundation herds and flocks:
  - bull, boar or stallion studs or species females that distribute large amounts of semen or embryos, respectively;
  - specific pathogen-free herds or flocks; and
  - foundation genetic breeders – all species.
- (ii) Newborns and commercial multiplier herds and flocks:
  - chick hatcheries;
  - dairy calf rearing facilities;
  - sows with piglets;
  - breeder flocks that produce chicks for commercial egg laying or meat; and
  - multiplier herds that produce replacement commercial females for many farms.
- (iii) Commercial livestock used for breeding and production:
  - beef cow herds on pasture;
  - dry sows;
  - lactating and dry dairy cows; and
  - sheep, goats or horses on pasture.
- (iv) Feedlots and production operations – with no breeding:
  - beef feedlots;
  - swine finishing (fattening) barns;
  - lamb feedlots;
  - poultry grow-out barns; and
  - laying hens.
- (v) Areas of animal commingling – all species:
  - auction markets;
  - buying stations;
  - slaughter plants;
  - rendering plants; and
  - traditional 'wet' meat markets with different species commingling.

Flow of people and traffic should move from the least contaminated to the most contaminated areas. Boots and clothes should be washed before a person can return to animals that are higher up on the pyramid. Providing boots or shoe covers for visitors is strongly recommended. Dee *et al.* (2004a,b) reported that providing disposable plastic boots and bleach footbaths were effective for preventing the mechanical transmission of porcine reproductive and respiratory syndrome virus (PRRSV) to pigs. On pig and poultry operations, the rules are often very strict, and all visitors to the farms wear plastic boots and disposable coveralls. Some poultry and pork companies require 24–72 hours of down time after visiting phase (iii), (iv) or (v) operations before a person can return to phases (i) and (ii). Downtime can help alleviate some disease spread from professional visitors, who have been shown to transfer disease between different farms (Hagenaars *et al.*, 2018). At least ten integrated poultry and pork companies in the USA, Canada, Europe and other countries that have been assessed have all have implemented biosecurity pyramids that were similar for the different phases of production.

6. After visiting areas where foot-and-mouth disease, African swine fever, or other diseases that require notification are prevalent, all World Organisation for Animal Health (OIE), federal government and local government guidelines should be followed on downtime, cleaning and disinfection before being in contact with other animals. In the USA, for

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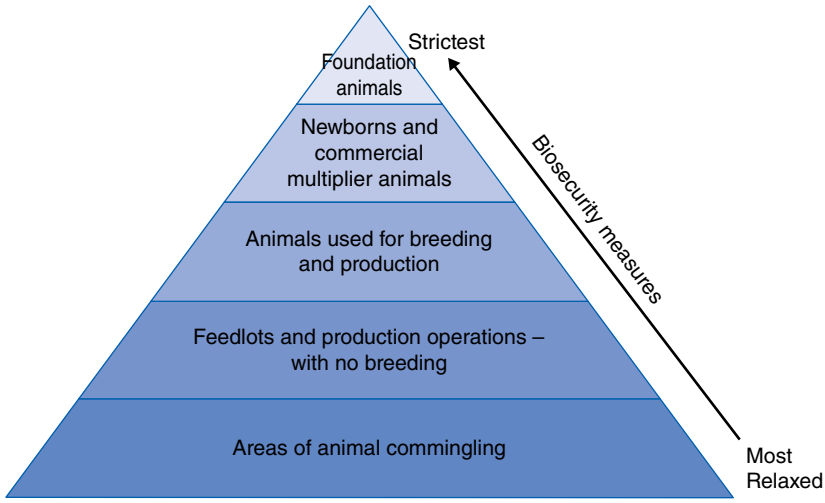


Fig. 23.1. Biosecurity Pyramid – the strictest biosecurity measures and sanitation should be observed at the top of the pyramid with more relaxed measures in lower levels.

example, federal government controls are regulated by USDA/APHIS – the Animal and Plant Health Inspection Service (APHIS) of the US Department of Agriculture (USDA) and/or by the Centers for Disease Control and Prevention (CDC) of the US Department of Health and Human Services (USDHHS). For foot-and-mouth disease, Amass *et al*. (2003) have described the prevention of disease transmission by having contaminated people shower and change into clean clothes before they come into contact with susceptible animals.

7. Clean techniques should be used for administering injections, ear tagging and surgical procedures. Milking equipment and pregnancy testing can also spread disease; so the milking machine should be cleaned after milking a cow with mastitis, and sleeves should be changed after palpating a cow that has a disease transmissible to other animals. Practices should be improved by working with the local veterinary specialists and meat quality assurance teams.

8. A logbook should be kept for all visitors, truck drivers, employees and other people who come to the farm.

9. If a severe disease outbreak occurs, live markets and other points of animal concentration must be closed. Several network analysis studies have shown that live markets are hubs for disease transmission (Volkova *et al*., 2011; Rautureau *et al*., 2011).

10. Producer groups, government officials and meat-buying customers must work together to assure that regulations and procedures that help to prevent the introduction of diseases and the transmission of food-borne threats are obeyed. Diseases that may disrupt the economy must be prevented from entering areas that are free of these diseases.

Terminology

Before a coherent discussion of biosecurity can ensue, it is important to define the terminology to be used. A quick review of published information on biosecurity reveals that the term biosecurity, along with a number of related terms (agrosecurity, biosafety, biocontainment, biodefence), have differing meanings to different individuals or groups (e.g. see Sandia National Laboratories, 2004), while few definitions for the use of the terms are available to review. In fact, not many well-known dictionaries even provide definitions for the word biosecurity and its associated terms. Lack of standardized terminology is particularly problematic when, for example, one considers the quantity of regulatory policies developed that use such terms to govern biosecurity, biosafety and biocontainment for a wide array of entities.

Kirkpatrick and Selk (2006), in a discussion of biosecurity in the beef cattle operation, stated that 'biosecurity is used to describe programmes for preventing the introduction of pathogens considered potentially harmful to the health and well-being of the [beef cattle] herd'. Clearly, using their definition, biosecurity is a veterinary term addressing the

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prevention of disease introduction for purposes of the protection of animal health. Conversely, the National Research Council (2006) has defined the term biosecurity to mean 'the policies and measures taken to minimize the risk of introducing an infectious pathogen into the human, agricultural animal, and research animal populations'. This latter definition is clearly broader, as it includes protections for both animal and public health.

The Sunshine Project (2003)[1] stated that the meaning of the term biosafety 'shifts with diplomatic and scientific context, its two major usages relating to laboratory containment and to biotechnology hazards' and that biosecurity 'is a closely related term increasingly heard in arms control and in health and agriculture; but which also lacks a consistent usage'. The Project also stated that: 'On a very practical level, there may be differences between means to prevent an unintended release into the environment (sometimes referred to as 'biosafety') and means to prevent abuse or theft (sometimes referred to as 'biosecurity')'. Use of the term biosecurity in this context, once again, has a meaning differing from those proposed by other authors.

Although not a standardized definition, for purposes of the discussion in this chapter, the term biosecurity is defined to mean: a series of management practices designed to minimize or prevent the exposure to, and introduction of, sub-populations of livestock to human and animal diseases infectious agents. Such management practices (as previously described) may include, but may not necessarily be limited to, testing and screening protocols for surveillance and process verification, isolation and quarantine, immunization, waste management, selective purchasing and monitoring.

The term biosecurity conveys the same meaning as the terms agrosecurity, agrodefence and biodefence. However, in this context, biosecurity does not convey that intentional dispersion of human or animal infectious agents is prevented by farmers – as it may be applied by research laboratories, and the terms bioterrorism or agroterrorism are used to reflect intentional diversion of human or animal infectious agents.

The term biosafety is defined to reflect a differing risk: the prevention of accidental release (loss of control) of human and animal disease infectious agents into the environment, or the prevention of exposure of another sub-population of livestock to an infectious agent. In this context, the term biosafety implies that there should be accountability for accidental dissemination of infectious agents. The term biocontainment, then, conveys a meaning similar to that of biosafety: a series of management strategies to prevent the spread of human or animal infectious agents within or among sub-populations of livestock (i.e. control of a detected infectious outbreak).

Therefore, in livestock production, a biosecurity plan may incorporate biosecurity (as here defined), biosafety and biocontainment components. Clearly, the most thorough of plans would address all three facets to manage the transmission of infectious agents.

Traceability of Livestock

An important component of biosecurity is the ability to track the movement of animals. In many countries, the trace-back and identification of animals has been in place for many years. Countries such as Denmark and Australia, in which meat export is vital to the economy, were some of the first countries to mandate traceability. In the USA, the Animal Disease Traceability (ADT) regulations took effect in March 2013 and require the identification of livestock shipped across state lines (USDA/APHIS, 2012, 2016). After the bovine spongiform encephalopathy (BSE) outbreaks in Europe, and the cases of BSE in Canada, government authorities put in place better programmes for tracking the movements of livestock. These programmes are continually evolving and use a range of identification methods, from simple tags to other more sophisticated computerized systems that use electronic tags.

In addition to government programmes, private industry has programmes for verification of the origin of meat and poultry. Some large meat-buying customers demand source verification, and innovative niche marketers of meat products are forming alliances with producers in which source verification is one of the requirements.

Animal Health

The World Organisation for Animal Health (OIE) and the governments of individual countries and states/provinces within a country maintain lists of animal diseases whose occurrence must be reported to veterinary and human health agencies. The listed diseases are those that would have the greatest economic impact on livestock and poultry producers if an outbreak were to occur. Some of them are

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zoonotic and can be transmitted from animals to humans while others cannot be transmitted to humans but would be economically devastating to animal sub-populations. In the USA, a list of Select Agents and Toxins that are regulated by USDA/APHIS and the USDHHS under the Final Select Agent Rules given by the Select Agents Regulations 7 CFR Part 331 and 9 CFR Part 121 (USDA/APHIS, 2013a,b) and 42 CFR Part 73 (USDHHS, 2013), or a combination of these two sets of rules, is available from the National Select Agent Registry (2013). The list (excepting exclusions), includes viruses, bacteria, fungi, toxins, genetic elements, recombinant nucleic acids and recombinant organisms (National Select Agent Registry, 2019) and is provided in Box 23.1.

Over the years, efforts to control animal health threats have prevented the introduction of, or have resulted in the eradication of, many animal diseases in the USA and other countries. For example, under Select Agent Regulation 9 CFR 71.3, USDA/APHIS lists foot-and-mouth disease, rinderpest, African swine fever, hog cholera, Teschen disease, contagious bovine pleuropneumonia, European fowl pest, dourine, contagious equine metritis, vesicular exanthema, screwworms, glanders, and scabies in sheep as diseases that 'are not known to exist in the United States' (USDA/APHIS, 2000).

Conversely, USDA/APHIS (again in 9 CFR 71.3), lists equine piroplasmosis, bovine piroplasmosis or splenetic fever, scabies in cattle, pseudorabies, acute swine erysipelas, tuberculosis, Johne's disease, brucellosis, scrapie, bluetongue, anthrax, chlamydiosis, poultry disease caused by Salmonella enteritidis serotype Enteritidis and Newcastle disease as 'communicable' animal diseases 'endemic in the United States'. Box 23.2 provides a list of animal diseases that, in an effort to standardize global animal health biosecurity, biosafety and biocontainment measures, are reportable when detected by member nations to the OIE (2019). Many of the diseases listed – that would be of concern to livestock producers – also are zoonotic.

Animal health outbreaks of concern in the USA have included highly pathogenic avian influenza (Texas, Washington, Alabama) and exotic Newcastle disease (most recently in California). Due to the potential for mutation and transmission among humans – which could lead to a pandemic – officials globally monitor the prevalence and movement of the H5N1 avian influenza A virus and Newcastle disease.

Environmental Considerations Surrounding Transportation

Transportation of animals, animal associated product and deceased animals all contribute to a robust biosecurity plan. One of the best methods for increased biosecurity is physical isolation of an operation, such as being set away from the road and far away from other farms (Lakshman, 2017). The importance of physical location in relation to major roadways was highlighted by Seedorf and Schmidt (2017) who demonstrated that livestock trucks can disseminate bioaerosol in the vicinity of the vehicle while in motion. When it comes to separation from other animal facilities nearby, Wang *et al*. (2015) found that poultry production clusters in Asia share labourers between operations and increase the risk of disease spreading (Wang *et al*., 2015). In addition to physical separation from other commercial facilities, proximity to non-commercial animals should be considered. Derksen *et al*. (2018) found that backyard poultry growers 'lack simple biosecurity measures' and harbour some disease of concern to commercial producers (such as avian influenza and Newcastle disease). Backyard poultry flocks have already demonstrated their danger to commercial flocks, such as the 2018 California Newcastle Disease outbreak that originated from a backyard flock (Williams, 2019).

Though physical separation from other flocks or herds is ideal, this is often difficult to control, and sometimes more control can be exerted over personnel and vehicles. While visitors' downtime and sanitation has already been discussed, how other commodities are produced and shipped is also an important consideration. For example, the feed mills that feed is purchased from are a potential source of pathogens and should have their own biosecurity plan to reduce the risk of contamination in the target animal feed populations (Huss *et al*., 2018).

Management of farm outputs is equally important. Poor ventilation and waste management both allow for recontamination of the environment if not properly managed (Leibler *et al*., 2016). In the event of an outbreak resulting in large numbers of livestock sacrifices (such as foot-and-mouth), it is imperative to the future health of the herd that the disposal of animals is handled properly. Pratt and Fonstad (2017) conducted a study on the effects of mass livestock burial on the environment and found that if certain factors (such as clay content,

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Box 23.1. Select agents and toxins list from the US Department of Agriculture Animal and Plant Health Inspection Service (USDA/APHIS) and the US Centers for Disease Control and Prevention (CDC), as of 21 January 2019 (National Select Agent Registry, 2019) for species of interest.

The biological agents and toxins listed below have been determined to have the potential to pose a severe threat to both human and animal health, to plant health, or to animal and plant products under the Select Agents Regulations 7 CFR Part 331 and 9 CFR Part 121 (USDA/APHIS, 2013a,b) and 42 CFR Part 73 (USDHHS, 2013). Agents with an asterisk (*) are Tier 1 agents; these have a risk of causing a high consequence event higher than that for other listed agents.

An attenuated strain of a select agent or toxin that does not pose a severe threat to public health and safety, animal health or animal products may be excluded from the requirements of the above Select Agent Regulations under an established procedure. The list of these excluded agents and toxins can be found at: https://www.selectagents.gov/SelectAgentsandToxinsExclusions.html.

HHS SELECT AGENTS AND TOXINS

1. Abrin
2. *Bacillus cereus* Biovar *anthracis**
3. Botulinum neurotoxins*
4. Botulinum neurotoxin producing species of *Clostridium**
5. Conotoxins (Short, paralytic alpha conotoxins containing the following amino acid sequence $X_1CCX_2PACGX_3X_4X_5X_6CX_7$)
6. *Coxiella burnetii*
7. Crimean-Congo haemorrhagic fever virus
8. Diacetoxyscirpenol
9. Eastern Equine Encephalitis virus
10. Ebola virus*
11. *Francisella tularensis**
12. Lassa fever virus
13. Lujo virus
14. Marburg virus*
15. Monkeypox virus
16. Reconstructed replication competent forms of the 1918 pandemic influenza virus containing any portion of the coding regions of all eight gene segments (Reconstructed 1918 Influenza virus)
17. Ricin
18. *Rickettsia prowazekii*
19. SARS-associated coronavirus (SARS-CoV)
20. Saxitoxin

South American Haemorrhagic Fever viruses:

21. Chapare
22. Guanarito
23. Junin
24. Machupo
25. Sabia
26. Staphylococcal enterotoxins A,B,C,D,E subtypes
27. T-2 toxin
28. Tetrodotoxin

Tick-borne encephalitis complex (flavi) viruses:

29. Far Eastern subtype
30. Siberian subtype
31. Kyasanur Forest disease virus
32. Omsk hemorrhagic fever virus
33. Variola major virus (Smallpox virus)*
34. Variola minor virus (Alastrim)*
35. *Yersinia pestis**

OVERLAP SELECT AGENTS AND TOXINS

36. *Bacillus anthracis**
37. *Bacillus anthracis* Pasteur strain
38. *Brucella abortus*
39. *Brucella melitensis*
40. *Brucella suis*
41. *Burkholderia mallei**
42. *Burkholderia pseudomallei**
43. Hendra virus
44. Nipah virus
45. Rift Valley fever virus
46. Venezuelan equine encephalitis virus

USDA SELECT AGENTS AND TOXINS

47. African horse sickness virus
48. African swine fever virus
49. Avian influenza virus
50. Classical swine fever virus
51. Foot-and-mouth disease virus*
52. Goat pox virus
53. Lumpy skin disease virus
54. *Mycoplasma capricolum*
55. *Mycoplasma mycoides*
56. Newcastle disease virus
57. Peste des petits ruminants virus
58. Rinderpest virus*
59. Sheep pox virus
60. Swine vesicular disease virus

USDA PLANT PROTECTION AND QUARANTINE (PPQ) SELECT AGENTS AND TOXINS

61. *Coniothyrium glycines* (formerly *Phoma glycinicola* and *Pyrenochaeta glycines*)
62. *Peronosclerospora philippinensis(Peronosclerospora sacchari)*
63. *Ralstonia solanacearum*
64. *Rathayibacter toxicus*
65. *Sclerophthora rayssiae*
66. *Synchytrium endobioticum*
67. *Xanthomonas oryzae*

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Box 23.2. Farm animal diseases, infections and infestations for which, when detected, the World Organisation for Animal Health (OIE) must be notified (OIE, 2019).

Multiple species diseases, infections and infestations

Anthrax
Crimean Congo haemorrhagic fever
Equine encephalomyelitis (Eastern)
Heartwater
Infection with Aujeszky's disease virus
Infection with bluetongue virus
Infection with *Brucella abortus, Brucella melitensis* and *Brucella suis*
Infection with *Echinococcus granulosus*
Infection with *Echinococcus multilocularis*
Infection with epizootic haemorrhagic disease
Infection with foot and mouth disease virus
Infection with *Mycobacterium tuberculosis* complex
Infection with rabies virus
Infection with Rift Valley fever virus
Infection with rinderpest virus
Infection with *Trichinella* spp.
Japanese encephalitis
New world screwworm (*Cochliomyia hominivorax*)
Old world screwworm (*Chrysomya bezziana*)
Paratuberculosis
Q fever
Surra (*Trypanosoma evansi*)
Tularemia
West Nile fever

Cattle diseases and infections

Bovine anaplasmosis
Bovine babesiosis
Bovine genital campylobacteriosis
Bovine spongiform encephalopathy
Bovine viral diarrhoea
Enzootic bovine leukosis
Haemorrhagic septicaemia
Infectious bovine rhinotracheitis/infectious pustular vulvovaginitis
Infection with lumpy skin disease virus
Infection with *Mycoplasma mycoides* subsp. *mycoides* SC (contagious bovine pleuropneumonia)
Theileriosis
Trichomonosis
Trypanosomosis (tsetse-transmitted)

Sheep and goat diseases

Caprine arthritis/encephalitis
Contagious agalactia
Contagious caprine pleuropneumonia
Infection with *Chlamydophila abortus* (Enzootic abortion of ewes, ovine chlamydiosis)
Infection with peste des petits ruminants virus
Maedi-visna
Nairobi sheep disease
Ovine epididymitis (*Brucella ovis*)
Salmonellosis (*S. abortusovis*)
Scrapie
Sheep pox and goat pox

Equine diseases

Contagious equine metritis
Dourine
Equine encephalomyelitis (Western)
Equine infectious anaemia
Equine influenza
Equine piroplasmosis
Infection with African horse sickness virus
Infection with equid herpesvirus-1 (EHV-1)
Infection with equine arteritis virus
Infection with *Burkholderia mallei* (Glanders)
Venezuelan equine encephalomyelitis

Swine diseases

Infection with African swine fever virus
Infection with classical swine fever virus
Infection with porcine reproductive and respiratory syndrome virus
Infection *with Taenia solium* (Porcine cysticercosis)
Nipah virus encephalitis
Transmissible gastroenteritis

Avian diseases

Avian chlamydiosis
Avian infectious bronchitis
Avian infectious laryngotracheitis
Avian mycoplasmosis (*Mycoplasma gallisepticum*)
Avian mycoplasmosis (*Mycoplasma synoviae*)
Duck virus hepatitis
Fowl typhoid
Infection with avian influenza viruses
Infection with influenza A viruses of high pathogenicity in birds other than poultry including wild birds
Infection with Newcastle disease virus
Infectious bursal disease (Gumboro disease)
Pullorum disease
Turkey rhinotracheitis

Other diseases

Camelpox
Leishmaniosis

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soil permeability and groundwater gradients) are acceptable, the burial of animals poses no risk to the surrounding environment; though if these requirements are not met there could be long-lasting consequences that could affect livestock production on or near the site in the future.

Biosecurity for the Beef and Dairy Industries

Biosecurity, biosafety, and biocontainment on the farm and during livestock transportation are crucial as the opportunities for disease transmission continue to escalate (i.e. via global travel, industry concentration and/or bioterrorism). Several templates exist to assist livestock producers as they implement protocols for managing biosecurity, biosafety and biocontainment, and most of these are available via the internet.

For example, scientists at Oklahoma State University (Kirkpatrick and Selk, 2006) published an outline of requirements for achieving biosecurity in beef cattle operations online. The authors stipulated that, 'producers must make a decision on the level of risk they are willing to accept' and indicated that the level of biosecurity measures implemented on an individual operation may also depend on the scope, production target and potential 'economic consequences' of animal disease. Kirkpatrick and Selk (2006) recommended that each producer classify their individual operation's needs based on a six-point scale, where 1 reflected a closed, specific pathogen-free herd, while 6 reflected a farm/ranch that allowed the entry of new animals with no medical records and no isolation. They listed 'Components of a Biosecurity Program' and provided examples for such programmes.

To achieve true biosecurity on the farm, one of the most ideal recommended systems has been published by the Bovine Alliance on Management and Nutrition (BAMN) for use in dairies, and their guide is accessible via the USDA/APHIS website (see BAMN, 2001). The BAMN guide outlines four procedural steps that producers should take to develop an appropriate on-farm biosecurity programme, which include: (i) identify products and their value; (ii) identify and prioritize risk; (iii) evaluate how diseases are introduced to the dairy; and (iv) implement a plan for disease control. Likewise, BAMN has also published guidelines for producers to follow when they are considering biosecurity related to feedstuffs.

In contrast to the readily available biosecurity measures that might be taken on the farm to prevent the introduction of infectious agents into livestock populations, very little information exists to assist producers with biosafety and biocontainment. Indeed, the management of the production of feed, along with controls for water and the environment, may be considered to be biosafety measures (prevention of the accidental dissemination of infectious agents), but such logic is less straightforward.

In fact, true biosafety and biocontainment measures on the farm would minimize the likelihood that serious infectious agents could be disseminated to another sub-population, and producers are less likely to implement programmes addressing such objectives if legal liability, or economic disincentives, exist to do so. Clearly, if sound biosafety measures had existed in the UK during the foot-and-mouth disease outbreak in 2001, in conjunction with sound biosecurity procedures on farms, the outbreak would not have escalated and affected the numbers of animals that it did because disease transmission would have been controlled.

Likewise, in the case of major animal disease outbreaks, it is likely that government agencies would impose biocontainment (e.g. quarantining or sacrificing, in certain cases, large numbers of livestock) measures on individual producers if those producers had not detected the outbreak or had not taken internal measures to prevent disease dissemination. One of the most important measures to be implemented in such a case is to immediately shut down livestock markets, as this prevents diseased livestock from being transported over a wide area. In the USA, it is clear that, if bioterrorism were to be detected, multiple agencies would be involved with containment of a resulting outbreak once it was detected.

Interestingly, particularly in light of the economic consequences of an animal disease outbreak, available data suggest that biosecurity, biosafety and biocontainment procedures are not well implemented by US livestock producers. For example, APHIS administers the National Animal Health Monitoring System (NAHMS), and during completion of the Dairy NAHMS 2002, collected information concerning biosecurity on US dairies (USDA/APHIS, 2004). Although a high percentage of producers (> 92%) had implemented insect and rodent control procedures on farms, only slightly more than half of the producers had maintained closed

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herds or controlled access to cattle feed by other livestock and wild game, and less than 15% of all producers had mandated visitor sanitation requirements or did not allow visitors on the farm. Also of note, only 20% of producers had implemented procedures to control birds. In fact, only 5.1% of dairies had developed 'written procedures specifically related to preventing the introduction and spread of disease' and over 75% of operations had performed no testing whatsoever to monitor animal disease prevalence or to verify adequate protection.

Biosecurity for Pigs and Poultry at Large Integrated Companies

In contrast to the beef and dairy industries, fully integrated pork and poultry companies have detailed programmes for the prevention of the introduction of disease into their herds or flocks (Seaman and Fangman, 2001; Nelson and Tablante, 2004; BC Poultry Association Biosecurity Committee and Cox, 2006; Pescatore, 2006).

Rigorous testing or isolation of incoming breeding animals is mandatory. Rodents are controlled, and netting is used to keep wild birds out of the pig and poultry houses. Vehicles and people moving between different farms follow procedures to prevent disease transmission; such as vehicles washed and tyres disinfected while employees must wear clean clothes and visitors wear company-provided boots and coveralls. Truck drivers loading out market pigs are not allowed to enter the building where the pigs are raised; the pigs are brought out of the building by farm personnel.

Some companies require that all employees and visitors shower at the facility and wear company clothes that are laundered at the site. Tools and other supplies coming into the farm have to be sprayed with disinfectant. The large integrated companies often have stricter biosecurity than some independent producers. For example, a survey in Denmark indicated that 10% of producers allowed truck drivers to enter the production area (Boklund *et al*., 2003); this is a poor practice.

Animal health has always had an impact on the financial viability of livestock production operations. But today, efforts to expand export opportunities and public safety concerns are vastly different than at any time in history. Animal health issues, particularly zoonotic diseases, now have correspondingly greater impact on the economics of production. For these reasons, livestock producers must 'bite the bullet' and take seriously the need for implementation of biosecurity, biosafety and biocontainment principles on the farm/ranch.

While US swine operations are primarily vertically integrated, it is important to point out that not all countries have the same pork production structure; for example, in Scotland, more than two thirds of pork producers keep less than ten pigs (Correia-Gomes *et al*., 2017). While a survey conducted by Correia-Gomes and co-authors (2017) reported that the level of disease was low in their herds, they also point out that the majority of small-scale swine operations are on mixed-species farms, which increases the risk for cross-species disease spread. Equally as important, small-scale poultry operations come with their own challenges. In Europe, the sanitary slaughter of small-scale poultry operations has led to investigation into the usefulness of mobile slaughter units, which would allow for an increased mitigation of disease when compared to traditional on-farm slaughters (Mancinelli *et al*., 2018).

Public Health

Human infection resulting from a food-borne pathogen is a public, high-impact event that elicits outrage in modern society and, hence, results in immediate and widespread effects on product demand and trade. Livestock are a major reservoir for pathogens. To address modern food-safety concerns, research funding has, historically, targeted the development of packing plant decontamination technologies (Hardin *et al*., 1995; Reagan *et al*., 1996; Dorsa, 1997). Efforts to develop pre-harvest biosafety controls for food-borne pathogens have received less funding emphasis, though scientists are slowly developing such controls. The proceedings of a National Cattlemen's Beef Association (NCBA)-sponsored *Escherichia coli* (*E. coli* O157:H7) summit in the USA in 2003 suggested that producers should strive to 'evaluate adoption of interventions or Good Management Practices (GMPs) that have been scientifically validated … [and] that use a combination of interventions' (NCBA, 2003).

Efforts to control the dissemination of *E. coli* O157:H7 in the beef supply chain also reflect the implementation of biosecurity, biosafety and biocontainment programmes targeting that organism and provide a useful case study for assessing the effectiveness of pre-harvest efforts to control food-borne

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pathogens. The research literature suggests that the initial infection or exposure of cattle to *E. coli* O157:H7 occurs early in life and from a variety of sources; it is then abundant in the bovine production environment from that point forward and may be widespread on cow–calf ranches as well as in feedlots and dairies. Thus, most management practices that would theoretically be implemented on a livestock production operation to control food-borne pathogens would be considered to be biosafety and biocontainment procedures.

Childs *et al.* (2006) conducted a molecular study to characterize how *E. coli* O157:H7 is transmitted from livestock production channels through the system to contaminate meat products. Pulsed-field gel electrophoresis and multiplex-DNA marker gels yielded fingerprint patterns for bovine hide *E. coli* O157:H7 isolates obtained at packing plants. This allowed the determination of genetic homology among samples collected from hides/colons and environmental samples. Isolates recovered from the hides of cattle at harvest were genetically related to isolates recovered from feedlot pen floors, cattle shipping trailers, packing plant pen water troughs and the hides/colons of other animals. Although much of the pathogenic contamination on cattle at packing plants was not sourced to the preceding production facilities, researchers found that feedlot, transportation trailer and the packing plant holding pen environment, as well as cross-contamination events, contributed to the contamination found on harvest-ready cattle hides. In the livestock production environment, pathogens deposited at various production sites from previously housed cattle were allowed to persist, and a constant potential for contamination with food-borne human disease pathogens was thereby sustained (Childs *et al.*, 2006; Small and Buncic, 2009). Regardless of contamination location, there have also been improvements in the time it takes to confirm pathogen presence and classification. Across all pathogen of concern, decreasing the time it takes from presumptive to confirmed positive (using technologies such as biosensors) is of both an economical and animal welfare benefit (Vidic *et al.*, 2017). There have also been major developments in pathogen classification and description. Whole genome sequencing (WGS) allows a higher level of pathogen subtyping regardless of species that allows a more precise epidemiological and treatment response (Weinroth *et al.*, 2018).

Pathogen-shedding in Beef Cattle and Its Control

Transportation and consolidation of livestock as they progress through production and marketing channels may further contribute to dissemination of food-borne pathogens. For example, beef calves that had been vaccinated and pre-weaned 13–29 days before transport shed less *Salmonella* than calves that had had no vaccinations and had been weaned only one day before transport (Bach *et al.*, 2004).

In another study of 200 fed cattle in a commercial feedlot, Barham *et al.* (2002) provided data showing that the prevalence of *E. coli* O157:H7 had declined between the feedlot and the packing plant, though the reverse was true for *Salmonella* spp. Transport trailer prevalence of *E. coli* O157:H7 and *Salmonella* spp. was 5.4% and 59%, respectively. The authors concluded that transportation may result in cattle stress that influences shedding of some food-borne human pathogens (e.g. *Salmonella* spp.). However, based on their results, the prevalence of other pathogens may not be influenced by transportation stress. Dewell *et al.* (2008) found that cattle that became behaviourally agitated at the feedlot during loading had twice the risk of being positive for *Salmonella* as those that did not Another factor was time off feed; feedlot cattle taken off feed for more than 18 hours had twice the risk of testing positive for *Salmonella* (Dewell *et al.*, 2008).

Similarly, Beach *et al.* (2002) showed an increase in hide prevalence of *Salmonella* spp. following transport to a packing plant, while the prevalence of *Campylobacter* on feed cattle hides decreased following transport. Those authors concluded that, for feedlot cattle, transportation did not affect the shedding of *Salmonella* or *Campylobacter*, but did affect contamination on cattle hides at the time of harvest (Beach *et al.*, 2002). Other factors that may affect shedding of *E. coli* O157:H7 are: (i) the condition of feedlot pens – cattle from muddy pens shed more *E. coli* than cattle from dry pens (Smith *et al.*, 2001a,b); and (ii) vehicles, which may also be a source of contamination. For *E. coli* O157:H7, the feedlot pen that the cattle originated from may be a larger source of contamination than transportation factors (Stanford *et al.*, 2011). Wray *et al.* (1991) found that the washing and cleaning of vehicles reduced *Salmonella* contamination from 22.6% of vehicles to 6.5%. Reicks *et al.* (2007) found that before loading at the feedlot for transport to the

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slaughter facility, clean trucks had a lower percentage of *Salmonella*-positive samples than did dirty trucks, but that after transport, clean and dirty trucks had a similar prevalence of *Salmonella*. Furthermore, feedlot cattle transported in clean and dirty trucks had a similar prevalence of *Salmonella* on their hides after arrival at a slaughter plant.

Washing live feedlot cattle in an attempt to remove pathogens is highly stressful during cold weather and may increase the percentage of dark cutters while not removing much of the mud because the mud is stuck on like cement, and washing will not remove it. In contrast, the washing of clean grass-fed cattle is effective for reducing contamination, though to reduce stress and improve animal welfare, the handlers must avoid spraying high-pressure water into the animal's face. Also, during freezing weather, the washing of live cattle should be confined to their legs, and irritating disinfectants should not be used. Some packing plants effectively remove a portion of the hide pathogens by washing stunned and bled feedlot cattle. They have developed high-pressure wash cabinets and other equipment for the removal of mud. However, the best approach to the mud problem is better management of feedlot pens to reduce mud. In new feedlot construction, for instance, the pens should be 2–4% sloped.

Based on these and other studies, biosafety and biocontainment procedures during livestock production should most likely consider, and be extended through, transport of animals to their next destination. In addition to live animal pathogen control prior to shipping, proper cleaning of animal transportation vehicles has also been seen to reduce viable bacteria on trucks. Contamination at the lairage is also a concern. In the UK, 50% of swabs from lairage pens tested positive for either *E. coli*, *Salmonella* or *Campylobacter* (Small *et al*., 2002, 2003).

Although epidemiological studies have not shown that the management of environmental food-borne pathogen contamination will result in reduced pathogen prevalence on the exterior of animals and on carcasses at the time of harvest (Rasmussen and Casey, 2001), such management is necessary before the use of microbiological intervention systems during livestock production can be completely effective. Therefore, the effectiveness of management and intervention practices in controlling environmental human pathogens found in livestock production environments must be evaluated as a system. Hussein *et al*. (2001) stated that, 'Because of the complexity of the problem, the on-farm and off-farm factors affecting beef safety should be elucidated, their roles clearly defined and their additive impacts determined'.

Woerner *et al*. (2006b) provided data indicating that 7.1% of pre-evisceration carcasses tested positive for *E. coli* O157 if faecal prevalence on the feedlot pen floor was less than 20%, while pre-evisceration prevalence increased to 12.5% if the faecal prevalence was greater than 20%. Research results illustrate that if biosafety and biocontainment procedures are to be implemented by livestock producers to control human food-borne pathogens, such measures must be specifically designed to reduce pathogen loads on the exterior surfaces of animals before they enter packing plants for harvest.

Other interventions to reduce pathogens in beef

A novel approach for reducing beef pathogen prevalence was proposed by Brett Finlay at the University of British Columbia (Finlay, 2003) and Andrew Potter at the University of Saskatchewan. These researchers developed a vaccine that may prevent the attachment of *E. coli* O157:H7 in the large intestine of cattle. Potter *et al*. (2004) showed that when cattle were vaccinated with type III proteins secreted by *E. coli* O157:H7 (such as Tir and EspA), pathogen numbers and the number of cattle shedding *E. coli* O157:H7 were both reduced.

To date, the most effective technology for reducing the prevalence of *E. coli* O157:H7 in fed cattle has been that utilizing feed and/or water as the vehicle of decontamination. Anderson *et al*. (2000) and Callaway *et al*. (2002) proposed that sodium chlorate could be used to reduce pathogen loads in livestock and, during research trials, sodium chlorate eliminated organisms reliant on nitrate reductase metabolism from the gastrointestinal tract of animals. At present, federal US approval status for the use of sodium chlorate as a feed or water ingredient for food-borne pathogen control is unclear; notwithstanding, this compound may offer potential in future human food-borne pathogen biosafety and biocontainment systems.

Direct-fed microbial (DFM) products are already approved for use in reducing pathogen prevalence in livestock. Brashears *et al*. (2003a) demonstrated a methodology for isolating competitive exclusion products (*Lactobacillus acidophilus* NPC-747) to

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be fed to cattle to inhibit the growth and proliferation of *E. coli* O157:H7. Brashears *et al.* (2003b) also published findings of studies reporting on the effectiveness of such DFM feed additives. Younts-Dahl *et al.* (2004) reported that the provision of a diet containing *Lactobacillus acidophilus* NP-51 plus *Propionibacterium freudenreichii* to feedlot cattle was effective in reducing the prevalence of *E. coli* O157 on the hides of harvested cattle from 50.0% in control cattle to 25.0% in treated cattle. Since 1971, neomycin sulfate has been approved in the USA for use in the treatment of cattle, horses, sheep, swine, goats, cats, turkeys, chickens, ducks and mink for bacterial enteritis. However, research results now exist suggesting that this chemical may also be effective in reducing the prevalence of *E. coli* O157:H7 in the faeces of treated calves.

Woerner *et al.* (2006a) reported results from a study that included the following feedlot cattle treatments: (i) feeding neomycin sulfate; (ii) feeding *Lactobacillus acidophilus* NPC-747; (iii) vaccination with an *E. coli* 157:H7 bacterin vaccine (produced by Fort Dodge Animal Health, Kansas City, USA); and (iv) all possible combinations of these treatments. Pathogen prevalence was highest on the hides and in faeces of cattle receiving no treatment (the controls), and the prevalence of *E. coli* O157 was lower both on and in treated cattle. Neomycin appeared to be the most effective single intervention, reducing the prevalence of *E. coli* O157 in faeces and on hides by 45.8% and 31.8%, respectively, compared with the control values. When used singly, the feeding of *Lactobacillus acidophilus* NPC-747 and vaccination were similar to each other in effectiveness, reducing pathogen prevalence (from control levels), respectively, by 17.6% and 20.3% on hide samples, and by 32.5% and 31.1% in faeces (Woerner *et al.*, 2006a).

The NCBA has published a series of 'Production Best Practices' for differing sectors of the beef industry as a primary result of the 2003 *E. coli* summit (NCBA, 2003). One of this set of best practices was developed for the pre-harvest control of *E. coli*. The concept of implementing such practices to achieve biosafety and biocontainment for *E. coli* O157:H7 contamination of live cattle would essentially incorporate a combination of intervention strategies in conjunction with controlled management practices (Gansheroff and O'Brien, 2000). A production facility that follows production best practices should use microbiological testing to establish an *E. coli* O157:H7 prevalence history in animals and in the environment, and then use the resulting data comparatively to verify the effectiveness of biosafety and biocontainment management programmes.

Shedding of pathogens in pigs and its control

Research has clearly shown that pigs resting in the lairage at the meat plant become internally contaminated with *Salmonella*. Necropsy data have shown that on the farm, only 5.3% of the pigs were contaminated, but that *Salmonella* contamination was found in 39.9% of the pigs in the lairage (Hurd *et al.*, 2001). In a later study by Hurd and colleagues (Rostagno *et al.*, 2003), swab tests of pork plant lairages at two high-capacity abattoirs indicated that they were heavily contaminated with *Salmonella*. Overall, there were 36 different *Salmonella* serovars isolated from pigs, trailers and pens, and the ileocaecal lymph nodes became contaminated after a 2.5-hour rest period.

Better cleaning of lairage pens will reduce *Salmonella* contamination but not eliminate it. In one study, cleaning reduced *Salmonella* contamination in the pens from 25% of the samples to 10% (Swanenburg *et al.*, 2001). In another attempt to reduce *Salmonella* contamination of pigs, Hurd *et al.* (2005) reduced the time that animals rested in the lairage from four hours to 15–45 minutes; holding the pigs for a shorter period significantly reduced shedding of *Salmonella* but the short resting period had a very detrimental effect on meat quality. Conversely, other studies have shown that resting pigs for one to three hours in the lairage will reduce PSE (pale, soft, exudative) pork and improve meat quality (Milligan *et al.*, 1998; Pérez *et al.*, 2002; Warriss, 2003). To resolve this conflict between pork quality and contamination, a multifaceted approach will be required. Below are some suggestions.

1. Better cleaning of lairage pens. A small study by Schmidt *et al.* (2004) found that cleaning the lairage pens had mixed results in reducing contamination of the pigs, but was very effective in cleaning the pen floors. A further study (O'Connor *et al.*, 2006) showed that contamination in different parts of the lairage was highly variable. This may be a factor in explaining the mixed results from lairage cleaning. However, cattle placed in lairage pens that were positive for *E. coli* were eight times more likely to test positive on their hides (Grand Dewell, 2007, personal communication).

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2. Shedding of *Salmonella* by pigs can be reduced by eliminating overnight holding of the animals in the lairage and maintaining a three-hour maximum rest time.

3. Pigs from *Salmonella*-free and *Salmonella*-positive farms should be kept in separate parts of the lairage, and the clean pigs should be processed first. This separation of *Salmonella*-free and *Salmonella*-positive pigs will help to reduce contamination (Swanenburg *et al*., 2001; Nowak *et al*., 2007).

4. The washing and sanitizing of trucks will greatly reduce contamination. Rajkowski *et al*. (1998) found that cleaning and sanitizing pig trucks reduced contamination of the floor samples by *Salmonella* from 41.5 to 2.7%. To prevent meat plant pathogens from causing disease back on the farm, many companies have a rigorous programme of trailer sanitation. After washing and disinfection, the truck and trailer must be completely dry before it is next loaded. Complete dryness is essential to eliminate the transmission of PRRSV (Dee *et al*., 2004a,b). Jeff Hill (2006, personal communication) states that Premium Standard Farms dries trailers in a heated room with fans to ensure complete dryness. Heating the interior of the trailer to 71°C for 30 minutes is effective against PRRSV (Dee *et al*., 2005).

Note

[1] The Sunshine Project, which is no longer active, was an international non-governmental organization (NGO) that was dedicated to upholding prohibitions against biological warfare and preventing the abuse of biotechnology by the military. It maintains an archive website in Germany, from which the definitions of biosafety and biosecurity quoted in the text are taken.

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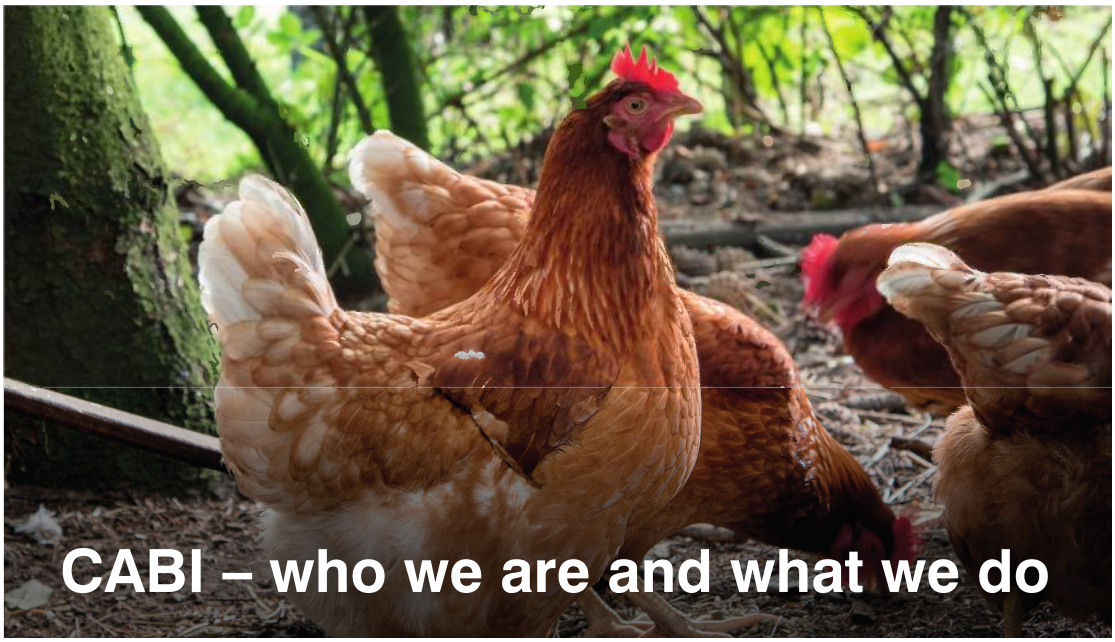
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