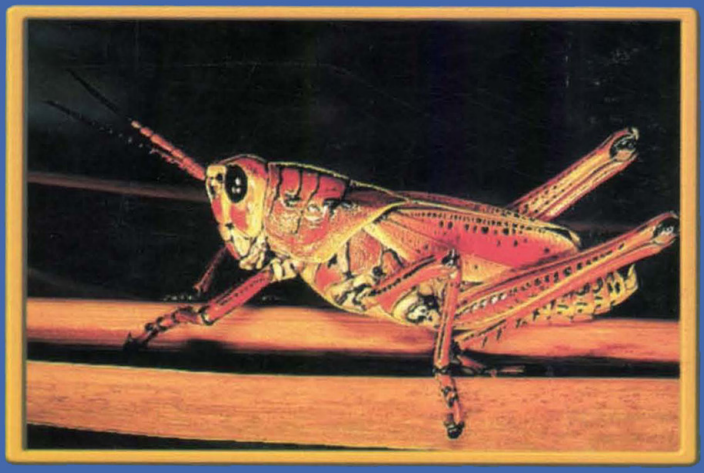
ECONOMIC ZOOLOGY
BIOSTATISTICS
AND
ANIMAL BEHAVIOUR



SHUKLA . MATHUR
UPADHYAY . PRASAD

ECONOMIC ZOOLOGY
BIOSTATISTICS
AND
ANIMAL BEHAVIOUR

Economic Zoology
Biostatistics
and
Animal Behaviour

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Contents

ECONOMIC ZOOLOGY

Chapter		*Pages*
1.	Economically Important Phytoparasitic Nematodes	1–12
2.	Insect Pests of Some Economically Important Crops	13–62
3.	Some Important Parasites and Pests	63–82
4.	House Hold Insects	83–115
5.	Mites and Ticks	116–126
6.	Apiculture	127–141
7.	Lac Culture	142–153
8.	Sericulture	154–177
9.	Edible Fresh Water Fishes	178–194
10.	Fish Culture	195–216
11.	Economic Importance of Fish	217–223
12.	Fish Diseases	224–232
13.	Poultry	233–255
14.	Dairy Farming	256–268
15.	Rat Menace and Its Control	269–283

BIOSTATISTICS

Chapter		Pages
1.	An Introduction to Biostatistics	1–8
2.	Graphic Representation of Frequency Distribution	9–17
3.	Measures of Central Tendency	18–34
4.	Measures of Validity	35–43
5.	Normal Distribution	44–52
	Log/Antilog Tables	53–56

ANIMAL BEHAVIOUR

Chapter		Pages
1.	Introduction and Significance of Study of Animal Behaviour	1–18
2.	Concepts and Patterns	19–66
3.	Approach and Methods	67–93
4.	Communication	94–136
5.	Reproductive Behaviour in Animals : Courtship and Mating	137–173
6.	Aggressive and Territorial Behaviour	174–203
7.	Parental Behaviour	204–231
8.	Behavioural Genetics	232–244

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ECONOMIC ZOOLOGY

1

Economically Important Phytoparasitic Nematodes

The nematodes have been recorded from Egyptian history as far back as 1553 to 1550 BC. The nematode parasiting man and other animals, attracted the attention of various workers like Muller (1776) and Dujardin (1845) but the phytoparasitic nematodes remained unnoticed due to their microscopic size till the beginning of 20th century. The presence of plant nematodes had been noticed by Needham (1743) in the wheat galls. Roffredi (1775) declared that nematodes are responsible for a number of plant diseases. Bastian (1865) 'Father of Nematology', had made noteworthy contributions and established 'Nematology' as a separate branch.

Phytoparasitic nematodes are elongated worms generally 0.3 mm to 5.0 mm in length. The anterior end is provided with oral aperture which is surrounded by lips and posteriorly it tapers to a terminus which may be pointed or hemispherical. In male the anus serves as reproductive aperture. The female reproductive aperture is distinct which is ventral in the position. Both sexes are normally vermiform, however, sometimes females are slightly broadened towards the posterior end.

Phytoparasitic nematodes are obligate parasites and feed only on the living plants. These nematodes, when move through the tissues of the plants are known as migratory endoparasite. The female which is attached to the root permanently is known as sedentary endoparasite. The nematodes feeding on the plants from outside are termed as ectoparasites.

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Life History

The development of phytoparasitic nematodes is of very simple type. The eggs are somewhat oval in shape. They undergo a series of divisions, form first stage larvae, moult within the eggs and the second stage larvae emerge out from the eggs. The second stage larvae resemble the adults except for their smaller body size. In some nematodes external stimuli is required for the hatching. The second stage larva starts feeding on living plants, undergoes 3 moults and attains mature adult stage.

Parasitism

The nematodes parasitising plant can be distinguished from non-parasitising forms by bearing a style which helps the nematode to puncture the protective wall of the host plant. The nematode injects the secretion of oesophageal glands. This secreation contains the enzymes which dissolve the cell wall, digest the plant material and prepare the cell contents suitable for ingestion. The nature of damage varies according to the species of nematodes. *Pratylenchus, Radopholus* and *Tylenchulus* feeding on host plants cause necrosis at the site of penetration. *Augunia* causes gall formation and *Trichodorus* checks the growth of root which produces stubby roots. Thus, nematodes affect the growth, structure and reaction of the host tissue penetrated.

Ectoparasites feed on the peripheral tissues of stem and roots. Sedentary ectoparasites do not entirely live inside the host tissues. They are found to be attached to the host tissues for longer periods. Migratory ectoparasites move from one part to another of the host tissues. Migratory endoparasites penetrate the host tissues inside and come out easily. Sedentary ectoparasites grow out of the host tissue and the posterior region is found to be projecting outside the host tissue.

Symptoms of Plant Nematode Infestation

The symptoms of plant nematode infestation depend upon the damaged plant parts under particular environmental conditions. *Aptielenchoides* causes the damage of buds and shoot tips, distortion of stem and crinkling of foliage. The larvae of *Anguina* cause damage to leaf and distortion of stem in wheat. *Ditylenchus* causes extensive rot of the potato tuber and onion bulbs. *Pratylenchus* and *Radopholus* cause rot of the root and lesions. *Meloidogyne* causes root knot or gall formation in a number of plants. Some specific symptoms are also associated with nematode damage viz., poor crop growth, winter injury and wilting of tree, loss of seedlings etc.

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Some Phytoparasitic Nematodes

1. *Trichodorus* spp.

This is world-wide in distribution and known as **'stubby root nematode'** (Fig. 1). This is ectoparasite on vegetables, grains, fruit crops and fodders. Due to the attack of this nematode the growth of the root tip is checked resulting in the formation of stubby root. The saliva secreted by this nematode checks the activity of cambium thereby retards its dividing ability. Thus, the affected plants have very poor root system with short rootlets which may form 'coarse root'.

T. christiei completes its life cycle in about 16 days which may take longer period at lower temperatures.

Prevention and control. The control of this nematode is very difficult because the eggs are found unaffected by any treatment. The larvae and adults can be destroyed by fumigation. The rotation of host plant by non-host plant

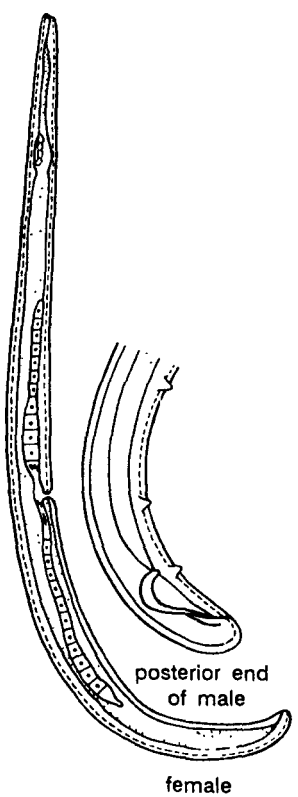

Fig. 1. *Trichodorus.*

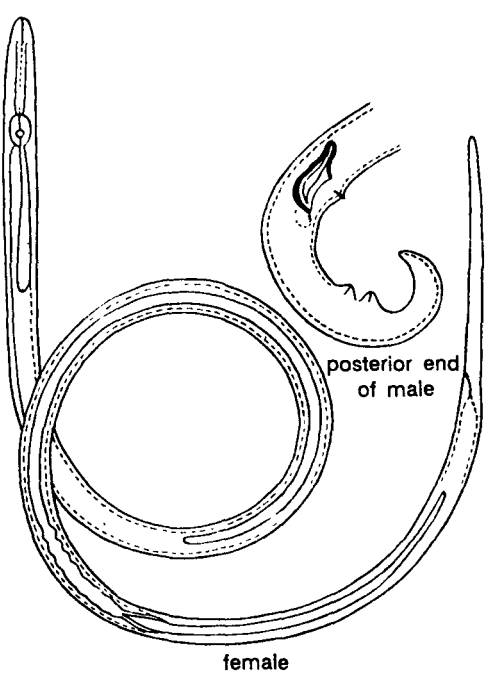

Fig. 2. *Rhadinaphelenchus.*

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as Asparagus (*Asparagus afficinale* L. var. *altilis* L) or any other suitable non-host plant may play important role to control this nematode.

2. *Rhadinaphelenchus* spp.

This is pest of coconut and oil palm and causes **'Red ring' disease.** In primary stages of infection the yellowing and drooping of lower leaves is followed by the formation of brown or red discolouration of stem tissue in ring form.

The life cycle is completed in about 7 days. The short period of life cycle causes growth of population of this nematode within a short duration of attack. Generally the infestation is recorded from the trees which are 4 years old (Fig. 2).

Prevention and control. The attacked trees should be destroyed by burning. Immediate steps should be taken to control the infestation. Some beetles are responsible for spreading the nematodes, so these beetles should be destroyed by spraying insecticides.

3. *Xiphinema* spp.

The species belonging to this genera are known as **'Dagger nematodes'** which transmit the virus to sugarbeet, turnip, spinach seedling, cucumber and potato. They are ectoparasites and cosmopolitan in distribution. They inhabit the

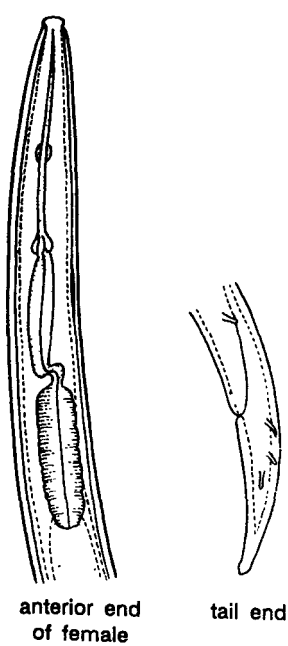

Fig. 3. *Xiphinema.*

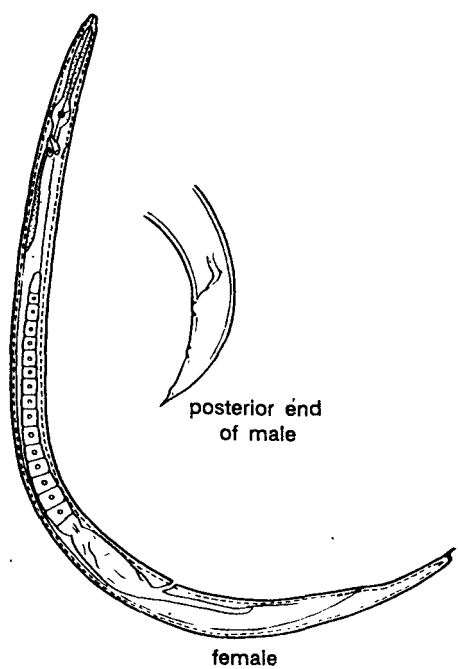

Fig. 4. *Aphelenchoides*

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cultivated soil. The formation of root lesions and stunting of shoot has been observed in strawberry attacked by *Xiphinema* species. In the case of severe attack, considerable destruction of root system has also been noticed. The development from egg to the adult takes 2 to 3 years. The life span of the female is about 5 years (Fig. 3).

Prevention and control. The fumigation of soil with suitable nematicides destroys the nematodes of upper soil surface.

4. *Aphelenchoides* spp.

The species of this genus is called as **'leaf and bud nematode'** because it damages the leaves and buds of host plants. They are ecto and endoparasites both. *A. besseyi* is reported to attack on strawberries, rice and vanda orchids, and causes 'summer crimp' in strawberries, and yellow bud blight in Vanda. They start to attack from the base of the plants and reach upwards towards the flowers. In heavy infestation the plants may be completely defoliated before flowering (Fig. 4).

Prevention and control. The treatment of seed with 40% of 3-p-chlorophenyl-5-methyl rhodamine is quite helpful to control the nematode. The infestation propagating materials should be treated with hot water at 50°C for 5 minutes.

5. *Hoplolaimus* spp.

The species of this genera are commonly called as '**Lance nematodes**' and are world-wide in distribution. They are ectoparasites and migratory endoparasite. The major host plants are a variety of agricultural, forest and horticultural crops viz., cotton, millets, maize, sugarcane etc. In case of onions, apples, palm oak and roses the spiral nematodes cause stunting and slow development of root systems. The lawn grasses have also been found damaged by lance-nematodes (Fig. 5).

Prevention and control. The use of some selected nematicides is quite helpful to control the lance-nematodes.

6. *Belonolaimus* spp.

The species of this genus are commonly called as '**sting nematodes**' and are migratory parasites in nature. The host plants attacked by this genus are maize, cotton, groundnut, soyabean, strawberries and cowpea. The sunken dark lesions appear on the affected root and also on the root tips. At the time of repeated damage the tips are found swollen and form new rootlets. In grape, the stubby roots are special features of symptom. The species of this genera are reported from the sandy soil (Fig. 6).

Prevention and control. The fumigation of soil with ethylene dibromide has been found to be much effective for control. The crop rotation by non-host plants viz., tobacco and watermelon may help to control the sting nematodes.

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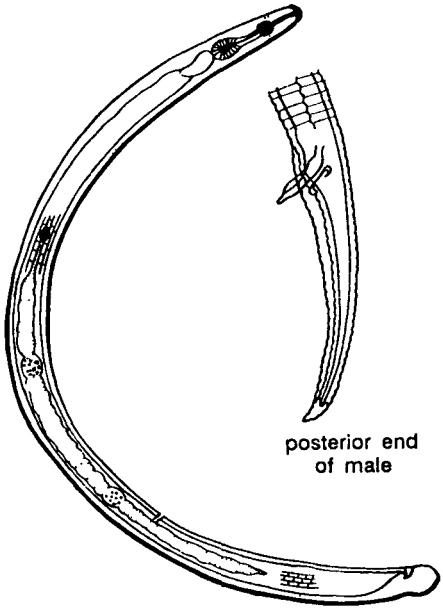

Fig. 5. *Hoplolaimus.*

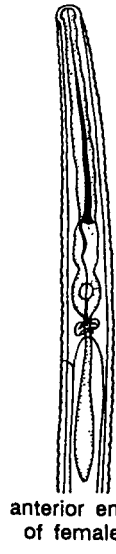

Fig. 6. *Belonolaimus.*

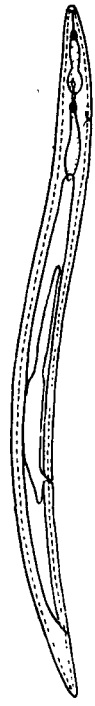

Fig. 7. *Pratylenchus.*

7. *Pratylenchus* spp.

The species of this genus are called as '**Root lesion nematodes.**' They are endoparasite of maize, cotton, wheat, sugarcane, sunhemp, cowpea, tomato, banana, pineapple, apple, grape, strawberry etc. They are cosmopolitan in distribution. The stunting and malnutrition of the affected plants are main symptoms of the attack by the nematode. The uprooted plants show poor development of root system. Brown to dark lesions in the cortex have also been reported. Different stages of nematode can be identified by careful examination of the lesions.

The life cycle is completed within 30 to 70 days depending on the host plant and environmental conditions (Fig. 7).

Prevention and control. The treatment of soil with nematicide is quite helpful to control these nematodes in orchard crops. The crop rotation with non-host crops and destruction of weeds of hosts in annual field crops is also recommended for the proper control.

8. *Radopholus* spp.

The well known species of this genus is *Radopholus similis* (Fig. 8) which is commonly called as the '**Burrowing nematode**'. It is distributed in tropical

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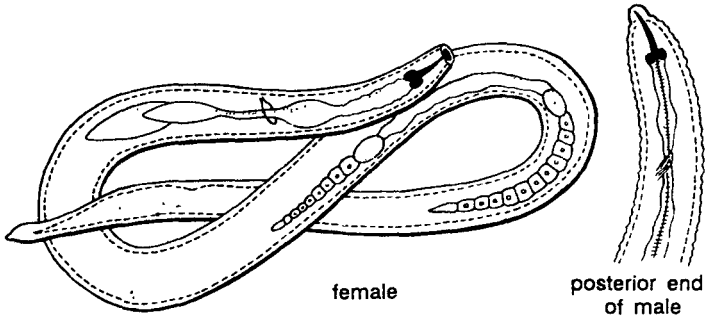

Fig. 8. *Radopholus.*

and subtropical regions. It causes severe damage to a number of economically important plants viz., banana, sugarcane, citrus, tea, coffee etc.

It damages the cortex of young roots of host plants. All stages of the nematode are found inside the infested roots. The infested roots of the host plants are later penetrated by a pathogenic fungus which causes severe damage to the roots of host plant.

The development of this nematode from the egg to the adult stage requires 2 to 3 weeks. The optimum soil temperature for the development of this nematode has been found to be 24°C. All developing stages are found within the cortex under suitable conditions.

Prevention and control. The infested soil should be ploughed but no plantation should be done on it for about six months to control the nematodes. The rhizomes should be treated with hot water (55°C for 5 minutes) before plantation. The resistant varieties of host plants should be selected for plantation.

9. *Meloidogyne* spp.

The species of this genera are commonly called as '**Root-knot nematodes**'. They are found to be present on light sandy soils in the warmer regions. They cause severe damage to potato, papaya, brinjal, tomato, jute, groundnut etc. (Fig. 9).

The symptoms of infested plants include yellowing of leaves and stunting of shoots. The most distinguishing symptom is the formation of knots in the roots. The shape and size of root-knots vary according to the host plant and environmental factors. Sometimes infested host plants even die in severe infestation.

The eggs hatch into larvae which are found free living in the soil. The second stage larvae attack new host root. The larvae which develop into females establish feeding zone, in the pericycle, moult 3 times and develop into females. The larvae which develop into males are parasitic in nature. For copulation male leaves the host and enters the sac-like matrices of the female.

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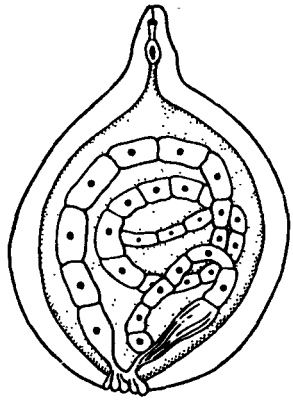

Fig. 9. *Meloidogyne.*

Prevention and control. To control the root-knot nematodes, flooding of the infested area is recommended. The flowing and summer ploughing are quite helpful to control the nematodes. The treatment of soil with methylbromide is recommended at the rate of one pound per 100 sq. feet.

10. *Heterodera* spp.

The species of this genus are commonly known as '**Cyst nematodes**'. The formation of cysts containing eggs is the characteristic feature of this nematode. The well known species in this genus are the sugar beet nematode, *H. schachtii,* the golden nematode of potato, *H. rostochiensis,* and the oat cyst nematode, *H. avenae.* In Indian climates *Heterodera* species are of common occurrence. The woody perennial plants are not infected by *Heterodera* species. More than 50% of the crop is damaged by this nematode in Rajasthan. In case of severe infestations in fields 100% loss of crops has been reported form Rajasthan (Fig. 10).

The yellowing of foliage and stunting of shoots are the major symptoms of attack by the species of this genus. In case of severe infestation the roots of host plants become hairy which causes complete failure of the crop.

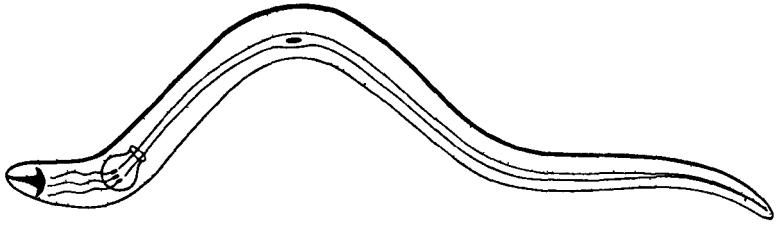

Fig. 10. *Heterodera*

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The fertilized female lays eggs inside the cysts. The hatching of first instar larvae takes place within the eggs. The second stage larvae emerge from the eggs, move freely in the soil and attach with the host roots. These larvae penetrate the root mostly just behind the root tip. The second stage larva undergoes second, third and fourth moults and leaves the host in the form of adult male. In case of the development of the female the second stage larva remains sedentary and attains adult stage after its fourth moult. The adult female has its head attached to the root and body projecting outside it. The complete life cycle takes about one to two months.

Prevention and control. The crop rotation is found to be the cheapest and best method for the control of *Heterodera* species. The fumigation of infested soil with methyl bromide is quite helpful to control these nematodes.

General Control Measures

The phytoparasitic nematodes are not as host specific as zooparasites, so a single parasitic nematode has a wide host range and each parasitic nematode may infest almost all the host species. The pattern of life history is less variable in comparison to zooparasites. The adults are either parasitic or free living but in either case the infective stages are found living freely in the soil. The sole idea behind the control of phytoparasitic nematodes is to stop the life cycle at any stage whichever is possible in the particular species. The following control measures have been taken here in detail.

[I] Phytotherapy

The treatment of host plants by heat, chemical and nutritional supplements covers the phytotherapy. This method is not much successful although employed in the field up to certain extent.

1. Thermotherapy. The whole plant is exposed to steam in a closed chamber for control of nematodes viz., *Anquina, Xiphinema, Heterodera, Meloidogyne, Radopholus* etc. This treatment is recommended for 10 to 65 minutes at 43 to 55°C temperature. Sometimes the affected plants are treated with a mixture of hot water and formaldehyde (0.5% formalin). The time and temperature of treatment may vary according to the host plant. The hot water formalin treatment should be maintained at 55°C for 1 to 4 hours.

2. Chemotherapy. The treatment of affected plants by chemicals (nematicides) is termed as chemotherapy. This includes the spraying of parathion (0.05-1% spray with emulsifire), methylbromide (30 ml. upto 20 h for every litre space fumigated) and Nemagon (5-8 gallons per acre for soil treatment.)

3. Nutritional supplements. The host plants should be supplied with highly nutritional substances to tolerate the infestation of nematodes. The fertilizer containing potash may be helpful to save the plants from root infecting nematodes. So, a well balanced supply of nutrients may develop the capacity to tolerate the nematode infestation.

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[II] Cultural control

The cultural control includes a number of agricultural practices and handling of seeds and host plants.

1. Crop rotation. The phytoparasitic nematodes having high degree of host specialization can be controlled by means of crop-rotation. In this method a gap of time is provided between two successive host plants during which either no crop is grown or a non-host-crop is grown. During this gap the infective stages of nematodes do not find their proper host. The resistant variety of host plants can also be included for crop rotation. For this practice the gap period is to be calculated and the host range of the parasite is also to be known. This method is most successful to control the *Heterodera* species.

2. Trap crop. This method is common to control the infestation due to *Heterodera* spp. and *Meloidogyne* spp. The trap crop is planted between two successive host crops. When the trap crop is attacked by maximum number of parasites, it (trap crop) should be removed from the field before the parasites mature and produce the eggs for next generation. Thus, the soil becomes free from parasites. The removal of trap crop should be performed at carefully calculated period so that maximum number of parasitic nematodes can be pulled out from the field.

3. Handling of seed. The nematode galls of wheat are mixed with seed grains. The mixed galls are poured into brine solution and the floating galls are removed with a sieve by repeated stirring of the seed. The brine solution is prepared by disolving 40 pounds of common salt in 25 gallons of water.

4. Other agricultural practices. The ploughing, harrowing and discing expose the parasitic nematodes to the sun drying and mechanical injury. These help to control the parasitic nematodes up to some extent.

[III] Soil treatment

The treatment of soil by fumigants is most effective method to control the phytoparasitic nematodes. Alongwith it few physical means have also been introduced to control these phytoparasitic nematodes.

1. Physical treatment. It includes the treatment with heat, radiation and ultrasonic waves.

(a) Heat. The treatment of soil with steam pipes or by electric instruments has been found to be an effective control measure. During the course of treatment care should be taken that the temperature should not be increased up to the level which may be harmful to the crops. This method is effective to control the species of *Heterodera.*

(b) Radiation. The exposure of soil to X-rays and γ-rays has been found to be most effective to control the infection by the species of *Heterodera.* The application of this method is not common in the field because of its high cost.

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(c) Ultrasonic waves. The high frequency of sound waves like ultrasonic waves, when comes in direct contact with the soil, damage the soil nematodes. This method is very expensive so it is not possible to apply in the field on commercial basis.

2. Chemical treatment. The most effective control measure for all phytoparasitic nematodes is the soil fumigation. The soil should be fumigated at least 2 to 3 weeks before planting. A mixture of granular type of fumigants and fertilizer should be applied to the field with ploughs. The chemicals which are in liquid form can be incorporated into the soil with the aid of injectors. The rate of application and amount of chemicals are variable according to the degree of infestation and nature of the chemical. Some of the most important chemicals are given here viz., Dowfume MC-2 (98% Methylbromide and 2% Chloropicrin), Dorlone (Telone 75.2% and Dowfume W. 85.24% by weight), Picfume (Technical Chloropicrin), Nemagon (1,2-dibromo-3-chloropane) and D.D. (dichloropropane-dichloropropene).

[IV] Biological control

The phytoparasitic nematodes are attacked by a number of parasites and predators. The parasites and predators include the groups of organisms like fungi, protozoa, insects, oligochaetes and nematodes. Some plants have also been found to be killer of phytoparasitic nematodes viz., some species of marigold reduce the number of the nematodes from infested area. The larvae of root-knot nematodes can be controlled by the roots of marigold. The introduction of parasites and predators should be chosen very carefully so that they may not harm the crops and the soil condition.

IMPORTANT QUESTIONS

» ***Long answer type questions***

1. Give an account of the phytoparasitic nematodes and their control measures.
2. Enumerate the symptoms of plant nematode infestation and mention about general control measures of phytoparasitic nematodes.

» ***Short answer type questions***

4. What are the symptoms of plant nematode infestation ?
5. What is phytotherapy of phytoparasitic nematodes ?
6. Write note on the cultural control of phytoparasitic nematodes.
7. Give an account of the treatment of soil for the control of phytoparasitic nematodes.
8. Write notes on the symptoms of plant nematode infestation.

» ***Very short answer type questions***

9. What are the host plants of stubby root nematode ?
10. Give name of the host plants of dagger nematode/leaf and bud nematode/lance nematode/sting nematode/burrowing nematode/root-knot nematode

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» ***Objective type questions***

1. Write common name of *Trichodorus* spp. :
   (a) Stubby root nematode (b) Dagger nematode
   (c) Leaf and bud nematode (d) Root lesion nematode
2. Write common name of *Xiphinema* spp. :
   (a) Lance nematode (b) Leaf and bud nematode
   (c) Dagger nematode (d) Root lesion nematode
3. Write common name of *Aphelenchoides* spp. :
   (a) Burrowing nematode (b) Leaf and bud nematode
   (c) Cyst nematode (d) Root-knot nematode
4. Write common name of *Hoplolaimus* spp. :
   (a) Lance nematode (b) Sting nematode
   (c) Root lesion nematode (d) Cyst nematode
5. Write common name of *Belonolaimus* spp. :
   (a) Root lesion nematode (b) Leaf and bud nematode
   (c) Burrowing nematode (d) Sting nematode
6. Write common name of *Pratylenchus* spp. :
   (a) Cyst nematode (b) Sting nematode
   (c) Root lesion nematode (d) Dagger nematode
7. Write common name of *Radopholus* spp. :
   (a) Burrowing nematode (b) Root-knot nematode
   (c) Leaf and bud nematode (d) Cyst nematode
8. Write common name of *Meloidogyne* spp. :
   (a) Lance nematode (b) Root-knot nematode
   (c) Leaf and bud nematode (d) Cyst nematode
9. Write common name of *Heterodera* spp. :
   (a) Cyst nematode (b) Lance nematode
   (c) Root-knot nematode (d) Burrowing nematode
10. Who is known to be the father of nematology ?
    (a) Needham (b) Bastian (c) Dujardin (d) Muller

Answers

1. (a), 2. (c), 3. (b), 4. (a), 5. (d), 6 (c), 7. (a), 8. (b), 9. (a), 10. (b)

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2

Insect Pests of Some Economically Important Crops

Insects are of great importance to the mankind due to the vital role played by them in human health and economy. Some are beneficial while others are harmful in different ways. The insects attack a large number of crops in the field. Some of the insect pests of important crops are given in this chapter.

Pests of Sugarcane

Sugarcane is one of the most important cash crops in some regions of India. This crop is attacked by a number of insect pests which cause great damage to it.

1. *Pyrilla perpusilla* Walker

Sugarcane Leafhopper

Class ..... Insecta
Order ..... Hemiptera
Family ..... Fulgoridae
Genus ..... *Pyrilla*
Species ..... *perpusilla*

Distribution. The sugarcane leaf hopper is commonly distributed through out India. The great loss due to this pest has been recorded from Uttar Pradesh, Madhya Pradesh and Maharashtra. In Uttar Pradesh this pest causes severe damage in Meerut, Muzaffarnagar and Saharanpur districts.

Food plants. Though *Pyrilla* is a major pest of sugarcane but it also attacks maize, wheat, barley, bajra, oats, sorghum, sudan grass etc. Sometimes this pest is found on bhindi, karela and cauliflower but these vegetables are not alternative host plants of *Pyrilla.*

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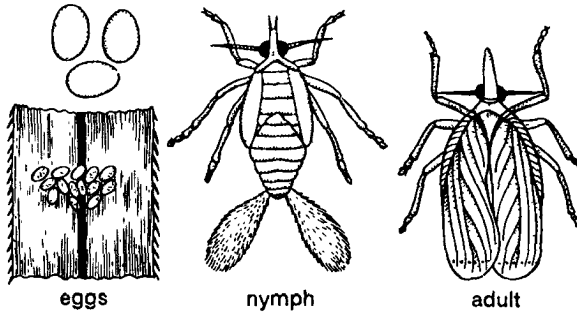

Fig. 1. Life history of *Pyrilla perpusilla.*

General appearance. The adult insect is pale straw in colour and very active. Its body length is about 8 to 10 mm. The head is prolonged anteriorly into snout-like structure and has prominent red eyes. A pair of whitish brown anal processes, covered with white mealy wax, are also found which help in up and downward active movement of the insect.

Life history. (Fig.1). It breeds throughout the year. The female lays eggs in clusters (300 to 500 eggs) on the lower surface of the leaves during summers (April) and inside the leaf-sheaths during winter (October and November). The eggs are oval, shining and pale-white or greenish in colour. They are covered by a white filamentous material secreted by the anal tuft of the females. The cluster of eggs is arranged in 3 to 5 longitudinal rows containing 30 to 50 eggs each. The eggs are hatched into nymphs after 7 to 22 days of laying in summers but in winters the hatching period increases. The nymphs are dirty white in colour and are provided with a pair of anal tufts of 1 mm. The nymphs start to suck the cell sap of the leaves. After five moults, the nymphs are changed into imagins and this takes about 6 to 8 weeks in summer and about 4 months in winter. The life span of the adult male is 5 to 7 weeks and that of the female about 5 to 8 weeks. In monsoon season the whole life cycle is completed in 40 to 60 days only. It is recorded that four overlapping generations of *Pyrilla* occur in a year and it is difficult to say as to when one generation is started and completed. The actual periods recorded for the egg laying of first, second, third and fourth generations are April, June, August and November to December respectively.

Damage. Both nymphs and adults suck the cell sap of suculent leaves of sugarcane by their rostrum. As a result, the leaves turn pale yellow and dry up. They secrete a sweet sticky transparent liquid known as HONEY DEW which attracts the harmful fungi resulting into a good growth of black shooty mould due to which the rate of photosynthesis is retarded thereby loss in the manufacture of food by the sugarcane plant. Because of the attack of this pest the quality and quantity of sugar is affected. The per cent decrease of sucrose content has

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been recorded from 2 to 5 and the total reduction in sugar has been noticed to be about 35%.

Prevention and control. (1) The egg masses should be collected and destroyed by burning, burying or spraying phenyl water.

(2) The quantity of nitrogen should be well balanced in the soil.

(3) The resistant varieties of sugarcane should be taken e.g. Co. 385.

(4) Ratoon crops should be avoided.

(5) The spraying of 0.25% endosulfan or 0.025% fenitrothion is much effective.

(6) The dusting of infested crop by 5 to 10% BHC dust from September ownwards is also very much effective.

(7) The spraying of 0.12% to 0.25% wettable powder of agrocide at the rate of 30 to 60 gallon per acre is quite effective.

(8) The spraying of 0.01% endrin emulsion at the rate of 500 litre per acre or 0.25 to 0.35 litre endrin of γ-BHC mixed with 10 litre kerosene oil should be fogged on crops.

2. *Emmalocera depressella* Swinhoe

Sugarcane Root Borer

Class ..... Insecta
Order ..... Lepidoptera
Family ..... Pyralididae
Genus ..... *Emmalocera*
Species ..... *depressella*

Distribution. This is a serious pest of sugarcane in eastern part of India viz., Uttar Pradesh, Bihar and Madhya Pradesh. In Punjab, Haryana and Pakistan this pest causes minor damage.

Food plants. It is a major pest of sugarcane but in the absence of this crop the root borer feeds on sorghum, maize, sarkanda etc.

General appearance. The moth is dirty, pale brownish in colour so that it can not easily be detected even in the infested crops. It is about 20 mm in length with wing-expanse. The white hind wings are shorter and wider in comparison to the fore-wings.

Life history (Fig. 2). The female moth on an average lays 230 to 285 eggs on the leaves, stems or on the ground. The laid eggs may be single or in batches. These eggs are scale-like, creamy-white and laid in the month of may. After 5 to 7 days the egg hatches into a young caterpillar of about 2 mm in length. The caterpillar is pale yellow in colour and provided with 5 pairs of prolegs. Just after emergence it bores into the stem below the soil surface. With the help of their cutting and chewing type of mouth parts the caterpillars cut right across the stem resulting into the formation of dead-hearts. The larval stage is of about 35 to 45 days during which they attain maximum length of about 25 to 30 mm. The borers, when left underground, attack the other sugarcane shoots and plants. The full-grown larva moves above the soil surface in the stem, makes an

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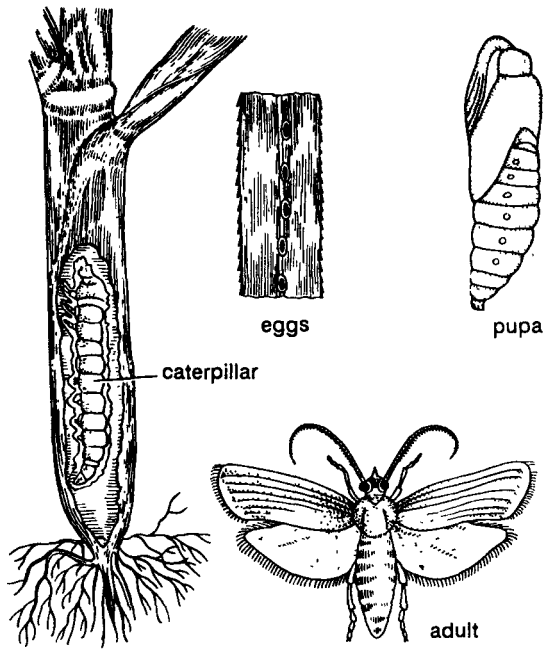

Fig. 2. Life history of *Emmalocera depressella*.

emergence hole in the form of a silken-tube above the soil surface and pupates inside the sugarcane.

After 9 to 14 days of pupation period the moth emerges from the holes. The life cycle is completed in about 50 days. Four complete generations have been recorded in a year. The caterpillars of fifth generation undergo hibernation in winter.

Damage. This pest causes heavy damage to the young cane plants particularly from April to June. They feed voraciously on the stem below the soil surface resulting into the formation of dead-hearts. The young canes die and the older ones dry and fall down. The attack of this pest causes 10% reduction in cane production and 0.3% decrease in sucrose content.

Prevention and control. (1) The attacked shoots should be removed and destroyed.

(2) Ratooning of cane should be avoided.

(3) Resistant varieties of sugarcane viz., Co 513 and Co 313 should be grown in the infested area.

(4) The moths should be light-trapped and destroyed.

(5) The canes should be harvested below the soil surface killing the caterpillars.

(6) 10% BHC dust at the rate of 8 kg per acre should be applied in the rows of cane.

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(7) Aldrin at the rate of 10 litre per acre, mixed in the soil, can kill the eggs, larvae and pupae.

3. *Chilo infuscatellus* Snellen

Sugarcane Shoot Borer

Class ..... Insecta
Order ..... Lepidoptera
Family ..... Crambidae
Genus ..... *Chilo*
Species ..... *infuscatellus*

Distribution. This pest is found throughout India and also causes damage to sugarcane crop in Afghanistan, Burma, Taiwan, Pakistan and Philippines

Food plants. Sugarcane is the main host of this insect but it is also found feeding on bajra, maize, sarkanda and some other grasses.

General appearance. The moth has straw-coloured fore wings and hind wings are white in colour with apical light buff areas. The moth is about 30 to 40 mm in length with wing expanse.

Life history. (Fig. 3). The female moth lays 10 to 35 eggs in clusters on the lower surface of sugarcane leaves. The eggs are scale-like and creamy-white in colour. The total number of eggs laid by a single moth is 300 to 400. After

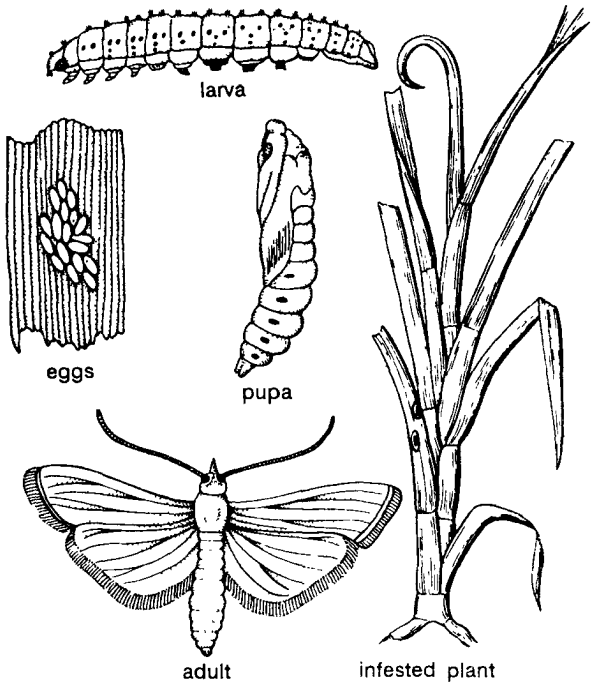

Fig. 3. Life history of *Chilo infuscatellus*

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4 to 5 days of laying, the eggs are hatched into larvae called caterpillars. The caterpillars, with the help of their cutting and chewing mouth parts, bore inside the shoot at base of cane plant, They feed voraciously and attain full-grown stage in 3 to 4 week's time. After full growth the larvae start the formation of a chamber for pupation and pupate there. After 5 to 7 days of pupation period the adult moths emerge from the pupae which come outside through an exit previously prepared by the caterpillars. The life span of the moth is about 2 to 4 days. The whole life cycle is completed in 35 to 45 days. Four to five generations have been recorded in a year.

Damage. The caterpillar stage of this pest causes damage to sugarcane resulting in the formation of dead-heart. The attack of pest is recorded mainly from April to June. During heavy infestation of this pest about 70 % loss of young shoots has been recorded. When canes are fully grown, the attack of this pest does not cause the dead-heart formation.

Prevention and control. (1) The shoots attacked by this pest should be removed from the field and destroyed.

(2) Ratooning of canes should not be practised.

(3) Moths should be trapped and destroyed.

(4) 10% BHC dust, mixed with the soil, should be sprayed twice during April to June which can control the pest.

(5) The pre-sowing treatment with lindane or chlordane causes heavy mortality of the pest.

4. *Tryporyza nivella* Fabr. (*Scirpophaga nivella* Fabr).

Sugarcane Top Borer

Class ..... Insecta
Order ..... Lepidoptera
Family ..... Pyralididae
Genus ..... *Tryporyza*
Species ..... *nivella*

Distribution. This is distributed throughout India and specially is most destructive in Meerut, Sitapur and some districts of Madhya Pradesh. It is also reported from Pakistan, China. Taiwan, Philippines, Thailand, Sri Lanka and Burma.

Food plant. Sugarcane is main host of this pest but it is also found feeding on sarkanda, kahi and other grasses.

General appearance. The moths are silvery white in colour and males are comparatively smaller than the females. Females are about 25 to 40 mm across the wings when spread and provided with a tuft of yellow, orange or brownish silken hairs over the tip of the anal segment.

Life history. (Fig. 4). The adult female moth lays about 500 elongated and oval eggs in clusters of 30 to 60 eggs on the lower surface of leaves of sugarcane. The clusters of eggs are covered with brown tuft of hairs in which eggs can

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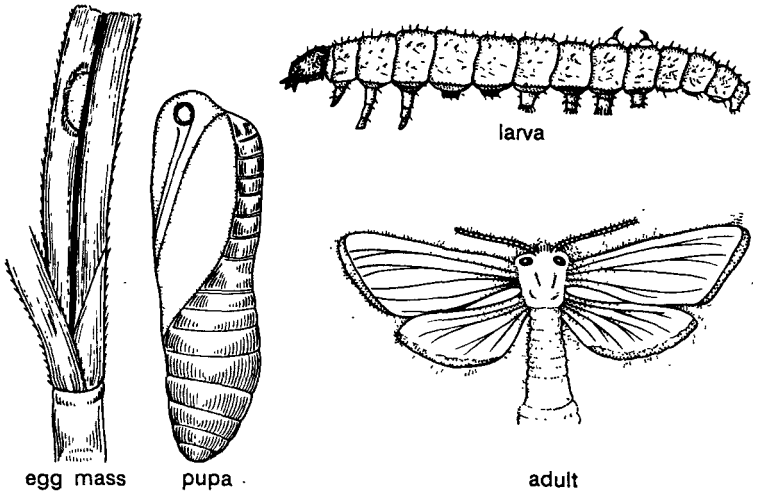

Fig. 4. Life history of *Tryporyza nivella.*

easily be seen in sun light. After 5 to 7 days of laying, eggs are hatched into caterpillars which are about 2 mm in length and are black headed. Just after emergence the young caterpillar starts boring into the mid-rib of a leaf and enters into the young terminal shoot through the rolled base of the top leaves. They feed voraciously up to 10 to 15 cm and destroy growing buds which results into dead-hearts. They can not bore into the ground. They attain full grown stage through five stages after 30 to 40 days of larval period. The full grown larva is about 30 mm in length, sluggish and creamy-white in colour. Full-fed caterpillar forms a characteristic chamber with an emergence hole just above the node. Now, larvae pupate in this chamber and after 7 to 10 days of pupation period they emerge out as moths. The life span of moth is of 4 to 5 days. The moths are found sitting on the tops of the canes in the morning hours. During night, moths become very active and mate for egg laying. Four to five over-lapping generations have been recorded in one year. It is interesting to notice that the caterpillars of the last generation do not pupate and undergo hibernation inside the tops of cane for the whole winter season in northern India. The pest is very active from March to November.

Damage. The caterpillar feeds upon the growing buds in the months of March and April and further bores up to 4 to 5 nodes of the top-shoot resulting in drying of the leaves forming dead-hearts. First two broods attack young plants before the formation of canes causing death of plants. The attack of this pest causes reduction in the cane crop and the quality of sugar is also affected.

Prevention and control. (1) Hand picking of eggs from green leaves and their destruction from April to July.

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(2) Attacked stems of canes containing dead-hearts should be removed and destroyed along with the caterpillars.
(3) Ratoon crops in infested area should be avoided.
(4) Moths should be trapped by light and destroyed.
(5) After harvesting in March the stubbles and leaves should be burnt.
(6) Insect-free sets of resistant varieties of cane should be planted.
(7) The spraying of 0.02% endrin at the time of egg hatching is quite effective to kill the eggs and young larvae.
(8) Dusting of 5% BHC at the rate of 20 to 30 pounds per acre in months of April and May is also effective.

5. *Aleurolobus barodensis* Maskell (Sugarcane White Fly)

Classs ..... Insecta
Order ..... Hemiptera
Family ..... Aleurodidae
Genus ..... *Aleurolobus*
Species ..... *barodensis*

Distribution. The pest is distributed throughout the Indian subcontinent specially Uttar Pradesh, Madhya Pradesh, Bihar, West Bengal and Orissa. It has been reported to be a very notorious pest of Punjab and Haryana.

Food plants. Its main host plant is sugarcane but it can also feed on sarkanda, wheat, barley and other grass plants.

General appearance. Adults are small, fragile and pale-yellow insects provided with prominent black eyes. It is about 3 mm long with wings expanded. The female is longer with heavy body in comparison to the males.

Life history. (Fig. 5). The fertilized females just after copulation lay 60 to 70 creamy white conical eggs in a line near the mid rib anywhere on the lower surface of the cane leaves in the months of November to December. After a couple of hours, eggs change to dark-black colour and become visible easily. After 8 to 10 days of laying, eggs are hatched into 0.36 mm long young nymphs of pale yellow colour. The nymphs with the help of their piercing mouth parts suck the cell sap of the leaves. The nymphs move here and there in search of proper host leaf and get settled at suitable cane leaf. They attain full growth through 4 instar stages which takes 25 to 30 days. The nymphs now enter into the pupal stage which is an exception in Aleurodidae because there is usually an incomplete metamorphosis in the Hemiptera. The pupal stage lasts for 8 to 10 days and then the adults are emerged. The life span of adults is about 2 days only. Nine generations have been recorded in a year. They migrate from old to new sugarcane plants in the month of March.

Damage. The nymphal stage causes damage to canes by sucking the cell sap of the leaves with the help of piercing mouth parts. The maximum attack is recorded in the months from July to November. They cause immense damage

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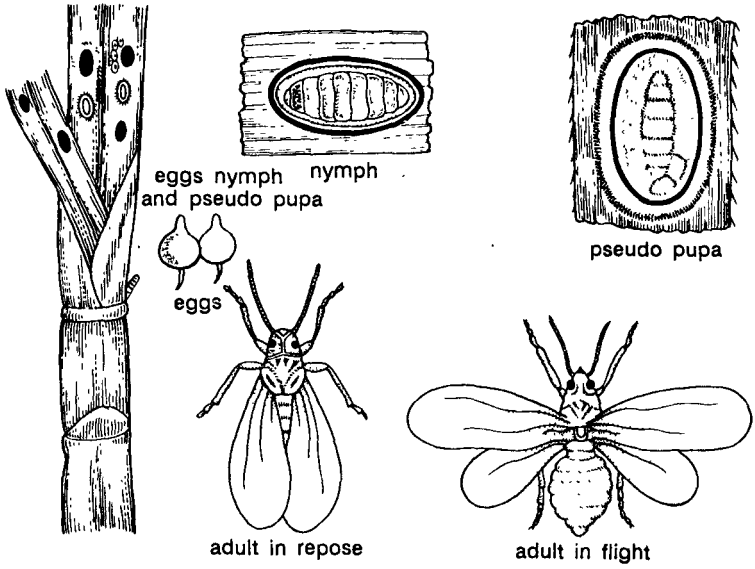

Fig. 5. Life history of *Aleurolobus barodensis*.

to ratoon crops. The plant looks pale in colour and apices of the leaves are unopened. The sucrose content is decreased up to great extent.

Prevention and control. (1) The nitrogen content should be balanced in the field.

(2) Attacked leaves should be collected and destroyed.
(3) Ratoon crops should be avoided.
(4) Resistant varieties of sugarcane should be planted.
(5) Water-logging should be avoided.
(6) Old canes should be harvested fully before new plantation.
(7) The spraying of 0.2% BHC, 0.1% malathion or 0.12% endrin is quite effective.
(8) Three c.c. of folidol in one gallon of water should be sprayed to kill 90% population of the pest.

6. *Bissetia steniellus* Hampson (Gurdaspur Borer)

Class .. .. Insecta
Order ..... Lepidoptera
Family .... Crambidae
Genus .. . . *Bissetia*
Species .... *steniellus*

Distribution. This pest is distributed in the districts of Haryana, Punjab, Uttar Pradesh and Rajasthan. It is also recorded in Pakistan and Vietnam.

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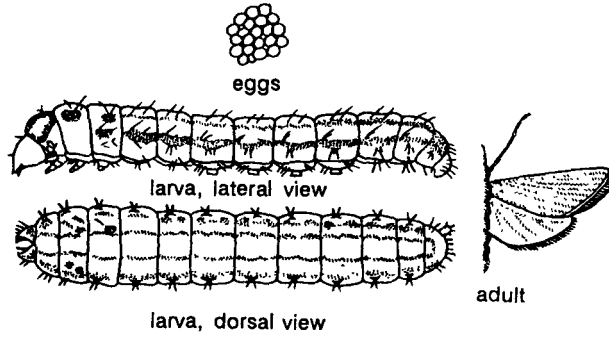

Fig. 6. Life history of *Bissetia steniellus*.

Food plant. Sugarcane is the only host plant of this pest. So far no other host plant has been recorded for this pest.

General appearance. The moth is brown coloured and 25 to 45 mm in length across the expanded wings. Adult has a number of dark spots on the outer line of the fore wings.

Life history. (Fig. 6). The female moth lays 100 to 300 scale-like eggs in the form of clusters on the mid-rib of the sugarcane leaves. The eggs are hatched after 5 to 9 days. Just after hatching the young larvae enter into cane on the top part by a hole situated above the node. They feed voraciously and form zigzag galleries inside, which results in the drying of the canes. The larvae after about 10 days leave the dried sugarcane and attack the neighbouring fresh canes. They attain full grown stage through 5 stages which take 20 to 27 days after which pupation of the larva takes place inside the cane. After 6 to 12 days of pupation period the adult moths emerge out. The life span of the adult moth is 4 to 5 days. Two to three generations have been recorded in a year and the whole life cycle takes 5 to 6 weeks.

Damage. The larvae feed gregariously on the top part of the cane and form galleries resulting in the complete damage of the plant. After sometime larvae leave the first destroyed cane and attack another fresh cane. About 25% of crop destruction has been recorded. In heavily infested fields about 75% crops are destroyed in the field.

Prevention and control. (1) The cane plants affected by borer should be removed and destroyed.

(2) Ratoon crops should be avoided.

(3) Stubbles should be removed and destroyed.

(4) The injection of 0.1% endrin in the borer galleries is found to be quite effective.

(5) The resistant varieties of cane should be planted.

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Pests of Paddy

1. *Leptocorisa varicornis* Fabr.

(Rice Bug or Rice Gandhi Bug)

Class .... Insecta
Order .... Hemiptera
Family ....Coreidae
Genus .... *Leptocorisa*
Species .. ..*varicornis*

Distribution. This pest is widely distributed in India, Tropical and subtropical parts of oriental region. In Uttar Pradesh, Gandhi bug causes severe damage to paddy crop.

Food plants. It mainly feeds on paddy but has also been found feeding on millets, maize, bajra, juar, rai, sugarcane and some grasses.

General appearance. This is green or light brown in colour and about 20 mm in length. According to its name 'gandhi' it emits a strong unpleasant smell. It has long legs, 4 jointed antennae and 3 jointed tarsi. They are very active in the morning and evening hours. The abdomen of the females is slightly swollen at the apex.

Life history. (Fig. 7). It breeds throughout the year and attacks paddy crops in the months of August to October. The adult female lays about 24 to 30 eggs in rows on the leaves and each row may have 6 to 20 eggs. The eggs are black, oval, flattened having concave margins. These eggs are fixed on the leaf by a gummy substance secreted by them. It is about 1 mm in length. After 6 to 7 days of laying, the eggs hatch into young nymphs which are pale green, long legged and devoid of wings. Within 15 to 18 days young nymphs grow to become adult and during this process nymphs pass through six stages.

The life span of the adult bug is of 33 to 35 days. The nymphs and adults are found clustering on paddy crop, although they are not of gregarious nature. Five generations have been recorded in paddy growing season. The whole life cycle is completed in 4 to 5 weeks. This pest multiplies from July to November, hibernates from December to February and feeds on grasses from March to June.

Damage. This is a major pest of rice and attacks the paddy field at the milky stage. The nymphs and adults both suck the juice from developing grains in months of August to October as a result of which the ears become white and do not form the mature grains. The attacked seeds are marked by black spots of fungus which appears around the punctured point.

Prevention and control. (1) Insects should be picked up by hand net and killed by strong-crude oil emulsion.

(2) In irrigated fields the crude oil emulsion should be sprayed which forms thin film of oil resulting into the killing of bugs and nymphs.

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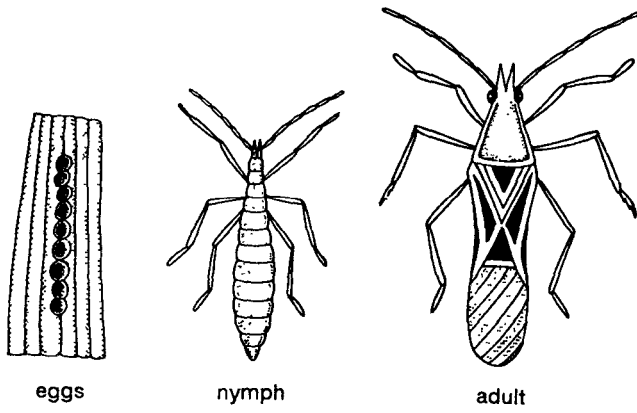

Fig. 7. Life history of *Leptocorisa varicornis*.

(3) Pests should be attracted by light trap and destroyed.
(4) The variety of rice used should be such in which grains come out at a late stage from the sheath.
(5) Wild grasses should be removed from the paddy growing areas.
(6) 0.25% BHC dust should be sprayed before flowering.
(7) The dusting of paddy fields by 2.5% aldrin, 5% chlordane and 5-10% BHC has been found to be useful for the control of the pest.

2. *Tryporyza incertulas* Walker

(Tana Bedhak)

Class ..... Insecta
Order ..... Lepidoptera
Family ..... Pyralididae
Genus ..... *Tryporyza*
Species ..... *incertulas*

Distribution. This pest is widely distributed throughout the oriental region. It is a major pest of paddy in Andhra, Orissa, Tamil Nadu and Bengal.

Food plants. This yellow moth borer is a specific pest of rice and feeds only on paddy crop.

General appearance. The moth is 15-20 mm in length and has a wing expanse of 24-45 mm. The female moth is bigger than the male and has distinct black spot on each of the bright yellowish forewing. The male moth has pale whitish yellow coloured front wing without any spot.

Life history. (Fig. 8). The moths become active, fly and mate after dusk. The female moth lays about 200-300 eggs during its life span of 5-7 days. The eggs are laid on the underside of tender paddy leaves in 2-5 clusters of 60-100 eggs each and are covered with a tuft of buff coloured hairs of the female. The

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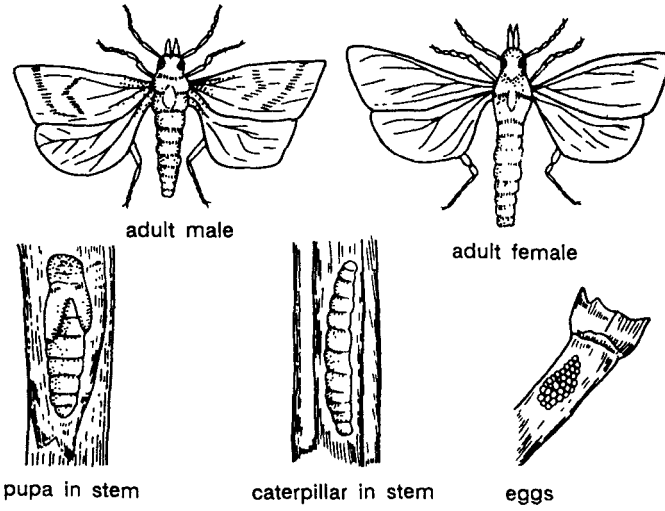

Fig. 8. Life history of *Traporyza incertulas*.

freshly laid eggs are oval, flattened and dirty white in colour which become darker and turn brown at the time of hatching. The eggs, after 6-8 days of incubation period, hatch into the tiny black-headed caterpillars. The newly hatched caterpillar suspends with the fine threads and disperses within a radius of 10 cms with the help of air. Some may crawl alongwith the leaf blade. The caterpillars, upon reaching the leaf sheath, enter through the space between leaf blade and inner sheath, and soon bore into the stem. On reaching near the root they bore into the inner stem and start feeding inside causing 'Dead Heart'. During the heading stage of paddy the caterpillar bores directly into the peduncle and damages the inner walls of stalk causing 'white ear head'. The caterpillar, after destroying one tiller, sometimes migrates to other plant or another tiller of the same plant.The larval period lasts for 20-30 days passing through 6 stages of different instars. The well grown caterpillar is smooth, yellowish white in colour and about 2.5 cm in length. Now the full grown caterpillar prepares an emergence-hole just above the water level in the field, pupates inside the attacked stem and emerges out as a moth after 9-12 days through the same hole. Whole life cycle takes 38-55 days. The number of broods reported are 5 in Andhra and Tamil Nadu, 3 in Bengal and 2 in Orissa where they are active throughout the year.

Damage. The caterpillar stage of this pest causes damage to paddy crops. They bore into the stem near the root causing 'dead heart' of central shoots which easily comes off when pulled. The plants attacked in early stages are killed altogether, whereas, in the plants infested during flowering stage, the ear heads dry up which are devoid of grains and are called as 'white ears'. An

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average loss of about 100-500 kg. of paddy per hectare has been recorded from Andhra Pradesh.

The damage caused by this pest is severe in southern states of India but in Northern states the damage is not serious. The late varieties of paddy are attacked more severely than the early varieties.

Prevention and control. (1) The spraying of 0.08% methyl parathion, 0.05% phosphamidon, 0.6% diazion granules after 20-30 days of intervals can control the pest.

(2) Twelve kg. of 6% lindane granules should be broadcast in the paddy field containing water up to 15 cm deep. Three replicates are necessary at the interval of 30 days.

(3) After harvesting, paddy fields should be ploughed in order to destroy the larvae in the stubbles.

(4) Stubbles should be burnt to destroy the hibernating larvae.

(5) Resistant varieties of paddy should be used for sowing.

3. *Hieroglyphus* (Kharif grasshopper)

Class ..... Insecta
Order ..... Orthoptera
Family ..... Acrididae

Hieroglyphus banian Fabricious
Hieroglyphus nigrorepletus Bolivor

Distribution. Kharif grasshoppers are widely distributed in the paddy areas of India, eastern districts of Uttar Pradesh, Malaya and Hawaii.

Food plants. They are major pests of paddy crops. But due to polyphagous nature they feed also on maize, millets, sugarcane, jawar, bazra, sunhemp, arhar and grasses.

General appearance. The adult is greenish dry grass coloured yellow hopper which is 4-5 cm in length. There are three black lines running laterally on either side of the thorax in *H. nigrorepletus* but only 2-3 black markings in *H. banian*. Both the species are found in full winged and small winged forms.

Life history. (Fig. 9). The female when ready to lay eggs, trails its abdomen on the soft ground in search of suitable site for egg laying. Female lays egg in masses (Egg pod), each containing 30-40 eggs, by inserting her abdomen in the soil 5-8 cm deep along the sides of the field bunds in the months of September to November. The remaining space of the egg chamber, after complete egg laying, is field with froth and finally covered over with mud by its hind legs. The hatching of eggs takes place in the month of June or early July of the following year, a few days after the first shower of the monsoon. The newly emerged nymphs are generally green coloured, sometimes pink which become green later. They start feeding actively on grasses and attain full grown nymphal

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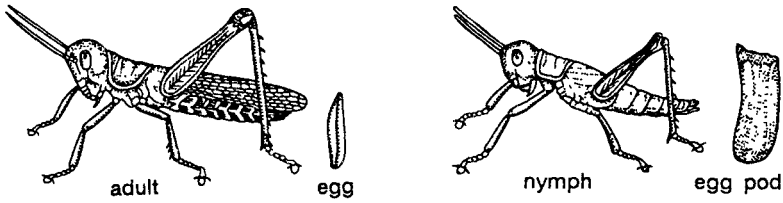

Fig. 9. Life history of *Hieroglyphus nigrorepletus*

stage by the middle of September within 8-10 weeks by casting off their skin 5 to 6 times at every interval of 10-15 days. The young hoppers are like the adults except for the absence of wings. Only a few days after attaining adulthood they start mating in September or early October. The male dies after copulation while female starts egg laying and dies after oviposition.

Damage. Both, adult and nymph damage paddy crop by feeding on leaves and shoots. At the time of severe infestation the plants are completely defoliated which affect the growth of plant thereby resulting into low yield. In epidemic form, they completely damage the crops moving from field to field over large areas as happened in Rajasthan a few years ago. Millets, sugarcane, grasses and other graminaceous plants are also damaged.

Prevention and control. (1) Hoppers and adults should be collected and destroyed.

(2) 0.02% dieldrin, 0.04% heptachlor and methyl parathion are used for effective control.

(3) The affected field should be ploughed to a depth of 10-15 cm after harvesting the crop. Thus, eggs can be destroyed.

(4) 30% aldrin at the rate of 25 ounces per hectare has been found to be much effective in aerial spraying on sugarcane crops.

(5) Some birds like kite and crow eat the adults and nymphs, whereas, woodpecker and blue jay destroy the eggs by eating.

4. *Pachydiplosis oryzae* : Wood-Mason—Mani (The rice gall midge)

Class ..... Insecta
Order ..... Diptera
Family ..... Cecidomyiidae
Genus ..... *Pachydiplosis*
Species ..... *oryzae*

Distribution. The rice gall midge is a sporadic major pest and is found in Assam, Andhra Pradesh, Bihar, Maharashtra, Mysore, Orissa, Uttar Pradesh and West Bengal. It also damages paddy crop in Africa, Pakistan and South East Asia.

Food plant. It feeds only on paddy crop.

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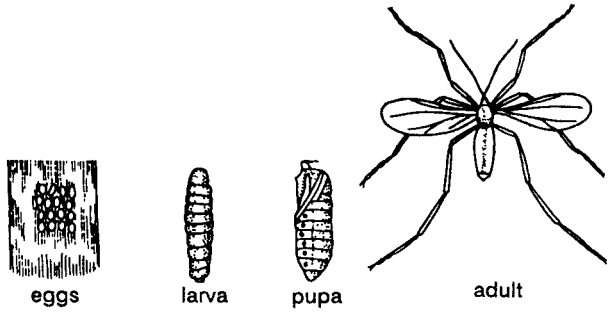

Fig. 10 Life cycle of *Pachydiplosis oryzae*.

General appearance. It is a mosquito sized small fly. The body of the female is bright red coloured and provided with stout abdomen, whereas, males are more slender and dark coloured. The adults are found to be very active during night and hide themselves during day time.

Life history. (Fig. 10). The adult female lays reddish elongated eggs singly or in clusters of 2-6 eggs on the under surface of the paddy leaves. The newly laid eggs are reddish, elongated and broader at one end, measuring 0.5-0.6 mm in length. After few days, eggs become chocolate coloured and after 2-4 days of incubation period they hatch into coloured larvae of about mm length. The tiny larva crawls on the leaf sheath till it reaches the base of the shoot. Now larva bores into the stem near the growing point (bud) and after feeding for about 10 days it pupates. The pupa is pinkish red coloured measuring 2-2.5 mm in length. The pupa wriggles its way up with abdominal spines and cuts a hole on the tip of gall from which the adult emerges after 4-7 days. The life span of adult is of 3-4 days. The life cycle is completed within 15-23 days. Five to eight overlapping generations of this pest have been recorded in one year.

Damage. The larval stage causes damage to the crop. The extent of damage caused by this pest varies from region to region. The plants are attacked by maggots mostly attaining the age of 5-6 weeks. The maggot reaches the apical point of the central shoot for feeding which causes a number of physiological changes thereby hampering the growth of plants. The central shoot of tiller becomes hollow which is followed by the gall formation on the basal portion. The gall formed in young plants are not visible due to leaf sheath while in advanced stage of plants it is visible very clearly like projection. Now entire central shoot is turned into a hollow tube of silvery green colour (Silver shoot) and the tip remains green. The transplanted plants are attacked more than broadcast ones. Heavy attacks are recorded in water logged areas.

Prevention and control. (1) Early planting of crop minimize the damage.
(2) Adults are attracted towards light, so light trap should be managed in the field.

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(3) Alternative host plants should be removed to minimize the pest population.
(4) Granular application of Diazinon, Sevidol and Thimet 10 G a 1.25 kg per hectare is very effective.
(5) The spraying of phosphamidon 0.05%, carbaryl 0.2%, diazinon 0.05%, dimethoate 0.02% and lindane 0.5% reduces pest population very effectively.

5. *Mythimna separata* Haworth = *Pseudoletia separata* Walker (Armyworms or cutworms)

Class ..... Insecta
Order ..... Lepidoptera
Family ..... Noctuidae
Genus ..... *Mythimna*
Species ..... *separata*

Distribution. It is distributed throughout the Oriental region.

Food plants. Cutworm is a polyphagous insect found feeding on paddy, barley, maize, sugarcane, wheat and other millets.

General appearance. The full grown moth is pale brown in colour with a wing expanse of 3.5 cm in length. Front wings are provided with white spots in its centre. The moths are very energetic having strong power of flying. They are found to be very active during night and remain hidden during the day time.

Life history. (Fig. 11). Female moth, after mating, starts egg laying. The number of eggs laid per female has been recorded to be 500-700. The eggs are laid in clusters on the lower leaves and are covered with greyish hairs. Freshly laid eggs are small, spherical and greenish white in colour. After 4-5 days of incubation period eggs are hatched into young caterpillars of pale green colour. The caterpillars, up to half grown stage, are very specific because of its looping habit of crawling. They are found feeding in large number in field crops and grasses also. The crawlers take rest at the base of clums during day time and become very active for feeding with sunset. They climb on the plants, cut rachides and maturing ear-heads resulting in severe damage of the field crops. When they feel shortage of food in the damaged area they move together in large numbers like armies and further attack the paddy crop in the nearby field.

The caterpillar after attaining the full grown stage measures about 3.5 cm in length. On the dorsal side the caterpillar bears a narrow broken strip from anterior to posterior region. The body is smooth and slender and is provided with honey-combed head. The larval period lasts for 21-28 days passing through five successive larval instars.

Now full grown fifth instar caterpillars leave the plant and construct earthen chamber after entering into the soil and get pupated therein. The pupa is dark brown coloured measures 1.25 cm in length. After 10-12 days of pupal period, moth emerges out. Five generations have been recorded in single year.

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Damage. Its larval stage is the destructive phase of the life cycle. A number of crops are destroyed by Armyworms. The appearance of pest has been noticed after heavy rains and flood. The caterpillars attack the crop in the night and cut off half ripe ears. In day time they keep themselves hidden in the folds of leaves and cracks in the soil. The infestation period is from September to the second week of October.

Prevention and control. (1) Caterpillars should be hand-picked and killed.
(2) Grasses should be removed from the field.
(3) Till the maturity of the grain, 5-10 cm water should be impounded.
(4) Planting should be adjusted for the harvesting of crop by the middle of October.
(5) Dusting with 2% toxaphene or 5% aldrin dust @ 30-35 kg. per acre is effective.
(6) Sparying with 0.04-0.05% of diazinon or malathion or parathion or phosphomidan @ 800 litres per acre is very effective to minimize the pest population.

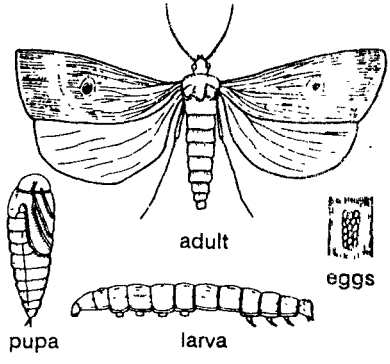

Fig. 11 Life history of *Mythimna separata.*

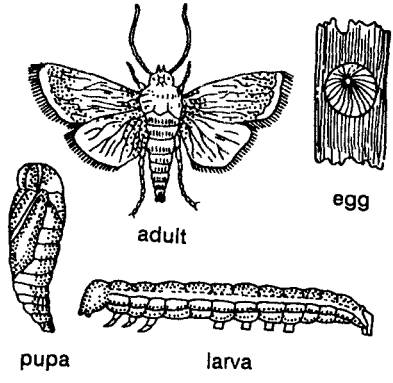

Fig. 12. Life history of *Spodoptera mauritia.*

6. *Spodoptera mauritia* Boisduval (Swarming caterpillar)

Class . . . . . Insecta
Order . . . . . Lepidoptera
Family . . . . . .Noctuidae
Genus . . . . . *Spodoptera*
Species . . . . . *mauritia*

Distribution. The swarming caterpillars are found throughout Tropical and Sub-tropical parts of the world.

Food plants. They feed on paddy, jowar, maize, wheat and sugarcane.

General appearance. The adult moth is medium-size black spotted and greyish brown in colour. The forewings are provided with an irregularly waved light line. The colour of hindwings is whitish.

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Life history. (Fig. 12). Female moth after mating, starts egg laying, in clusters of 100-400 eggs, on the lower surface of leaves. The eggs are yellowish in colour and covered with buff coloured hairs. After 6-8 days of incubation period eggs are hatched into caterpillars and start feeding at once on the young leaves of the host plant. The young caterpillar, after 4-5 moults, attains full grown stage and measures about 3 cm in length. Now it is greyish yellow coloured with reddish and yellowish strips across the body. The caterpillar stage lasts for 3 weeks and full fed caterpillars crawl down to the ground and pupate in the soil. After 10-12 days of pupation period adult moth emerges out from the pupa. Two to four generations have been recorded in a year according to the ecological conditions of the area.

Damage. The larval stage causes destruction of the crops. The caterpillars feed on the foliage of young seedlings in the nursery and transplanted plants. The caterpillars are nocturnal and feed only at night. During day time they keep themselves hidden from sun light. The caterpillars appear in swarms, therefore, entire crop of the field is damaged severely and looks as if the crop has been grazed by cattle in the field.

Prevention and control. Dusting of crop with 2% parathion dust at the rate of 30 to 35 kg. per hectare.

Pests of Pulse Crops (Grampod Borer)

1. *Heliothis armigera* (Hubner)

Class ..... Insecta
Order ..... Lepidoptera
Family ..... Noctuidae
Genus ..... *Heliothis*
Species ..... *armigera*

Distribution. This pest is cosmopolitan in distribution. In India it causes heavy damage to a number of pulses.

Food plants. It is polyphagous in nature but serious pest of gram (*Cicer arietinum* Linn), and red gram (*Cajanus cajan* (L). This is also found damaging sorghum, maize, cotton, okra, bhindi, tomato etc.

General appearance. The adult moth is of light brown or yellowish brown colour and is about 3.75 cm in length with wing expanse. Forewings are provided with wavy black linings and black spots on the upper surface while lower surface has kidney-shaped mark. The hind wings are white and provided with black bank on the outer margins. The adult is nocturnal in nature but found sitting on host plants in day time also.

Life history (Fig. 13). The adult female becomes active in dusk period and starts egg laying singly on tender leaves and flowers of plants. One female can lay a total of about 741 eggs in 4 days. The eggs are rounded, light yellowish in colour and look shining. After 2 to 4 days of laying, the eggs are hatched

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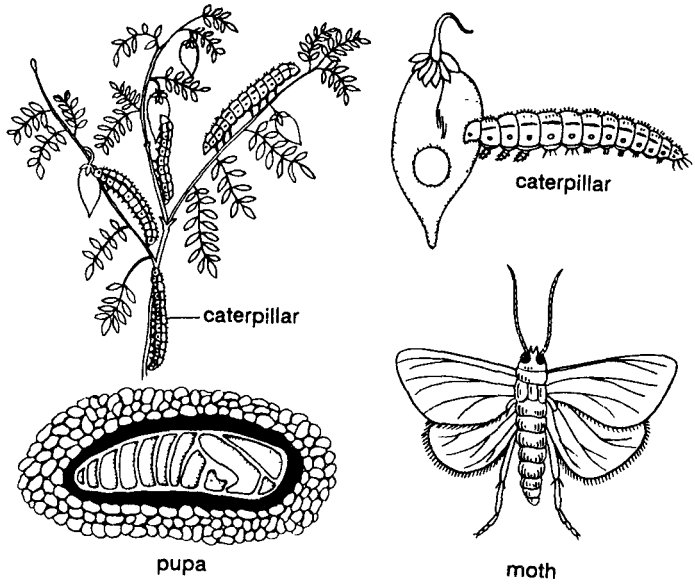

Fig 13 Life history of *Heliothis armigera.*

into young larvae in the months of April to October and start feeding voraciously on the tender pods of the host plant. The younger larvae are dark brown in colour but later they become yellow-green whitish and are provided with gray linings on both the sides of the body. The caterpillar becomes full grown after 13 to 19 days of hatching and attains a length of about 35 mm. It severely, damages the pods, foliage and grains. The full grown caterpillar leaves the pod and pupates in the soil. The pupa is of dark brown colour. The adult moth emerges out after 10 to 15 days of pupation in active season but in months of January and February they remain in the soil and emerge out in March and further start egg laying. The whole life cycle takes 3 to 7 weeks in summer and autumn months. Eight generations have been recorded in one year. In absence of proper nutritive host plants the caterpillars are found feeding on other caterpillars.

Damage. The caterpillars are polyphagus in nature but cause heavy damage to gram and red gram. This pest feeds on young pods, foliage and seed resulting in reduced yield of garm and red gram. In America it causes maximum destruction to cotton, hence there it is called 'American Cotton Boll Worm'.

Prevention and control. (1) After harvesting, the farms should be ploughed.

(2) The caterpillars hanging from pods can easily be picked up and destroyed.

(3) The crop rotation is best device to control this pest.

(4) The spraying of 0.1% carbaryl or 0.25% endrin is quite effective.

(5) 5% BHC dusting is also a good control measure.

(6) The dusting of the mixture of sodium fluosilicate and ash (1 : 8 w/w) is also effective.

(Z–37/Eco. Zool.)

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2. *Agrotis ypsilon Rott.* (Gram cutworm)

Class ..... Insecta
Order ..... Lepidoptera
Family ..... Noctuidae
Genus ..... *Agrotis*
Species ..... *ypsilon*

Distribution. This pest is distributed throughout the world and damages the crops in America, Africa, Australia, Burma, China, Taiwan, Europe, Hawaii, India, Indonesia, Japan, New Zealand, Sri Lanka and Syria, In India it causes damage to various crops in Punjab, Uttar Pradesh, Bihar, Madhya Pradesh and Bengal.

Food plants. Gram cutworms damage gram, peas, potato, lentil, mustard, wheat, maize, sugarcane, lucerne, ground-nut, barley, cotton, opium, tobacco etc.

General appearance. It is a stout medium-sized moth measuring about 25 mm in length. The moth is dirty or black coloured having some greyish patches on the back and dark lines on the forewings. This cutworm has small prothorax, hairs on the under side of the femur, and setae on the middle and hind tarsi. Another allied species *Agrotis flammatra* Schiff causes severe damage to chick pea in northern India. It also feeds on potato, cucurbits, okra, wheat, opium, tobacco, poppy etc. Its adult is heavy bodied greyish or wheat coloured measuring 5-6 cm in wing expanse.

Life history. (Fig. 14). The female moth after fertilization oviposits very small, creamy white, dome-shaped eggs singly or in clusters of about 30 eggs each. The eggs are laid at night on the under-surface of the leaves of the host plant, grasses or in the soil beneath the plants. The process of oviposition continues for 5-11 days and total number of eggs laid per female are as many as 350. After incubation period of two days in summer and 8-13 days in winter the eggs are hatched into caterpillars feeding on their own egg-shell and move like a semilooper. The caterpillars are dark coloured having greasy body. They are extremely active at night in cutting down much more foliage than they can devour. During the day time they hide in cracks and crevices (10-15 cm deep) in the soil. After about 30 days the larvae attain the maximum size of about 2 cm length, make earthen chambers in the soil and pupate underground. The pupal period varies from 10 days (summer) to 30 days (winter) after which moth emerges out usually at night. The life cycle is completed in 48- 77 days. Three generations have been reported to be completed in a year. Being a cold weather pest, it is found active from October to March in plains and migrates to hills for breeding during summer.

Damage. Only larval stage damages the standing crops at night. In India and other warm countries it is a severe pest of Rabi crops particularly of gram and potato. The younger caterpillars feed on the epidermis of leaves. The feeding

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habit changes with the growing stages of larval period. They damage the crops by cutting the stem either above or below the ground resulting in felling of the plants. The cut branches of host plants are dragged into the holes where the leaves are ingested by the caterpillars.

Prevention and control. (1) Clean cultivation should be adopted.

(2) The caterpillars should be hand-picked from small area.

(3) Field should be often flooded moderately.

(4) The application of 2% lindane after the sowing of crops can control the pest.

(5) Heptachlor, aldrin @ 2.25 kg. active ingredient per hectare should be applied to the soil before planting potato tubers.

(6) Various natural enemies *viz.*, mice, moles, grubs, wasps predaceous and parasitic flies destroy this insect.

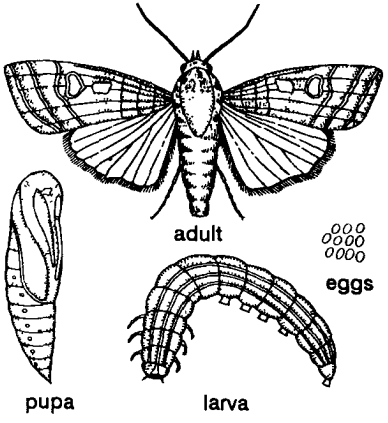

Fig. 14. Life history of *Agrotis ypsilon.*

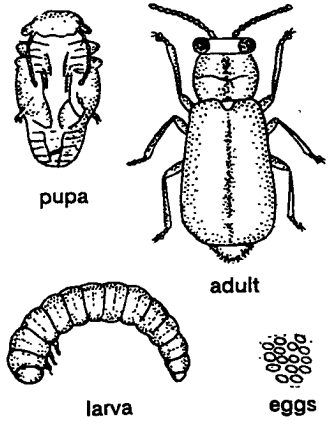

Fig. 15. Life history of *Raphidopalpa foveicollis.*

Pests of Vegetables

1. *Raphidopalpa foveicollis* Lucas =*Aulacophora foveicollis* Lucas (The red pumpkin-beetle)

Class ..... Insecta
Order ..... Coleoptera
Family ..... Chrysomelidae
Genus ..... *Raphidopalpa*
Species ..... *foveicollis*

Distribution. Widely distributed throughout Asia, Africa, Australia and Southern Europe. In India it is a serious pest in north western part.

Food plants. Cucurbitaceous vegetables *i.e.* pumpkin (*Cucurbita pepo* L.), ghia tori (*Luffa aegyptica*), tinda (*Citrullus vulgaris*), cucumber, melon etc. are host plants of this beetle.

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General appearance. The adult beetles are oblong, measure about 5-8 mm in length and 3.4-3.75 mm in breadth. The body is brilliant orange red coloured on the dorsal side while black on the abdomen. The abdominal region is covered with whitish soft hairs. Other species that cause damage to the vegetable crops is *Aulacophora atripennis* F. having grey coloured body.

Life history. (Fig. 15). The adult beetles hibernate from November to February in groups under dry weeds, bushes, grasses, plant remains or in crevices of the soil. After hibernation period beetles come out as season warms up in the beginning of March. The female, after mating, lays orange coloured oval eggs singly or in small clusters of 8-9 in the moist soil near the base of host plants. Single female can lay about 300 eggs. After 6-15 days of incubation period eggs are hatched into grubs. The newly hatched grubs are creamy yellow coloured and are provided with a brown head and prothorax. Since grubs remain below the soil surface, they start feeding on roots, underground stems of creepers, old fallen leaves and fruits of their host plants lying in contact with the soil. After 13-25 days they attain full grown grub stage by passing through 4 moults. Now full grown grubs move in the soil and get pupated in smooth, thick-walled, oval and waterproof earthen chambers in the soil at the depth of about 1 cm. After 7-17 days of pupal period the adult beetle emegres out and begins to feed on the host plants. After 7 days of emergence, beetle starts egg laying. The life cycle is completed in 26-37 days and generally 5 overlapping generations have been recorded from March to October.

Damage. The beetles as well as grubs both are destructive stages. Maximum damage of cucurbitaceous vegetable plants is caused by these beetles. They feed on the leaves, flowers and buds of younger plants. If the attack is severe the plants are found completely defoliated. The extent of damage is highest in the months of March and April due to the feeding on the germinating plants by the beetle. The grubs bore into the roots, underground stems and fruits of host plants touching the soil surface.

Prevention and control. (1) Beetles may be collected by hand nets and killed in kerosene oil.

(2) Cucurbitaceous vegetable plants should be sown earlier in November.

(3) Early varieties of cucurbitaceous vegetable should be grown.

(4) During the months of March and April younger plants should be dusted by ash.

(5) After harvesting, fields should be ploughed.

(6) Carbaryl or pyrethrum 5% should be dusted on crops when there is no dew on the plants.

(7) Spraying of methyl parathion or dimethoate 0.02% or malathion 0.05% have proved to be more effective.

(8) Spraying with lindane 0.1% at the rate of 200-300 liters per acre is also effective to reduce the pest population.

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2. *Pieris brassicae* Linnaeus (Cabbage butterfly)

Class ..... Insecta
Order ..... Lepidoptera
Family ..... Pieridae
Genus ..... *Pieris*
Species ..... *brassicae*

Distribution. It has world-wide distribution and is reported to damage cruciferous vegetable plants wherever grown.

Food plants. They are found feeding on cabbage, cauliflower, turnip, sarson, toria and other crops.

General appearance. The butterfly is of large size and pale white in colour. The dorsal surface of the body is provided with smoky shade. The female butterfly is about 6.5 cm across the spread wings having two black dots on the dorsal side of each fore wing, whereas, male butterfly is smaller in size and provided with black spots on the underside of each fore wing.

Life history. (Fig. 16). The female butterfly lays about 165 eggs on the leaves of host plants. The eggs are yellowish, conical in shape and laid in clusters of 50-90 eggs each. After an incubation period of 11-17 days in November-February and 3-7 days in March-May eggs are hatched into small, green caterpillars. The caterpillars start feeding voraciously on the leaves during early stages and by passing through 5 moultings in 15-20 days during March-April and 30-40 days during November- February, they attain full grown size. The full grown caterpillar measures 4-5 cm in length and becomes greenish yellow in colour. The body is covered with short hairs.

The full fed caterpillar undergoes pupation either on the leaf or on a tree or any suitable place near the food plant. After 7-14 days in March-April and 20-28 days in November-February butterfly emerges out from the pupae. The life span of adult butterfly varies from 2-12 days. Four generations of this pest have been recorded during October to April.

Damage. Caterpillar is the only destructive stage. The younger stage (Ist instar) just scrapes the surface of the leaf but later instars feed on the leaf of host plant from margin inwards. Ordinarily complete plant is eaten away voraciously by the caterpillars resulting in complete destruction of the host plant.

Prevention and control. (1) The pest population can be minimized by spraying the crops with malathion 0.05% or diazinon 0.02% up to three weeks before harvesting.

(2) If infestation occurs during the later stages of the growth of the plants, carbaryl 0.2% should be used to check the pest population.

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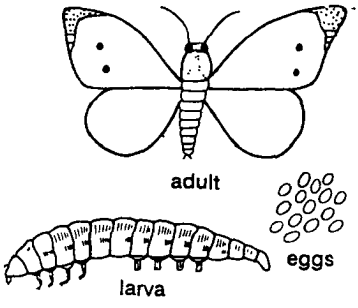

Fig. 16. Life history of *Pieris brassicae.*

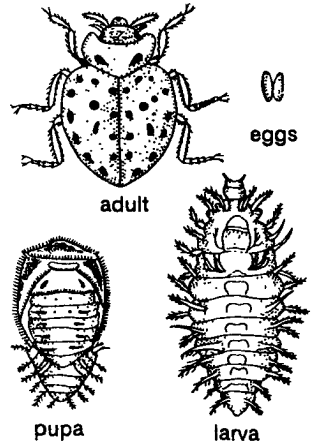

Fig. 17. Life history of *Epilachna dodecastigma.*

3. *Epilachna* (The Hadda beetle)

Class ..... Insecta
Order ..... Coleoptera
Family ..... Coccinellidae

Epilachna dodecastigma (Mulsant)
Epilachna vigintioctopunctata (Fabricius)

Food plants. The hadda beetles feed on different solanaceous vegetable plants like brinjal, potato, tomato and bittergourd.

General appearance. Two species of hadda beetles viz., *E. dodecastigma* and *E. vigintioctopunctata* are common. Beetles are about 8 mm in length and 5-6 mm in width. Adults of *E. dodecastigma* are deep red coloured having 7-14 spots on each elytron.

Life history. (Fig. 17). The beetle passes the winter season in hibernating phase of life, in the heaps of dry plants, cracks and crevices or in the soil. In the months of March-April they become active and female beetles start egg laying in clusters of 13-50 eggs each on the under surface of the leaves. One female can lay about 300 eggs during her life span. The eggs laid are yellow coloured and cigar shaped. After the incubation period of 2-3 days in summer and 4-9 days in winter eggs are hatched into grubs measuring about 8 mm in length and 4 mm in breadth. After passing through 4 different instars of 2-9 days each, the grub attains fulll grown stage and changes into pupal stage, and is found fixed on the leaves, stem or the base of plants. The pupa is yellow orange in colour having brown white margins on the upper surface. The pupal period lasts for 2-9 days. The life cycle is completed within 12-54 days. The pest completes 7-8 generations per year in plains while only one in hills. In

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plains the pest population reaches maximum from late April to early May. In hot and dry conditions beetles are unable to survive so that their population falls to the minimum level.

Damage. The adults and grubs both are destructive stages. The adults feed on the leaves in a semicircular pattern in rows, whereas, grubs nibble and scrape the upper surface of the leaves. The infested leaves then turn brown, dry and fall off resulting into complete defolation of plants.

Prevention and control. (1) The adults and eggs should be hand-picked and destroyed.

(2) Spraying of diazinon 0.02% and malathion 0.05% can minimize the pest population.

(3) Methyl parathion 0.02% spraying also minimizes the pest population.

(4) The fields of vegetable crops should be irrigated at the time of severe infestation of *E. dodecastigma* to minimize the damage.

(5) The effective control measure should be applied to control *E. dodecastigma* particularly when the weather temperature is found to be about 25°C.

4. *Leucinodes orbonalis Guenee* (Brinjal shoot and fruit-borer)

Class ..... Insecta
Order ..... Lepidoptera
Family ..... Pyraustidae
Genus ..... *Leucinodes*
Species ..... *orbonalis*

Distribution. It is widely distributed in Burma, South Africa, India, Germany, Congo, Malaysia and Sri Lanka.

Food plants. Brinjal.

General appearance. It is a medium-sized moth of about 20 mm across the spread wings. The wings of moth are white and provided with small hairs along the apical and anal margins. A number of black, pale and light brown spots are found on the fore and hindwings of the moth.

Life history. (Fig. 18). The caterpillars hibernate in winter and pupate in early spring. The adult moths appear in March-April. The female moth lays 80-120 creamy white eggs on the leaves, flower of young fruits. The eggs are laid either singly or in batches of 2-4 eggs each. After 3-6 days of incubation period eggs are hatched into caterpillars which start boring near the growing point of tender shoots of the host plants, fruits or into the flower buds. Single caterpillar can destroy 6 fruits. After 9-28 days the caterpillars become full-grown by passing through 5 stages of different instars. The mature caterpillars come out of their feeding tunnel and pupate amongst the fallen leaves forming boat shaped cocoons. The pupal period lasts for 6-17 days after which adult moth emerges out. The whole life cycle is completed in 20-43 days during active

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season. Five overlapping-generations have been recorded in one year. The life span of moth is of 2-5 days only.

Damage. The caterpillar is infective stage. It attacks the terminal shoots of young plants as a result the growing points of plants are killed. The caterpillars cut into the younger fruits under the calyx leaving no visible signs of infestation. Sometimes the whole of the crop is destroyed by the borers.

Prevention and control. (1) The affected fruits and drooping shoots, containing caterpillars inside, should be collected and destroyed.

(2) The spraying of carbaryl 10.15%, malathion 0.1%, diazinon 0.02%, endosulfan 0.05%, endrin 0.04% can control the pest population in the field.

(3) The biological agencies like Braconid wasps (*Bracon chinensis, Shirakia schoenobi*) and Ichneumonid wasps (*Trathela flavoorbitais, Pristomerus testaceus*) parasitise the larvae of this pest.

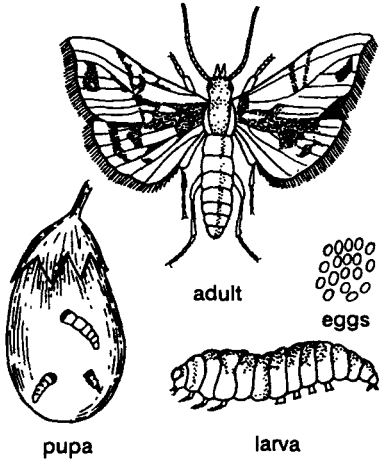

Fig. 18. Life history of *Leucinodes orbonalis.*

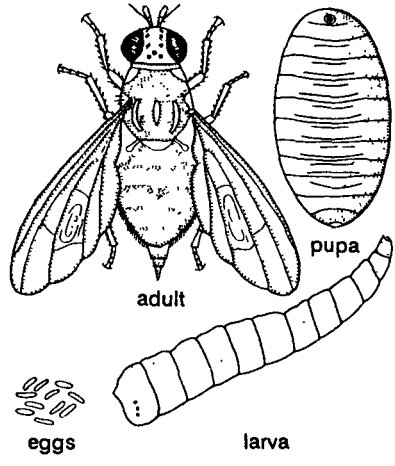

Fig. 19. Life history of *Dacus cucurbitae.*

5. *Dacus cucurbitae* Coquillett (Melon fruit-fly)

Class ..... Insecta
Order ..... Diptera
Family ..... Tephritidae
Genus ..... *Dacus*
Species ..... *cucurbitae*

Distribution. The melon fruit fly was first observed in Hawaii Islands in 1898 but since 1903 it has a wide range of distribution in Australia, Burma, China, East Africa, Formosa, India, Japan, Malaysia and Pakistan. It is commonly found damaging vegetables throughout India.

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Food plants. It is most destructive fruit-fly of musk-melon and pumpkins, and also found damaging other cucurbitaceous vegetables viz., Cucumber, torai, tomatoes and Karela.

General appearance. It is reddish brown fruit-fly having black and white spots. The wings are provided with brown bands and spots on the apex. Commonly it is found sitting in wing-spread position slightly more than the house fly. It measures about 7 mm in length and 3 mm in breadth with a wing expanse of about 14 mm. Some other species of *Dacus* are found damaging ripening fruits of mango, peach and guava.

Life history. (Fig. 19). The adult female fly just after emergence mates with the male at dusk and starts egg laying within 14 days. In winter season this preoviposition period may prolong. The fly selects suitable site for egg laying, makes cavity in soft fruits by the sharp ovipositor, lays about 12 cylindrical white eggs mostly in the evening hours. After egg laying the female releases a resinous secretion which cements the tissues near the puncture and makes it water-proof. One female lays, on an average, 58-59 eggs in 14-54 days. After 1-9 days of incubation period eggs are hatched into maggots. These maggots feed continuously on the pulp of the fruit resulting in its complete destruction. They can jump to a height of one foot which helps them in dispersal. The infested fruits decay due to secondary bacterial infection. The larva attains full grown adult stage after 3 days in summer and 21 days in winter and leaves the fruit. After falling down to the ground, they burrow in the soil up to the depth of about 5 cm and pupate there. The pupae are barrel-shaped and light brown in colour. The adult fly emerges out from the pupa in the morning hours after 6-9 days in rainy season and 21-28 days in winter. There are several overlapping generations in a year specially active throughout summer and autumn in Uttar Pradesh.

Damage. The damage is caused due to the maggots by feeding on the almost ripe fruits, riddiling them and polluting the pulp. The maximum damage is caused in July and August when about 50% fruits are under severe attack by this pest.

Prevention and control. (1) The infested fruits should be removed and destroyed regularly.

(2) Under the infested plants, constant stirring of soil should be perfomed.

(3) The fruits meant for food may be covered with cloth bags.

(4) The spraying of malathion 0.05% +molasses 1% or with trichorphon 0.15% is effective to control the pest.

(5) Dimethoate 0.03% is effective to decrease the pest population.

(6) The poison baits containing 500 gm of protein hydrolyzate and 2.5 kg of 50% malathion in 10 liters of water attracts and kills the adult flies.

(7) Natural enemies-several braconids like *Opius fletcheri* Silv. and *Opius compensans* Silv, parasitize the pupal stage of the pest and thus have a good checkup on population control.

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Pests of Fruits

1. *Idiocerus atkinsoni* Lethierry (Mango leaf-hopper)

Class ..... Insecta
Order ..... Hemiptera
Family ..... Jassidae
Genus ..... *Idiocerus*
Species ..... *atkinsoni*

Distribution. Mango leaf hoppers are widely distributed in India, Malaysia, Indonesia and Formosa. It is very much destructive in Bihar, Uttar Pradesh, Punjab, Maharashtra, Andhra Pradesh and possibly other states.

Food plant. They are monophagous, so feed only on mango.

General appearance. They are small insects of greyish brown colour measuring 5.1 mm in length. Dark grey wings are held roof like over the body. The head is broad and prominent and the hind legs are thickly covered with bristles. Two other species destroying the mango crop are *Idiocerus clypealis* Lethierry and *Idiocerus niveosparsus* in February from underneath the bark of trees. Now they start sucking the cell-sap.

Life history. (Fig. 20). They lay dull-white round eggs singly in the tissues of mango leaves, buds and flowers in the second week of February. The egg laying continues for few weeks. Single female can deposit an average of 200 eggs. After 4-6 days of incubation, egg hatches into tiny yellowish green coloured nymph which sucks the cell-sap of tender shoots, flowers and buds and excretes honey dew exposing the affected regions to fungal attack giving a dull blackish look to the mango trees. The nymphs resemble the adult but are wingless and legs are comparatively longer so they can jump from one place to other. The mature nymphs migrate to the stem and young leaves. Now, by passing through 3 stages in 8-13 days, nymph attains full grown size. The full grown nymph then moults, giving rise to winged adult hoppers. The whole life cycle is completed within 15-19 days. There is no feeding and egg laying in May-June. But they are crowded on the mango stem and undersurface of the leaves. On a slight disturbance they fly in all the direction. Normally, one generation is found but sometimes second generation starts with the onset of monsoon.

Damage. The nymphs and adults both are destructive stages which suck the cell-sap of young shoots, flowers and buds or entire inflorescence which dry and fall off. They secrete honey dew which covers the branches of the tree giving good surface for fungal growth. Thus, the growth of younger mango trees is hampered and older trees are unable to have much fruits. About 60% damage to mango crop is caused by mango hoppers.

Prevention and control. (1) Over-crowding of trees should be avoided as far as possible because it helps in spreading the pests.

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(2) The pest population can be reduced by spraying the trees with phosphomidon 0.02%, carbaryl 0.01% or endosulfan/dimethoate 0.03%.

(3) The trees should be sprayed with fish oil, resin wash or resin soap, kerosene or crude oil emulsion during winters before blossoms open.

(4) Natural enemies like *Pipunculus* sp. (Family : Pipunculidae order : Diptera) and caterpillars of *Epipyrops* sp. (Family : Epipyropidae, order : Lepidoptera) which feed on adult and *Dryinus* sp. (Family : Dryinidae, Order : Hymenoptera) parasitises the nymphs should be encouraged.

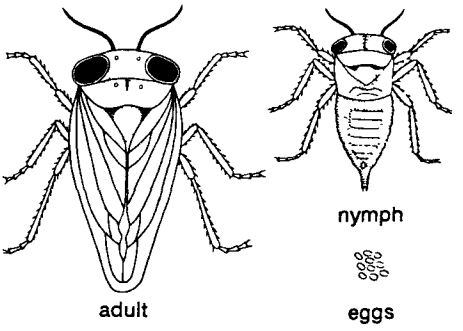

Fig. 20. Life history of *Idiocerus atkinsoni.*

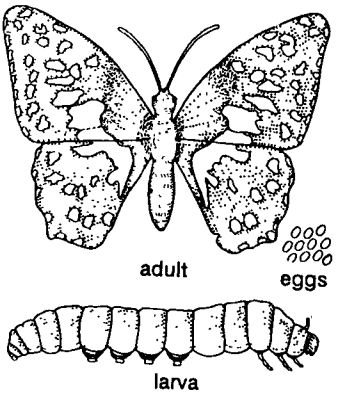

Fig. 21. Life history of *Papilio demoleus.*

2. *Papilio demoleus* Linnaeus (Lemon butter fly or Citrus caterpillar)

Class ..... Insecta
Order ..... Lepidoptera
Family ..... Papilionidae
Genus ..... *Papilio*
Species ..... *demoleus*

Distribution. The genus *Papilio* is distributed throughout the world. The lemon butterfly (*Papilio demoleus*) causes damage to citrus plants in Africa, Taiwan, India and Japan. In India, they are distributed all over the country.

Food plant. Citrus is the only host plant of this pest.

General appearance. It is a beautiful butterfly of large size measuring about 2.8 cm in length and 9.4 cm on wing expanse. It has black coloured head and thorax regions, whereas, creamy yellow coloured abdomen. The wings are dull coloured with yellow markings on them. Black coloured antennae are clubbed.

Life history. (Fig. 21). This pest is active throughout the year in plains but it hibernates in the pupal stage during severe winter on the hills. The female butterfly, after mating with male lays 75-200 eggs within 2-5 days, singly, on the under-surface tender shoots and leaves. The freshly laid eggs are smooth,

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rounded and pale or green coloured. After the incubation period of 3-4 days in summer and 5-8 days in winter, the eggs turn dark grey and are hatched into brown coloured caterpillars with white markings on the body. The young caterpillar emerges by cutting a hole in the egg-shell which becomes the food of the caterpillar. They prefer to feed on the young leaves of citrus. The full grown caterpillar is greenish with brown bands. Now full fed caterpillar becomes motionless while exposed commonly near the mid-rib and looks like bird droppings. They also discharge a repelling fluid at the time of any danger. The caterpillar stage lasts for 2 weeks in summer and 4 weeks in winter. Now it starts to secrete silken thread around its body and pupates on the leave, twigs or any other raised structure. The pupal period lasts for about 8-9 days in summer and 9-11 days in winter and butterfly emerges usually in the morning hours. The life span of the male is shorter (4 days) than the female (7 days). Four overlapping generations have been recorded in one year.

Damage. The caterpillars cause destruction of the citrus plants. They feed on the fresh leaves and terminal shoots. It has been observed that they start feeding from margin and reach the midrib. The severe attack by full grown caterpillars causes complete defoliation of citrus plants thus rendering them unfit for fruit bearing.

Prevention and control. (1) The caterpillars and pupae should be handpicked and killed.

(2) The spraying of 0.05% malathion is very much effective for the control of this pest.

3. *Cosmopolites sordidus* Germer (Banana weevil)

Class ..... Insecta
Order ..... Coleoptera
Family ..... Curculionidae
Genus ..... *Cosmopolites*
Species ..... *sordidus*

Distribution. It is a native of South East Asia and presently distributed throughout the banana growing countries viz., Australia, Hawaii Island, India, South Africa and Tropical America.

Food plant. It is monophagous insect so feed on banana plant only.

Life history. (Fig. 22). The female weevil makes hole inside the corm and lays only one egg in each. The process of egg laying is continued for few months and 10-50 eggs are laid by single female. After about 7 days of incubation period egg is hatched into a larva which bores inside the corm and makes a tunnel after few days of feeding. The larva attains full grown stage in 14-42 days and pupates inside the tunnel formed during larval stage. After 7 days, adult weevil emerges from the pupa and remains in the soil for some time. The

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weevil feeds on the underground part of the banana plant. In later stage they migrate towards the growing point for oviposition.

Damage. Only one genus of banana *i.e. Musa* is attacked by this pest. The weevils destroy the corm tissues and attack the seedlings which are destroyed or killed. The corms, tunneled by the weevil, sometimes break, but since the weevils do not attack the roots they (corms) do not topple over.

Prevention and control. (1) Cultural operations are most suitable to reduce the pest population by destroying the sheltering and feeding places of adult weevils.

(2) The pseudostems should be cut close to the ground and infested sucker never to be used for further planting.

(3) The pseudostem from which the bunches have been cut are chopped up, and scattered in the plantation, so that they rot quickly.

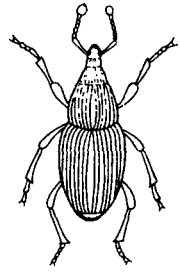

Fig. 22. *Cosmopolites sordidus.*

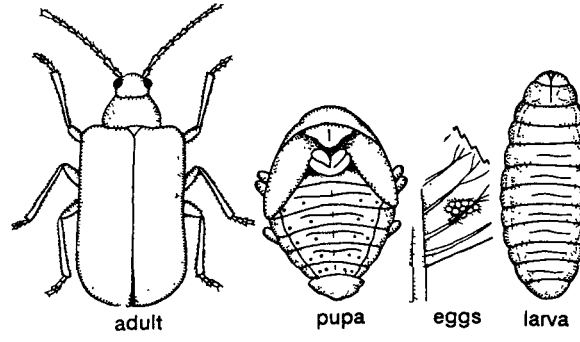

Fig. 23. Life history of *Galerucella birmanica.*

4. *Galerucella birmanica* Jacoby (Singhara bettle)

Class ..... Insecta
Order ..... Coleoptera
Family ..... Chrysomelidae
Genus ..... *Galerucella*
Species ..... *birmanica*

Distribution. It is distributed throughout the singhara growing belt of several states like Bihar, Uttar Pradesh, Madhya Pradesh, Delhi etc. It is also found in Pakistan, Sri Lanka and Burma.

Food plant. Singhara is the only host plant of this pest.

General appearance. The adult beetle is blackish brown in colour and about 6-8 mm in length.

Life history. (Fig. 23). The female after mating, lays eggs in clusters of 6-10 eggs each on the upper surface of singhara leaves. The maximum number of eggs laid by the beetle is about 254 in her whole life time. After 6-9 days

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of incubation period eggs are hatched into young grubs which are light brown in colour and attain full grown stage by passing through 4 moults after an interval of 3-5 days each. The full grown grub is dark brownish-grey in colour of about 8 mm in length. After 16-20 days the grub changes into pupa among singhara and other aquatic leaves. The pupa is oval in shape, orange red in colour with dark brown patches. The pupal stage exists for 5-7 days after which the adult beetle emerges out. The active period of adult phase starts from the beginning of July when they start laying eggs on seedling. If these seedlings are cut, the pest may disperse to different area. There may be 12-17 overlapping generations in one year.

Damage. Most of the singhara growing areas are affected by the pest. Beetles and grubs booth are destructive stages which feed on leaves of singhara plant floating on water surface. The infested leaves are riddled with holes and rendered useless thus checking the growth of plant and formation of flowers and fruits. Heavily infested crop looks blackish in the field. Severe infestation has been noticed from July to January but chiefly during August and September.

Prevention and control. (1) The adults and egg masses should be collected from leaves and destroyed in the beginning stages.

(2) The dusting of Carbaryl 5% on crop @ 15-20 pound per acre is effective. After an interval of about 10 days 2 or 3 dusting operations should be performed.

Pests of Cotton

1. *Earias vitella* Fabricius =*Earias fabia* Stoll (Spotted boll-worm)

Class ..... Insecta
Order ..... Lepidoptera
Family ..... Cymbidae
Genus ..... *Earias*
Species ..... *vitella*

Distribution. There are two species of spotted bollworms viz., *Earias vitella* and *Earias insulana*. Both the species are distributed in India, North Africa and Pakistan. The regions with greater rainfall are infested by *E. vitella* whereas, *E. insulana* attacks cotton crop in dry region.

Food plants. The main host plant is cotton but they are also found feeding on lady's finger (Bhindi), hollyhock, Deccan hemp, Shoe flower, Okra and some other malvaceous plants.

General appearance. *Earias vitella* is a small moth measuring about 12 mm in length and about 25 mm across the wings. The fore-wings have a broad green band extending from the base to the apex. The forewings of *E. insulana* are of greenish colour and the hindwings of both the species are of white colour.

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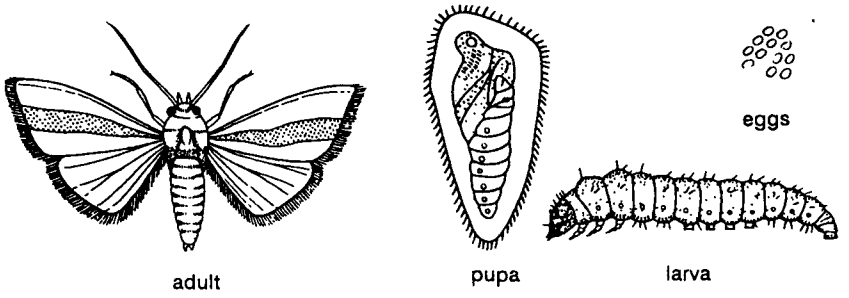

Fig. 24. Life history of *Earias vitella.*

Life history. (Fig. 24). The pest remains active and breeds throughout the year but in winter only pupae are found in debris. The pest is found in abundance during July to September.The adult moth appears in April, lays 200-400 eggs singly on bolls, bracts, shoots, flowers, top render leaves and buds. The hairy parts of the plant are most suitable for egg laying. The eggs are spherical and bluish green in colour. After an incubation period of 3-4 days in summer and 7 days in winter eggs are hatched into brownish white caterpillars provided with a dark head and prothoracic shield and measures about 13 mm in length. They start boring into the tender shoots and later on into flowers and bolls. The caterpillar passes through 6 stages of different instars and becomes full-grown in 10-15 days. The full-grown larva is brownish, measuring about 20 mm in length and provided with a patch of green, white, black and orange colours. The body is tapering towards both anterior and posterior sides. The full fed caterpillar moves out of boll and pupates in tough grey silken cocoon either on the plant or on the ground among fallen leaves. The pupal period lasts for about 15 days in summer, 21 days in autumn and 42-84 days in winter, and the moth emerges out. The whole life cycle is completed in about one month in summer. Eight overlapping generations are found in a year. The pest is carried from year to year by the roots of cotton plants and plants of bhindi left in the field with some fruits.

Damage. The infective stage is the caterpillar. The attack of this pest begins with the rain and continues all the year round except in winter. When the cotton plants are of 6-9 inches, the caterpillar bores into the top tender part of shoot which withers and droops causing 8-60% damage to crop. The caterpillars attack when the flower, bud and boll appear. A number of holes are found on the infested bolls plugged with excreta. One caterpillar can destroy many bolls in its life span of about one month. The infested bolls open prematurely and produce poor lint which fetches a lower price.

Prevention and control. (1) In the beginning stage during June-July the attacked shoots and bolls should be collected and destroyed.

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(2) At the time of attack from August onward all the infested flowers, buds and bolls infested as well as fallen should be collected and destroyed. Such plants should be shaken by dragging a rope over them so that attacked bolls may be dropped off the plants.
(3) All the alternate host plants should be destroyed from that area.
(4) After the crop is over the fruits of bhindi should not be left on plants.
(5) Resistant varieties only should be grown.
(6) Spray of carbaryl 0.1% at 15 day interval during August-September suppresses the pest population.
(7) Dusting of 5% fenitrothion at the rate of 25 kg/hectare is also effective.

2. *Pectinophora gossypiella* Saunders (*Platyedra gossypiella* Saunders) (Pink boll-worm)

Class ..... Insecta
Order ..... Lepidoptera
Family ..... Gelechiidae
Genus ..... *Pectinophora*
Species ..... *gossypiella*

Distribution. It is a cosmopolitan pest wherever cotton is grown. It is found in America, Africa, Australia and Asia. In India it is most destructive pest of cotton and is found in Andhra Pradesh, Uttar Pradesh, Punjab, Tamil Nadu and Maharashtra. The pest was first reported in the 19th Century from Mumbai.

Food plants. Cotton is the main food plant of this pest, but it feeds on lady's finger, hollyhocks, okra and other malvaceous plants also as an alternate host.

General appearance. It is a small grey brown moth measuring 8-9 mm across the spread wings and is provided with blackish spots on the forewings. The margins of hindwings are deeply fringed. The antennae are filiform. Moth flies around after dusk and hides during the day.

Life history. (Fig. 25). The pest passes winter as larva in the cocoon and few larvae may pupate in the last week of March and adult moths emerge in the first week of April. The formation of pupae from larvae takes place generally after the onset of monsoon so that large number of adults emerge out during July to the middle of August.

The female lays elongated flattened eggs singly or in clusters of 2-10 eggs on the bolls, leaves, flowers and buds. The freshly laid eggs are translucent whitish which later turn yellowish brown and deep brown before hatching. Single female can lay about 300 eggs. After 4-23 days of incubation, eggs are hatched into pale yellow coloured caterpillars with a dark head and greyish prothoracic shield. The newly hatched caterpillar bores soon into the bud, boll, shoot and flowers and the hole through which it enters the bolls is closed soon. It grows to the length of about 12 mm with pink body, brown head and 2 lateral grey strips. The caterpillar attains full grown stage at an age of 10-29 days. Sometimes

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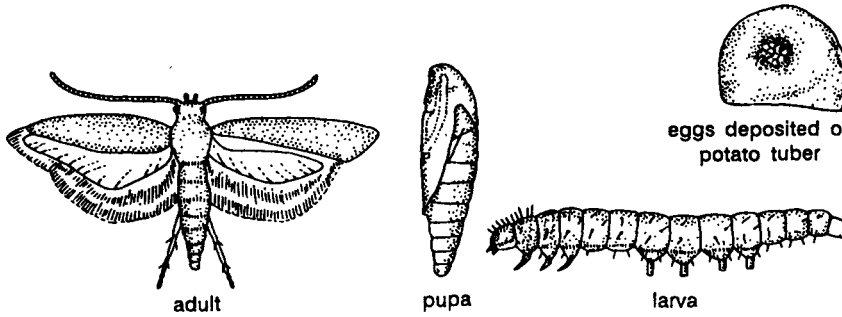

Fig. 25. Life history of *Pectinophora gossypiella.*

larval period may be prolonged to 2 years due to over-wintering. Now few caterpillars set their wayout to pupate in a silken cocoon in soil or under fallen leaves. After about 7 days of pupal period adult moth emerges out which starts mating the next night and commences oviposition on the second to fourth night, after which the female dies. The whole life cycle is completed in about 3-8 weeks. Four-five generations have been recorded between July-November.

The hibernating caterpillars keep themselves feeding on the bolls. They cut window holes in two adjoining bolls and join them together forming 'Double seed'. These double seeds are commonly left unpicked in the field, fall to the ground and become major source of infestation for the next year when they emerge as moths after passing winter. The life cycle is very long (5-10 months). Thus, the pest has two types of life cycle i.e. short life cycle and long life cycle.

Damage. Caterpillar is the only infective stage which bores the flowers, buds, shoots and bolls of cotton. The caterpillar bores inside the boll making a hole. Further, the hole is held up so it becomes impossible to identify the infested boll. Single boll may be attacked by 10 caterpillars. During the months of December and January 75–100 % bolls are damaged. American cotton is more heavily infested than the indegenous ones. The attacked seed cotton gives a poor ginning percentage, least oil extraction and poor spinning quality of cotton. Due to the attack of this pest there is excessive shedding of the fruiting bodies.

Prevention and control. Little can be done for the control of this pest when the attack is already on because caterpillars are most resistant against any control measure.

(1) The seed should be kept under 'Sun Heat Treatment' before sowing, by exposing for 3-5 hours in May-June to kill hibernating larvae.
(2) All the fallen leaves, bolls, cotton sticks should be collected and destroyed.
(3) The infested bolls should be picked up and destroyed.
(4) Ratooning of cotton should not be practised in attacked area.
(5) The infested area should be flooded or irrigated and ploughed which destroys the hibernating caterpillars in the field.

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(6) In the infested area, a rabi crop (gram, pea, etc.) should be grown after harvesting the cotton.
(7) Cotton seed should be heated at about 140 F by 'Simon Cotton Seed Heater' to kill the hibernating caterpillars.
(8) Seed should be fumigated with carbon-di-sulphide or methyl bromide at 5 cc of fumigant per 100 kg of seed. The ginning factories should also practice the fumigation method to destroy the gin-trash.
(9) Early ripening varieties of cotton should be sown and last picking should be performed earlier.
(10) The pest population can be reduced by spraying carbaryl 0.1% or endosulfan 0.05% at 15 days interval during August-September.
(11) Some natural enemies viz: mites, *Microbracon greeni* and *M.lefroyi* and *Oxycarenus laetus* have been noticed but none of them has been found to be effective for the control of this pest.

3. *Dysdercus koenigii* Fabricius =*Dysdercus cingulatus* =Fabricius (Red cotton bug)

Class ..... Insecta
Order ..... Hemiptera
Family ..... Pyrrhocoridae
Genus ..... *Dysdercus*
Species ..... *koenigii*

Distribution. This pest is distributed in India, Australia, Philippines and Sri Lanka. In India it is a serious pest of cotton in Uttar Pradesh, Bihar, Andhra Pradesh, Tamil Nadu and Maharashtra.

Food plants. Cotton is the main host plant of this pest. Apart from cotton, it also feeds on lady's finger, maize, hollyhock and Deccan hemp.

General appearance. The bug is a blood red pest. Females are longer (15mm) than the males (12 mm). They are provided with white bands across the abdomen. The membranous portion of their forewings, antennae and scutelium are black. Mouth parts are adapted for piercing and sucking. They form a straight beak of rostrum.

Life history. (Fig. 26). The pest is active throughout year and passes winter in the adult stage. The female lays eggs during spring in cluster of 70-80 eggs each under the moist soil surface, fallen leaves and in crevices. The eggs are spherical, yellowish-white about 1.2 mm in length. After about 7 days of incubation period in warm and moist weather, eggs are hatched into active 1 mm long red coloured nymphs which resemble the adult except in size. The wings are absent in nymphs. The nymphs feed gregariously on the cotton bolls. The female nymphs are longer than the male. The nymphs attain the adult stage by passing through 5 moults within 49-89 days. In winter, the life of the adult is about 3 months but in summer the life is very much variable. Pest breeds on

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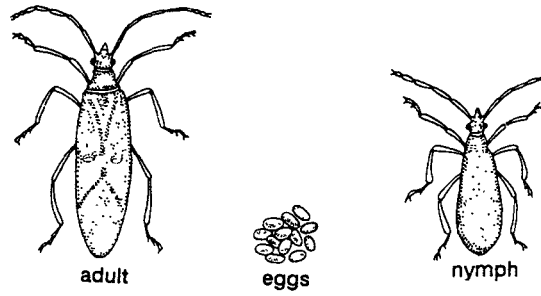

Fig. 26. Life history of *Dysdercus koenigii.*

cotton from August-November, takes shelter under leaves or debris from December-Middle of March and feeds on bhindi from April-July.

Damage. The bug sucks cell-sap of green bolls of cotton and leaves. If the attack is severe, bolls open badly and the lint is of poor quality. The seeds of infested cotton have low percentage of germination. The lint is stained by excreta of bugs or by their body juice as they are crushed in the ginning factories.

Prevention and control. (1) Cotton field should be ploughed to expose the eggs to sun light.

(2) Insects should be hand-picked and killed in kerosenised water.

(3) The crop of bhindi should be sown as trap crop and pests, collected there, should be destroyed.

(4) Moistened cotton seeds should be hung up at different place in the field where bugs congregate. They may be killed there by kerosenised water.

(5) Spraying of malathion 0.05% is effective to control the pest.

(6) Spraying of 1 litre endosulphan 35% EC, 0.25 litre phosphamidon =100% EC or 1 litre Fenitrothion 100% EC per hectare is very effective to reduce the pest population.

Pests of Oil Seed Crops

1. *Bagrada cruciferarum* Kirkaldy =*Bagrada picta* Fabricius (Painted bug)

Class ..... Insecta
Order ..... Hemiptera
Family ..... Pentatomidae
Genus ..... *Bagrada*
Species ..... *cruciferarum*

Distribution. It is widely distributed in Arabia, Burma, India, Iraq, Sri Lanka and East Africa.

Food plants. It feeds on mustard, rape and other cruciferous plants like cabbage, cauliflower, radish etc.

General appearance. The adult bug is flat, bright black coloured with reddish yellow spots and dots, and measuring 5-7 mm in length. The scutellum

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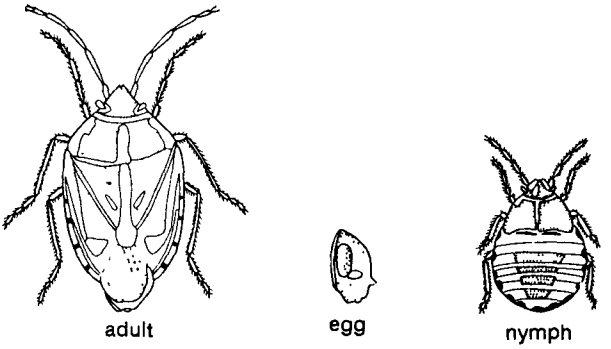

Fig. 27. Life history of *Bagrada cruciferarum*

is very large, at least half as long as the abdomen. The proboscis sheath is 4 jointed. The adults are very tenaceous and can survive under scarcity of food.

Life history. (Fig. 27). The pest is active from March to December. The adult stages, during winter, are found under the heap of dried oil seed plants lying in the field. The female bug lays 90- 218 oval, pale-yellow eggs singly or in clusters of 3-8 on the leaves, pods, stalks and on the soil. After the incubation period of 3-5 days in summer and 20 days in December-January eggs hatch into nymphs which resemble the adults except that they are smaller in size. The nymphs on emergence start feeding on the plants, pass through 5 different stages of instars and attain the adult stage after nymphal period of 16-22 days in summer and 25-34 days in winter. The whole life cycle is completed in 19-54 days. Nine over-lapping generations have been recorded in one year. The pest is most destructive from February to April in Uttar Pradesh.

Damage. Nymph and adult both are destructive stages which suck cell-sap from leaves and developing pods which consequently turn yellow and fall off, exposing the plant to bacterial and fungal attack through the punctures made by insects. Both the nymphs and adults excrete a resinous substance which destroys the pods.

Prevention and control. (1) The adults should be collected by hand nets and destroyed.

(2) Stubbles of old infested crops should be burnt.

(3) Dusting with pyrethrum dust (Pyro dust 4000) at the rate of 30-40 kg per hactare kills the insect.

(4) Pyrethrum extract, diluted 1000 times with water, should be sprayed at the rate of 80-100 gallons per acre. The spraying should be repeated after 10 days.

(5) The spraying of diazinon 0.02%, malathion 0.1%, dimethoate 0.03% is also effective to reduce the damage caused by the pest.

(6) The parasites *Liophanurus samueli,* Mani and *Typhodytes* sp. parasitize the eggs and *Alophora* sp. are known to parasitize the nymphs and adults.

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2. *Athalia lugens proxima* Klug.
=*Athalia proxima* Klug.
(Mustard sawfly)

Class ..... Insecta
Order ..... Hymenoptera
Family ..... Tenthredinidae
Genus ..... *Athalia*
Species ..... *lugens proxima*

Distribution. It is widely distributed in Indonesia, Taiwan, Burma and Indian sub-continent.

Food plants. Mustard, cabbage, cauliflower, tori, turnip, radish and other cruciferous plants.

General appearance. The sawflies are orange-yellow small insects of 4-5 m. rovided with black markings on the body. They have 2 pairs of dark coloured wings with black veins. The adults are active during the day time. The ovipositor of female is found to be saw-like. They are unable to fly for a long distance.

Life history. (Fig. 28). The adult female lays 30-35 eggs only in her life span of 2-8 days. The eggs are laid into the slit made by saw-like ovipositor in the tissues of leaf. After 4-8 days of incubation period eggs are hatched into larvae which feed on leaves in groups of 3-6 larvae from the edge inwards during the morning and evening periods. In day time the grubs are found hidden in leaves. If they are disturbed, they fall down to the ground and show feigned death. The young grub is greenish grey and hairless. The grubs attain full grown stage in 16-35 days by passing through 7 stages of different instars. The full grown grub is blackish in colour. The full fed grubs descend from the plant and enter into the soil to a depth of 25-30 mm and pupate there in the water-proof oval cocoons made of silk. After 11-31 days of pupal period adult emerges out in the month of October. The whole life cycle is completed in 31-74 days. Two-three generations have been recorded from October to March.

Damage. The grubs are the only destructive stage which attack from October to March in cold weather. They feed on the leaves of host plants and make holes causing stunting or dryness of plant. In case of severe infestation all the leaves and even epidermis of shoots are eaten by the grubs causing death of the host plant.

Prevention and control. (1) The young grubs should be hand-picked and destroyed.

(2) The spraying of 0.033% diazinon or thiodon is effective.

(3) Dusting of attacked crop with 2% folidol dust at about 25 kg per hectare is found to be very effective in reducing the pest population.

(4) The treated plants should not be used for human or animal consumption for at least 15 days.

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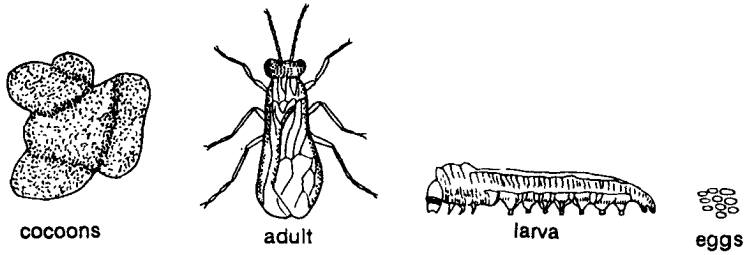

Fig. 28. Life history of *Athalia lugens proxima.*

Pests of Coconut Palm

1. *Oryctes rhinoceros* Linnaeus (Rhinoceros beetle)

Class ..... Insecta
Order ..... Coleoptera
Family ..... Scarabaeidae
Genus ..... *Oryctes*
Species ..... *rhinoceros*

Distribution. It is distributed throughout South East Asia, Southern China, Philippines and South Pacific Islands.

Food plants. They feed on coconut, date-palm and palmyra.

General appearance. It is elongated cylindrical beetle measuring about 5 cms in length. The body is stoutly built and is provided with a pointed horn of its head. The wings are very well developed and fit for flying up-to long distances.

Life history. The female, after attaining the age of 20 to 60 days, starts mating and lays 100 to 150 eggs below the soil surface preferably in the decaying organic matter. The eggs are oval and white coloured. Since they are laid inside the soil, any of the early developmental stages are not found on the tree. The eggs after 8-18 days of incubation period hatch into grubs which start feeding on the decaying matter around that area. The grub takes about 130 days to pass through 3 stages of different instars and pupates inside the chamber in the soil at a depth of about 30 centimetres. After 11-20 days of pupation period, adults emerge in the form of soft bodied beetles and fly towards the palm trees of the locality and start damaging the host plant. The beetles are active at night and are attracted towards light. Life span of adult is about 200 days. Only one generation of this beetle is completed in one year.

Damage. The adult causes infestation to the coconut trees. While feeding the young fronds they make burrows and throw out a fibrous mass. The infestation is marked by a number of holes on the fronds when they open out. The attack results in the destruction of growing plant, as a result of which the tree dies. The infestation causes more harm to young trees.

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Prevention and control. (1) The earlier developmental stages of beetles should be destroyed by tackling the breeding place like manure pits near gardens by spraying 0.01% aldrin.

(2) The beetles should be destroyed by inserting specially designed hooked rod of about 75 cm into the crown.

(3) The infested trees should be cut and destroyed.

2. *Rhynchophorus ferrugineus* Olivier (Red palm weevil)

Class ..... Insecta
Order ..... Coleoptera
Family ..... Curculionidae
Genus ..... *Rhynchophorus*
Species ..... *ferrugineus*

Distribution. It is distributed in India, Pakistan, Sri Lanka, Malaysia, Bangladesh, New Guinea and Philippines. In India it causes severe infestation in Assam, Tamil Nadu, Kerala, Orissa, Mysore and Maharashtra.

Food plants. It feeds on palm trees of soft tissues including coconut, the date-palm and the sago-palm.

General appearance. It is a cylindrical weevil of reddish-brown colour, provided with long curved snout. The male is provided with a tuft of hair on the dorsal side of the snout but the female is devoid of such hairs. The adult is diurnal and capable of flying.

Life history. The female after mating prepares a small hole in the soft tissues of the host with the help of her snout. She lays an oval white coloured egg in the hole thus prepared. Single weevil can lay 200 to 500 eggs in her life span of 3 to 4 months. After 2 to 5 days of incubation period eggs are hatched into soft whitish grubs which feed on soft tissues resulting in the formation of tunnel inside the trunk of tree. The full fed grubs attain the length of about 65 mm and now colour changes to yellow. After 2 to 4 months of larval period grub changes into pupal stage after spinning the cocoon. After about 14 days of pupal period adult emerges from the cocoon but remains within the case of cocoon for 11 to 18 days. The life span of adult varies from 50 to 113 days and in case of males it is longer than the females.

Damage. The larval stage causes damage by feeding on soft tissues of trees. They prefer to feed on the soft growing parts of the plant. As a result number of holes are formed in the plant. The adults are attracted towards host plants by a special smell of the palm juice flowing out from the wounds on the tree.

Prevention and control. (1) The attraction of this weevil towards palm tree may be checked by avoiding wounds on the tree.

(2) The fallen trunks or tree stumps should be disposed off from the field.

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(3) By pouring the emulsions of dimethoate 0.5% or lindane 1.0% into the holes, insects can be killed easily.

(4) Damaged trunks should be sprayed by 0.1% dieldrin solution to have a check on the pest population.

3. *Nephantis serinopa* Meyrick (Black-headed caterpillar)

Class ..... Insecta
Order ..... Lepidoptera
Family ..... Cryptophagidae
Genus ..... *Nephantis*
Species ..... *serinopa*

Distribution. It is distributed in India, Burma and Sri Lanka. In India it is a very notorious pest along the Western coast.

Food plant. It feeds on coconut palm.

General appearance. It is ash-grey coloured moth which measures 10 to 15 mm in body length. With its full wing expanse this moth attains 20-25 mm length.

Life history. The female moth after mating lays about 125 eggs in small groups on the under surface of the tip of old leaves of palm. The eggs at the time of laying are of creamy white colour which changes into pink colour before hatching. After 3 to 5 days of incubation period in summer and 10 days in winter eggs hatch into larvae of about 1.5 mm. The larva feeds on the green food materials forming a silken gallery in which it feeds and voids frass. After 40 days of larval period it attains the length of about 15 mm and changes into brown coloured pupa inside the gallery. After 12 days of pupal period a white adult moth emerges out from the pupa.

Damage. The caterpillar is the damaging stage which feeds inside the silk galleries made while feeding. A number of galleries are formed inside the trunk of tree, as a result the foliage dries up. The infestation by the black-headed caterpillars can be marked by the dried up patches in the fronds. Sometimes when ecological conditions favour the pest, the extent of damage causes high degree of economic loss.

Prevention and control. (1) The first attacked fronds should be cut and burnt during the primary stages of infestation.

(2) The parasitic insect, *Trichospilus pupivora* Ferriere (Hymenoptera), should be exercised in infested areas for biological control of the pest.

(3) The spraying of 0.2% BHC can kill 80% population of pests in the field.

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Pest of Tea

***Helopeltis atonii* Signoret**
(Tea mosquito bug)

Class ..... Insecta
Order ..... Hemiptera
Family ..... Miridae
Genus ..... *Helopeltis*
Species ..... *atonii*

Distribution. This pest is distributed in India, Sri Lanka, Indonesia and Vietnam. In India it is distributed in Southern region of the country.

Food plants. They mainly feed on tea plant but a number of alternate host plants like cashewnut, guava-fruit and some medicinal plants are also damaged by this pest in Mysore.

General appearance. The male bug is black coloured while the female is orange coloured across the shoulders. The adult is slender, 6 to 8 mm long and agile having good capability of flying. In the day time they are found concealed on the lower surface of the leaf.

Life history. The female bug lays about 500 elongated, sausage-shaped eggs in the axis of leaves and in the buds. The eggs after 5 to 27 days of incubation period, are hatched into wingless nymphs. The nymph looks like a spider due to absence of wings and presence of the long appendages. The nymph takes about 15 days in summer and 55 days in winter to complete its development through 5 moults to attain the adult stage. The bugs prefer the tea bushes of moist and warm places.

Damage. The nymphs and bugs both are destructive stages which puncture the leaf frequently to suck the juice from plant. During the course of feeding they eject the saliva so the tissues at the feeding site are necrosed and changed into brown coloured patch, as a result the whole of the leaf becomes black and ultimately falls down. If infestation is severe, tea plants suffer from defoliation and the shoot dies as a result of which the plants look like brooms.

Prevention and control. (1) The pest population can be reduced by collecting hand-nets early in the morning and late in the evening to kill the adults and nymphs easily.

(2) The spraying of malathion 0.05% on tea plantation is very effective. One should be very careful for residual problems of toxicity, so low values of insecticides are fixed before spraying

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Pests of Coffee

1. *Xylosandrus compactus* Eichhoff (=*Xyleborus morstatti* Hugedorn) (Coffee shoot-hole borer)

Class ..... Insecta
Order ..... Coleoptera
Family ..... Scolytidae
Genus ..... *Xylosandrus*
Species ..... *compactus*

Distribution. It is distributed in the southern part of India.

Food plant. The pest feeds on coffee plants but robusta coffee is most preferred.

General appearance. The adult beetle is cylindrical in shape and dark brown in colour.

Life history. The female beetle lays eggs into the tunnels, prepared by boring into bark of tertiary branches of plantation. A large number of tunnels are formed by the beetle. Single female can lay about 50 eggs. After about 7 days of incubation period eggs are hatched into white, apodous larvae. These larvae feed on ambrosi, a fungus, which grows on the excreta of beetle inside the tunnel. After 20 days of larval period they attain full grown stage and form cocoon near the exit. After 20 days of larval period they attain full grown stage and form cocoon near the exit. After 10 days, pupa emerges into adult beetle. The life cycle is completed between 35-40 days. Many generations have been noticed in one year.

Damage. The adult and larva both cause infestation. They form tunnel inside the branches of coffee, resulting into wilting, defoliation and ultimately plant dies. The surface area gets decolourised around the shot-holes. The secondary infection caused by the micro-organisms results into the death of shoots.

Prevention and control. (1) The infested shoots should be removed or destroyed in earlier stages.

(2) The spraying of 0.03% parathion, 0.02% endrin or 0.05% malathion is very effective for the control.

2. *Xylotrechus quadripes* Chevrolat (Coffee stem-borer)

Class ..... Insecta
Order ..... Coleoptera
Family ..... Cerambycidae
Genus ..... *Xylotrechus*
Species ..... *quadripes*

Distribution. It is distributed in India, Bangladesh, Sri Lanka, Burma and Africa.

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Food plant. It feeds on the apical leaves and buds of Jute.

Food plant. It feeds on the stem of coffee.

General appearance. The adult is black-brown coloured provided with prominent antennae. It is 1.25 cm in length. The characteristic yellow bands are found on the elytra of the beetles.

Life history. The female beetle, after fertilization lays eggs in the cracks and crevices of the primary branches or trunk. One female can lay about 100 eggs in 20-28 days. A after 10 days of incubation period eggs are hatched into caterpillars. The caterpillars start feeding on soft bark but later on they bore into the woody tissues resulting in the formation of tunnel in multidirections and remain there for 10 months. After attaining full grown stage, the caterpillar cuts an exit and pupates inside the tunnel near the exit. After about 30 days of pupal period adult beetle emerges out form the puparium. The emergence of adult takes place either in the months or April-May or September- December but only one generation is completed in one year. The autumn season is favourable for the emergence.

Damage. The larva causes infestation which bores into the coffee stem forming tunnels inside the shoot. The infestation causes killing of young plants and the older plants become unhealthy. If infestation is severe, the plantation may have to be abandoned or replanted.

Prevention and control. (1) The affected shoots along with borers should be removed and destroyed.

(2) At the time of egg laying the beetles can be hand-picked and killed.

(3) The eggs and young borers should be dislodged with the help of tough brushes.

(4) Spraying of 1% BHC reduces the extent of damage by borers.

Pests of Jute Crop

1. *Anomis sabulifera guenee* (The jute semilooper)

Class ..... Insecta
Order ..... Lepidoptera
Family ..... Noctuidae
Genus ..... *Anomis*
Species ..... *sabulifera*

Distribution. It is distributed in India, Bangladesh, Sri Lanka, Burma and Africa.

Food plant. It feeds on the apical leaves and buds of Jute.

Life history. The female moth lays eggs at the underside of young leaves. One female can lay about 150 eggs and all the eggs are laid singly. After 2 days of incubation period eggs are hatched into tiny caterpillars which start feeding on buds and apical leaves. The caterpillars, after 5 moults, during

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17 days, attain full-grown stage measuring about 4 cm in length. After completion of larval period, pupation takes place either on the plant or in the soil. After about 7 days of pupation period in summer, the adult moth emerges out but in winters it undergoes diapause phase and spends complete winter in pupal stage. The life cycle is completed in about 26 days in summer. A number of generations are completed in one year.

Damage. The caterpillar is the destructive stage feeding on the foliage. The half grown plants are severely attacked. The second generation may cause 90% damage to the crop under severe conditions. The top 10 leaves are commonly damaged causing retardation in the plant growth.

Prevention and control. (1) The infested field should be ploughed after harvesting to kill the pupae.

(2) By drawing a rope across the young crop, the caterpillars should be dislodged.

(3) The infested crop should be sprayed with **0.02% endrin and 0.04%** methyl parathion.

2. *Phenacoccus hirsutus* Cr (The jute mealy-bug)

Class . . . . . Insecta
Order . . . . . Hemiptera
Family . . . . . Coccidae
Genus . . . . . *Phenacoccus*
Species . . . . . *hirsutus*

Distribution. It is distributed in India and Bangladesh.

Food plant. It feeds on roselle fibre crop *(Hibiscus sabdariffa)* which is an important fibre allied to jute.

General appearance. The males are slender and provided with a pair of delicate wings. The female is sac-like in appearance, measuring about 3 mm in length and devoid of wings.

Life history. The female lays pink cylindrical eggs on the plants. The eggs laid remain inside the ovisacs. The eggs have rounded ends measuring about 0.3 mm in length. After 7-14 days of incubation period, nymphs emerge in batches from the ovisacs. The emergence of nymphs is in accordance with the sequence of egg laying batches. The nymphs after emergence crawl out on the host and settle down at a suitable spot.

Damage. The adult females and nymphs cause damage by feeding on the apical parts of plant, as a result the infested plant becomes stunted. The bushy-top is the symptom of the infestation by this mealy bug.

The infestation causes degradation in the quality of the fibre and the loss in the yield of fibres.

Prevention and control. The spraying of nicotine sulphate 0.5% or methyl parathion 0.01% is very effective.

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3. *Apion corchori* Marshall (The jute weevil)

Class ..... Insecta
Order ..... Coleoptera
Family ..... Apionidae
Genus ..... *Apion*
Species ..... *corchori*

Distribution. It is distributed in all jute growing areas of India and Bangladesh.

Food plant. This weevil feeds on jute plant.

General appearance. This weevil is brown or dull black coloured which is provided with small whitish setae on the body. It is 1.8 mm in length and 0.8 mm in breadth. The adult passes its winter in the bushes, hedges and shrubs and starts egg laying at the time of new crop.

Life history. In the active season, the female makes holes in the stem and lays eggs of about 0.4 mm in length. A single female can lay about 690 eggs during her whole life span. The bases of the petioles are the common sites for egg laying. After 3-5 days of incubation period, eggs hatch into larvae and feed on surrounding tissues. After 8-11 days of larval period the full fed stage of larva develops. At this stage the larvae are of about 2.8 mm in length and they make a chamber inside the stem and pupate there. After 4-6 days of pupation period the adult weevil emerges out from pupal case through a hole prepared by larvae or by the emerging adult weevil. The life cycle is completed in 15-24 days. The life span of the adult may be of 200 days. Many overlapping generations are found during the jute season.

Damage. The adult and the larva both are damaging stages. The females make a number of holes for egg laying affecting the quality of fibres. The larvae, feeding inside the stem also injure the quality of the fibre.

Prevention and control. (1) The infested plants should be removed from the field and destroyed.

(2) The stubble should be collected and destroyed after harvesting the crop.

(3) 0.03% methyl parathion can kill the grubs inside the plant.

(4) 0.02% endrin can kill the adult weevils very easily.

IMPORTANT QUESTIONS

» ***Long answer type questions***

1. Enumerate the pests of sugarcane and also give the life history, nautre of damage and prevention and control of two important sugarcane pests.
2. Enumerate the pests of paddy and give the life history, nature of damage and also prevention and control of any two paddy pests.
3. Give an account of the life history, nature of damage and prevention and control of gram pod borer and gram cut worm.
4. Enumerate the pests of vegetables and also given the life history, nature of damage and prevention and control of any two vegetable pests.

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5. Enumerate the pests of fruits and also give the life history, nature of damage and prevention and control of any two pests of fruits.
6. Enumerate the pests of cotton and also give the life history, nature of damage and prevention and control of any two pests of cotton.
7. Give an account of the life history nature of damage and prevention and control of *Bagrada cruciferarum* and *Athalia lugens.*

» ***Short answer type questions***

1. Give an account of the nature of damage, prevention and control of *Pyrilla perpusilla* and *Emmalocera depressella.*
2. Give an account of the nature of damage, prevention and control of *Leptocorisa varicornis* and *Tryporyza incertulas.*
3. Give an account of the nature of damage, prevention and control of *Heliothis armigera* and *Agrotis ypsilon.*
4. Give an account of the nature of damage, prevention and control of *Raphidopalpa foveicollis* and *Pieris brassicae.*
5. Give an account of the nature of damage, prevention and control of *Idiocerus atkinsoni* and *Papilio demoleus.*
6. Give an account of the nature of damage, prevention and control of *Earias vitella* and *Pectinophora gossypiella.*
7. Give an account of the nature of damage, prevention and control of *Bagrada cruciferarum* and *Athalia lugens.*

» ***Very short answer type questions***

1. Define the formation of dead-hearts in sugarcane.
2. Give name of the host plant of *Pyrilla perpusilla* or *Chilo infuscatellus* or *Tryporyza nivella* or *Bissetia steniellus.*
3. Give name of the host plant of *Leptocorisa varicornis* or *Tryporyza incertulas* or *Pachydiplosis oryzae* or *Spodoptera mauritia.*
4. Give name of the host plant of *Raphidopalpa foveicollis* or *Pieris brassicae* or *Leucinodes orbonalis.*
5. Give name of the host plant of *Idiocerus atkinsoni* or *Papilio demoleus* or *Galerucella birmanica.*
6. Give name of the host plant of *Earias vitella* or *Pectinophora gossypiella* or *Dysdercus koenigii.*
7. Give name of the host plant of *Bagrada cruciferarum* or *Athalia lugens.*

» ***Objective type questions***

1. Give common name of *Emmalocera* depressella :
   (a) Sugarcane leaf hopper (b) Sugarcane shoot borer
   (c) Sugarcane top borer (d) Sugarcane root borer
2. Give common name of *Bissetia steniellus* :
   (a) Sugarcane white fly (b) Gurdaspur borer
   (c) Sugarcane root borer (d) Sugarcane shoot borer
3. Give common name of *Leptocorisa varicornis* :
   (a) Rice Gandhi Bug (b) Rice Gall midge
   (c) Army worm (d) Tana bedhak

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4. Give common name of *Spodoptera mauritia* .
   (a) Cutworm (b) Army worm
   (c) Swarming caterpillar (d) Rice Gall midge
5 Give common name of *Agrotis ypsilon* :
   (a) Gram cutworm (b) Gram pod borer
   (c) Cabbage butterfly (d) Swarming caterpillar
6 Give common name of *Raphidopalpa foveicollis* :
   (a) Brinjal shoot borer (b) Cabbage butterfly
   (c) Melon fruitefly (d) The red pumpkin beetle
7 Give common name of *Idiocerus atkinsoni* :
   (a) Lemon butterfly (b) Mango leaf-hopper
   (c) Singhara beetle (d) Banana weevil
8. Give common name of *Pectinophora gossypiella* :
   (a) Spotted boll-worm (b) Red cotton bug
   (c) Painted bug (d) Pink boll-worm
9 *Bagrada cruciferarum* belongs to order :
   (a) Hymenoptera (b) Hemiptera (c) Lepidoptera (d) Coleoptera
10 *Heliothis armigera* belongs to family :
   (a) Noctuidae (b) Pieridae (c) Cymbidae (d) Gelechiidae

Answers

1. (d), 2. (b), 3. (a), 4. (c), 5. (a), 6. (d), 7. (b), 8. (d), 9. (b), 10. (a)

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3

Some Important Parasites and Pests

One of the major phenomena of the living world is parasitism. The vegetations are attacked by fungi, bacteria, viruses, nematodes, mites and insects, and animal forms from protozoa to man himself providing shelter and food for an almost uncountable number of plant and animal parasites. There is wide variation in the degree and nature of the damage to the host. A successful parasite develops a state of equilibrium with its host so no detectable damage is caused to the health or life of host. The damage produced may be so slight that repair and functional readjustment keep pace with the injury. In contrast, when the parasite gets out of control it may lead to the state of disease. The Arthropods constitute the largest single group of vectors of infectious agents. The term **Vector** means carrier. The role of vector may be purely accidental e.g. mechanical as in the spread of enteric bacteria by the house-fly (*Musca domestica*). On the other hand, the vector may have a fundamental and frequently an obligate relationship to the life cycle of the pathogen, in which its role is biological. Insects constitute the most important carrier group in the Animal Kingdom in the transmission of organisms producing diseases. Being carrier of enteric bacteria, the common house-fly has been referred to as 'the typhoid fly'. The house-fly also plays important role in the spread of cholera in tropical and oriental countries. The female of some species of mosquitoes, of which *Anopheles gambiae* is one of the best examples, have a preference for human blood and termed as **Anthropophilus**. Other species which feed without preference on the most available vertebrate are termed as **zoophilus**.

In this chapter few important parasites and pests and vectors are taken into consideration.

(Z–37/Eco. Zool.)

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I. Pathology/Damage Caused, Prevention and Control

Pathology, damage caused, prevention and control of *Leishmania*, *Trypanosoma*, **Giardia**, **Trichomonas**, **Schistosoma**, **Enterobius**, *Heterodera* and **Tribolium** have been discussed here.

Leishmania

Three species of *Leishmania* are pathogenic for human beings. They are :

(1) *Leishmania tropica* causes oriental sore
(2) *Leishmania brasiliensis* causes Espundia
(3) *Leishmania donovani* causes Kala-azar

1. *Leishmania tropica*

Phylum ..... Protozoa
Sub-phylum ..... Plasmodroma
Class ..... Mastigophora
Sub-class ..... Zoomastigina
Order ..... Protomonadina
Genus ..... *Leishmania*
Species ..... *tropica*

This parasite (Fig. 1) causes human skin Leishmaniasis (Oriental sore) which is distributed commonly in India, Pakistan, Central Africa, Iran and Iraq. The first host of this protozoa is man or other mammal and the secondary host is sand-fly.

Pathology. This species of *Leishmania* causes classical lesion of cutaneous leishmaniasis which is known as oriental sore. The tissue infection starts with the introduction of the leptomonas stage of the parasite into the dermis due to the bite of sand fly carrying leptomonas stage of this parasite. A wandering histiocyte in the vicinity picks up the parasite, which is soon changed to leishmania stage, multiplies and destroys the attacking macrophags resulting into the destruction of the tissue in the surrounding area. The destruction of cells starts in the centre of the lesion which become necrotic and the margins containing parasitised macrophags may become infiltrated with a giant and plasma cells. The lesion appears first as a macula, then a papul with a slightly raised centre covered with a thin blister like layer of epidermis. The lesion now bursts with the discharge of a small amount of clear or purulent exudate. At its base in the dermis, a granulating layer is formed and the margin becomes hard by infiltrating of fibroblasts. If there occurs bacterial or any other infection, an open frequently verrucous disfiguring ulcer develops. But if there is no secondary infection, it tends to dry up and the leishmaniasis slowly disappears with a slightly raised, depigmented wound at the site. Primarily there is only one ulcer for each infected sand fly bite at or near the point of inoculation on the exposed skin. Sometimes multiple new sores are formed from accidental autoinoculation if ulcers are open. The incubation period may vary from 2 weeks to 3 years but commonly it is for a period of 2 to 6 months.

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Prevention and control. This disease may be prevented by avoiding the bite of sand fly but of course it may not be practised properly by the persons of very poor economic community. It is very interesting to note that the preventive inoculation was first employed against oriental sore. Mothers in ancient time deliberately infected their children with material from active sores in order to prevent the later acquisition of a disfiguring facial ulcer. The relationship between this age old practice and the modern use of vaccination is well known in the medical history.

The resulting ulcers should not be terminated chemotherapeutically for a period of about 30 days of inoculation, otherwise immunization will not be satisfactory. Dog reservoirs should be destroyed. The sand flies should be killed by any method, around the human habitat.

Leishmania tropica can be treated readily with chemotherapy :

(1) Antimony tartrate should be applied locally after removal of scab and crusts to heal ordinary ulcers.
(2) Atebrin and berberin sulphate should be injected around sores.
(3) In case of secondary infection of ulcers, penicilline, bacitracin or other latest antibiotics should be injected.
(4) To avoid secondary infection regular cleaning and dressing of boils should be practiced.

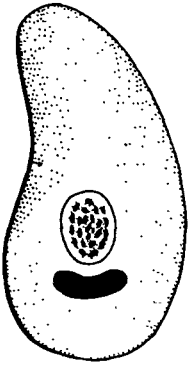

Fig. 1. *Leishmania tropica.*

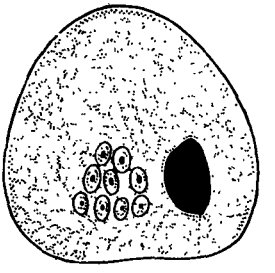

Fig. 2. *Leishmania brasiliensis.*

2. *Leishmania brasiliensis*

Phylum ..... Protozoa
Sub-phylum ..... Plasmodroma
Class ..... Mastigophora
Sub-class ..... Zoomastigina
Order ..... Protomonadina
Genus ..... *Leishmania*
Species ..... *brasiliensis*

This parasite (Fig. 2) causes a disease called as 'Espundia' and found to be distributed in epidemic form in the continent of America and Argentina in both the sexes and different age groups of man.

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Pathology. Like other species of *Leishmania* this is also transmitted by several species of *Phlebotomus.* The primary lesion is formed in the body of human-beings when the carrier sandfly injects the leptomonad stage of this species into the outer dermis. Now injected prarasites are engulfed by wandering histiocytes in which the parasites rapidly become leishmania form, multiply by binary division and soon destroy the cytoplasm of the host cells. Further, the histiocyte ruptures and sets the *Leishmania* free. Again they are engulfed by other macrophages in the vicinity in which they continue to multiply. In the very beginning, the lesion is in the form of a microscopic macula which transforms into a slightly elevated pustule, then opens at the centre to discharge semi-liquid necrotic material. At times the base of the crater may become covered with a granulating layer and the ulcers gradually dry up. More frequently the ulcer remains open with an oozing, glistering surface. If the inoculation is on the margin of the ear or the ear lobe, the parasites usually erode the skin and the underlying cartilage, leaving a multiplied auricle which may have a smooth or granulomatous surface.

The unique feature of the infection by this species is a tendency for parasites to migrate to secondary sites at or near muco-cutaneous junctions. The most frequent site is the nasal septum. These lesions may be ulcerative, indurable or granulomatous. Blocking of lymphatic capillaries leads to necrosis and extensive destruction of soft and underlying hard tissues, producing extensive erosive multilation of the nares, and at times of the nasa-pharynx, larynx and palatine bones. Granulomatous disfiguring of the nose, lips and cheeks is common in persons with negroid blood. These secondary lesions are typically complicated by bacterial invasions.

Prevention and control. (1) The sand flies should be controlled by any means.

(2) One should try to avoid the bite of sandfly.

(3) The wounds should be cleaned properly.

(4) The use of antibiotics and antiseptic means should be practised to avoid secondary infection.

(5) The treatment of uncomplicated primary lesion is similar to that of cutaneous leishmaniasis but sores after secondary infection are much more difficult to manage and require months or years of persistent treatment with antibiotics in association with antimonial preparations.

3. *Leishmania donovani*

Phylum ..... Protozoa
Sub-phylum ..... Plasmodroma
Class ..... Mastigophora
Sub-class ..... Zoomastigina
Order ..... Protomonadina
Genus ..... *Leishmania*
Species .... *donovani*

(Z–37/Eco. Zool.)

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This species (Fig. 3) is a causative agent of Kala-azar or visceral leishmaniasis. This disease is widespread in India, South China and in the Mediterranean countries. The life cycle of this parasite is similar as other species with the only difference that this species migrates to the reticular endothelial cells of the liver, spleen, bone marrow and visceral lymph nodes.

Pathology. The vector for this species is sand fly (*Phlebotomus argentipes*) and a few related species. The leptomonas stage of the parasite is introduced into the outer dermis. As parasites reach the skin of man, they are engulfed by phagocytes of the connective tissues. The phagocytes commonly involved in the act of engulfing is the macrophage (a large lymphoid wandering cell). The leishmania bodies are not destroyed by the phagocytes but they reproduce to pack the infective cells which burst soon. In this way parasite bodies spread from phagocyte to phagocyte. This slow spread of parasites among the phagocytic cells continues from a period of few weeks to a year or more. Now some monocytes reach into the blood stream via the lymphatics and are further carried to different organs. When the parasites parasitise the phagocytes of liver, spleen, kidney and bone marrow, the symptomatic kala-azar is developed. The liver is enlarged and the number of Kupffer cells increase especially in the portal spaces. The spleen is also enlarged. In this stage irregular fever, weakness, headache and changed number of blood cells have been noticed. Due to the destruction of large number of monocytes, the red bone marrow produces many monocytes at the expense of other defensive cells, such as neutrophils. So, due to reduction in all types of white blood cells except monocytes a condition "Monocytosis with leucopenia" develops which reduces the resistance of the body and ultimately the victim of kala-azar dies of some infections which the victim would normally be able to counter act.

The complications usually observed in kala-azar are mainly those of the digestive and respiratory tracts. It has been noted that diarrhoea and dysentery are intercurrent in origin. An important disorder is the respiratory syndrome. Children with kala-azar are commonly hospitalised primarily because of bronchopneumonia rather than for kala-azar.

Prevention and control. In India where reservoir hosts are not important the treatment of human cases and destruction of sand fly alone can greatly reduce the amount of visceral leishmaniasis.

In areas where dogs constitute a constant source of infection for sand flies, campaign to destroy all street dogs and other with obvious skin lesions will effectively reduce the reservoir of this disease.

The supportive or symptomatic treatment by good nursing care, enriched diet and even blood transfusion is important in severe cases of infection, like bronchopneumonia, severe diarrhoea and dysentery. The advents of sulfa drugs and especially the antibiotics has greatly reduced the hazards.

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Two types of drugs are given in the treatment of kala-azar e.g. antimonials and diamidines. The use of sodium and potassium antimony tartrates have been replaced by pentavalent antimonials of which ethyl stibamine (Neostibosan), urea stibamine and sodium antimony gluconate (solustibosan) have been the most effective drugs. Neostibosan and sodium antimony gluconate may be given intramuscularly, which is advantageous is mass treatment.

The diamidines are common in the cases where antimony drugs are not responding positively.

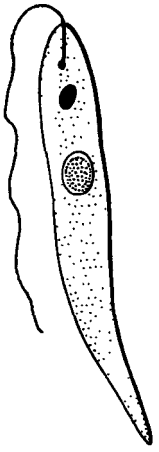

Fig. 3. *Leishmania donovani.*

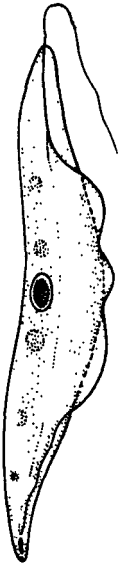

Fig. 4. *Trypanosoma rhodesiense.*

Trypanosoma

Three species of *Trypanosoma* cause variable degree of tissue pathology in human being. They are :

(1) *Trypanosoma rhodesiense* causes sleeping sickness.
(2) *Trypanosoma gambiense* causes Gambian trypanosomiasis.
(3) *Trypanosoma cruzi* causes Chaga's disease.

1. *Trypanosoma rhodesiense*

Phylum ..... Protozoa
Sub-phylum ..... Plasmodroma
Class ..... Mastigophora
Sub-class ..... Zoomastigina
Order ..... Protomonadina
Genus ..... *Trypanosoma*
Species ..... *rhodesiense*

This parasite has spindle shaped body (Fig. 4), central nucleus and small rod-shaped flagella. It causes African sleeping sickness. It is commonly found

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in African countries. The transmission of this species was demonstrated by Yark (1912) by *Glossina morsitans* (Tse-tse fly).

Pathology. This parasite causes an interstitial inflamatory reaction followed by irritated lesion and dark red circular spots. On introduction to the skin of human-beings from the proboscis of tse-tse fly, *Glossina morsitans,* this commonly subsides within a week or two as the trypanosomes gain entry into the circulating blood, where they multiply. Further parasites enter the lymph nodes where a second centre of inflammation occurs with hyperplasia of the endothelial lining of the blood sinuses and perivascular infiltration of leukocytes, due to toxin metabolites of trypanosomes. In later stage, that is after few months, the parasite invades the central nervous system causing pathological changes in the brain, especially an accumulation of round cells in the cerebrospinal fluid takes place. This produces lesions, the characteristic of third stage of trypanosomiasis, which results in classical sleepiness so-called sleeping sickness. The frequent episodes of drowsiness merge into a terminal coma, from which the victim can not be awakened. During neurological phase of sleeping sickness, various symptoms of brain and nerve damage become apparent.

Prevention and control. (1) *Trypanosoma rhodesiense* is a geographical varient of *Trypanosoma, brucei* which parasitises large game animals of West Africa. So, it is impossible to eradicate this species, therefore, human population must be protected by chemotherapeutic prophylaxis and fly control.

(2) The habitat of human-beings should be shifted from forest and heavy bush regions to open country area. The sanitary conditions of the locality should be improved to check the multiplication of tse-tse fly.

(3) Sodium naphuride or suramine is administered intravenously during the early stage of the infection.

(4) Intra muscular injection of antrypol or lomidine or other pentamidines or a combination of these two kinds of drugs which interact beneficially, can cure non neurological cases rapidly and permanently.

(5) Unfortunately, proper treatment of neurological phase of disease is quite difficult.

2. *Trypanosoma gambiense*

Phylum ..... Protozoa
Sub-phylum ..... Plasmodroma
Class ..... Mastigophora
Sub-class ..... Zoomastigina
Order ..... Protomonadina
Genus ..... *Trypanosoma*
Species ..... *gambiense*

A flagellate parasite (Fig. 5) of human blood transmitted by tse-tse fly. This is commonly distributed in central Africa, Egyptian countries and almost all

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territories which have low marshy land. It multiplies by binary fission in the blood stream of man.

Pathology. Just after inoculation of parasite, an interestitial inflammation occurs in the skin of human-beings which gradually subsides in 1 to 2 weeks. In the mean time parasites reach into the blood stream and initiate a rather heavy parasitemia. The parasites come more and more to lodge in the lymph nodes and later in the spaces of central nervous system and then the brain substance. Thus, following the initial lesion in the skin, three progressive stages of tissue relationship occur viz., parasitemia, lymphadenitis and involvement of central nervous system.

As soon as the parasite invades the lymph nodes, causing painful enlargement, there is a febril attack of about 7 days duration, then an apyreatic period, typically followed by one or more attack of fever. The parasites are found in the blood only during the episodes of the fever. During lymphadenitis the enlargement of lymph nodes, spleen and liver occurs which causes headache, arthritic pain and weakness of the leg. Further, precordial pain, disturbed vision, delayed sensation to pain, anaemia and extreme weakness appears. Now again an acute febrile attack may cause the death of the patient.

The involvement of central nervous system is commonly referred to a sleeping sickness which is one of the more advanced neurological symptoms. In more advanced condition, the patient sleeps continuously, convulsions oocur, then profound coma and finally death which frequently results due to intercurrent infection.

Prevention and control. The gambian trypanosomiasis in endemic areas may be reduced by

(1) Protecting the human-beings from the bite of tse-tse fly.
(2) Quarantine of persons coming from infected to uninfected territory.
(3) Campanigns to destroy the resting and breeding grounds to tse-tse fly.
(4) Mass treatment of people with curative and prophylactic drugs accompanied by tse-tse control. This programme is most suitable for this species which is essentially a man adapted strain or species and not common in animal reservoirs.

Certain drugs like tryparsamide and certain other arsenicals, suramine, sodium and dimidine compounds are most effective for treatment.

(1) Suramine is very effective in febrile-lymphadenitis stage but valueless after appearance of neurological phase.
(2) Tryparsamide has been the most widely used helpful drug in Gambian trypanosomiasis. It is administered by vein, once or twice weekly.
(3) Diamidines, particularly pentamidine and propamidine are especially valuable during earlier stage and substituted by tryparsamide if optic neuritis develops.

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Fig. 5. *Trypanosoma gambiense.*

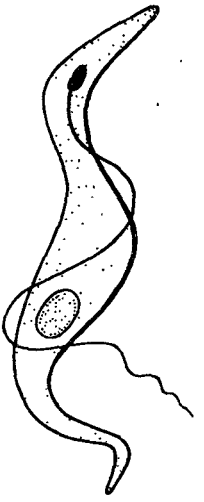

Fig. 6. *Trypanosoma cruzi.*

3. *Trypanosoma cruzi*

Phylum ..... Protozoa
Sub-phylum ..... Plasmodroma
Class ..... Mastigophora
Sub-class ..... Zoomastigina
Order ..... Protomonadina
Genus ..... *Trypanosoma*
Species ..... *cruzi*

This species (Fig. 6) is the causative agent of American trypanosomiasis or chagas disease. It is widespread in south and central America and is more common in children. This protozoa is also transmitted by bugs of Genus *Triatoma.* The transmission of this protozoa to man is not by the bug's bite but through its faeces.

Pathology. The inoculation of this species in human-beings may be any where on the exposed skin or on a mucous membrane. The most common location is at the outer canthus of the eye. Hear, the parasites multiply and are engulfed by the nearby macrophages. Their entry into outer macrophages produce a small granuloma (chagona) which obstructs the flow of lymph. After 4 to 5 days, parasites reach into the blood stream and circulate as typical trypanosomes for about one month and cause systemic toxemia. Further, in the meantime, parasites are lodged in visceral organs as reticulo-endothelial tissues, myocardium, endocrine glands and brain cells. They multiply there as leishmania forms and destroy the host cells. The colonies of the parasites which develop in myocardium, cause destruction of cardiac muscle, and in the brain cells cause extensive neuropathological changes. During the parasitemia phase of about 12 to 30 days,

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there exists marked toxic condition of typhoid fever, and in children sometimes fatal termination. If patient survives in this acute stage or if it is by passed, the symptoms of further cronic disease depend on the distribution of parasite in different visceral organs. This stage may last for years with gradual increase in the chronic manifestation with several alternating phases of fever.

Prevention and control. (1) In Chaga's disease, the transmission of parasites by triatomid bug (Kissing bug) can be checked by a very simple process i.e. having crack free houses in which there is no chance of hiding and breeding of the bugs. Reservoirs, however, are so varied and so common that there is no hope of eradicating chaga's disease.

(2) Primaquine and Puromycin are used for temporary relief from this disease.

Giardia lamblia intestinalis

Phylum ..... Protozoa
Sub-phylum ..... Plasmodroma
Class ..... Mastigophora
Sub-class ..... Zoomastigina
Order ..... Protomonadina
Genus ..... *Giardia*
Species ..... *lamblia*
Sub-species ..... *intestinalis*

This flagellate is cosmopolitan in distribution and causes diarrhoea in human beings. It inhabits the small intestine but is occasionally found in bile duct also. It is reported that children are more infested than adults.

This flagellate is pear-shaped with the dorsal side convex and the ventral flattened which deepens anteriorly to form a suction groove. It bears two nuclei and four pairs of flagella arranged symmetrically (Fig. 7). It divides by binary fission and feeds upon amino acids and vitamin contents of the blood within the intestine which causes intestinal disorder. This disorder causes epigastric pain, abdominal discomfort, loss of appetite and headache.

Pathology. The infection of **Giardia lamblia intestinalis** takes place as result of the ingestion of viable cysts of this parasite by human along with water or food materials. Its exposure is most frequent from finger contact with perianal skin and soiled underpants. The majority of persons infected by this parasite are asymptomatic but some have symptoms referable to the duodenum and a few to the gall bladder. **Giardia** never invades tissues, but sometimes causes irritation of the duodenal wall as result of the activity of the flagella and attachment of uncountable numbers to the mucosal surface of the intestine. The pain in 'the pit of the stomach' and mucous diarhoea is common symptom of the infection by this parasite. The patient loses weight and frequently becomes dehydrated. If there is involvement of gall bladder there may be inflammation of this organ.

Prevention and control. (1)The children and adults should develop habits of personal and group hygiene.

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(2) Drinking water and vegetables should not be contaminated with cysts.
(3) Before cooking, vegetables should be washed properly.
(4) Only symptomatic cases require treatment.
(5) The treatment with quinacrine (Atabrin) and chloroquin are quite effective in case of severe infection.

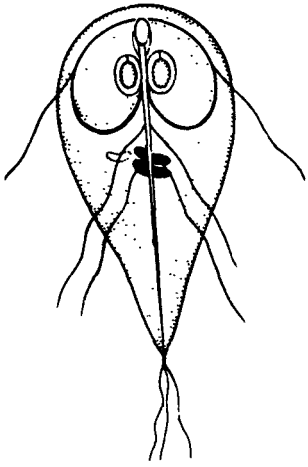

Fig. 7. *Giardia lamblia intestinalis.*

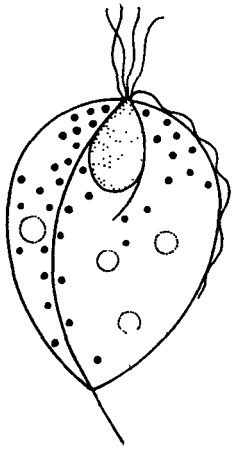

Fig. 8. *Trichomonas vaginalis.*

Trichomonas vaginalis

Phylum ..... Protozoa
Sub-phylum ..... Plasmodroma
Class ..... Mastigophora
Sub-class ..... Zoomastigina
Order ..... Polymastigina
Genus ..... *Trichomonas*
Species ..... *vaginalis*

This is a flagellate protozoa of rounded body (Fig. 8) containing only one nucleus and 4 to 6 flagella anteriorly and also flagellum posteriorly. This protozoa inhabits the vagina of women and causes vaginitis. The parasite secretes toxic substances that injure the cells grown in the tissue culture. Although generally thought to be a parasite of women, it also inhabits the male urinogenital tract and the prostrate gland.

The transmission of this parasite is accomplished principally through sexual intercourse, although there is possibility that it may at times be transferred from female to female through a contaminated toilet seat, a common douche or from grossly contaminated clothings.

Pathology. In the male, the infection *T. vaginalis* is essentially asymptomatic although at times it is associated with a nonspecific urethritis.

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The propogation of *T. vaginitis* in the vagina may be symptomless, it may cause vaginitis or sometimes it may be complicated by bacterial, fungal or spirochetal infection. This parasite is an important contributor to a distinct type of vaginitis characterised by leukorrhea, pruritus vaginae and vulvae, burning of vagina and vulva. The pH of vaginal discharge during the symptomatic infections is alkaline as distinguished from slightly acidic condition of the normal vagina. The disease is more annoying than disabling.

The diagnosis of this parasite is based on the recovery of the organism in the urine or prostatic discharges in the male, the vaginal discharges, urine and mucosal scraping of the vagina in the female.

Prevention and control. (1) The control of *T. vaginitis* is very difficult but atleast all married males, which are carrier of this parasite, should be advised of the hazard of transmitting the infection to their wives during sexual intercourse and should be given specific treatment.

(2) The infection in male is cured by hydroxy quinolines.

(3) The iodine and arsenic drugs and latest antibiotics are proved to be helpful to control the infection.

Schistosoma mansoni

Phylum ..... Platyhelminthes
Class ..... Trematoda
Order ..... Digenea
Genus ..... *Schistosoma*
Species ..... *mansoni*

It is commonly known as '**Blood fluke**' and found in the blood vessels of human-beings. Three species are found infecting the man. *Schistosoma mansoni* inhabits the blood vessels of large intestine and is distributed in Africa, Egypt and Tropical America (Fig. 9). *S. japonicum* inhabits the portal veins and mesentric vessels and is distributed in Japan, Philippines. Formosa, China and other oriental regions. *S. hematobium* inhabits the blood vessels of urinary bladder and urinary tract, and is distributed in Africa, India, South West Asia and Madagascar. The infection of blood fluke causes schistosomiasis in human-beings.

The sexes are separate and sexual dimorphism is very well pronounced. The males are smaller and broader whereas the females are longer and slender. Oral and ventral suckers are present in the male and female both. Life cycle is complicated and includes in intermediate snail host.

Life history. The mature female lays eggs in the form of chain of beads. The eggs of 23 species are different in shape and size. These eggs are carried out in water with the faeces in case of *S. mansoni* and *S. japanicum* and with urine in case of *S. haematobium*. When the eggs come in contact with water further development takes place and miracidium larvae come out after the hatching of the eggs. The miracidium is short, pear-shaped and tapering at the

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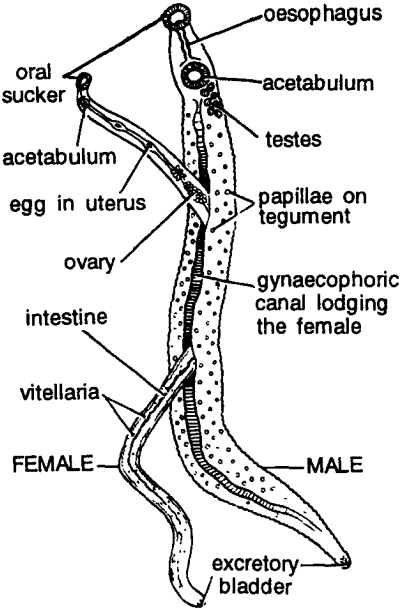

Fig. 9. *Schistosoma mansoni.*

posterior end. It is free, active swimmer and migrates to ponds, lakes and pools. Now miracidium penetrates into the snail host (intermediate host) in the foot and enters in the lymphatic system of the snail. It then passes through mother larval stage and daughter sporocyst stage and finally attains the cercaria larval stage with forked tails. The cercaria comes outside the snail body and moves freely in water. After few days the cercaria penetrates the skin of man particularly in the foot and enters in the veins of human-beings. Now larva loses its tail and is called as metacercaria larva. After passing through the heart and lungs metacercaria reaches the liver and feeds on portal blood and after maturation it migrates to its final habitat according to its species.

Pathology. The pathological changes may be categorised into three consecutive phases like biological incubation, acute phase and the chronic phase.

In the biological incubation phase, minute hemorrhages are produced at the sites of penetration in the skin. During next 4-5 days of penetration, there is considerable infiltration of cells around the delicate pulmonary capillaries through which the larvae are marching. When larvae break out the capillaries, acute inflammatory reactions are noticed. The larvae which are carried to unfavourable sites, are attacked and destroyed by phagocytes. Further, larvae reach to intra hepatic portal blood and provoke an acute hepatitis.

In the acute stage of infection, the production and extrusion of eggs by the worm cause severe damage and hemorrhage in the intestinal wall of human.

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In this phase of infection if the patient takes complete rest the intestinal and bladder lesions tend to heal. Some eggs are trapped in perivascular tissues resulting in the formation of pseudo-tubercle and block the smaller intestinal venules. Now the worms retreat into the larger mesenteric veins, so that eggs swept into the intra-hepatic portal vessels, are trapped in the small portal venules, filter into periportal tissues, and provoke pseudo-tubercle formation. Some times eggs and worms may be recovered at distant sites in the skin, myocardium or central nervous system.

In the chronic stage of infection continuous host cell proliferation and fibrous repair of the damage caused by the eggs occur. Fibrosis in intestinal wall and reduction in the diameter of the lumen take place. The already enlarged liver gradually develops extensive periportal fibrosis. The enlargement in the spleen and distension of collateral veins also occur. The wall of the urinary bladder thickened and fibrosed. The same chronic processes extend at times into adjacent pelvic organs and into the external genitalia. The usual intestinal symptoms are diarrhoea, hepatitis, anaemia, weight loss, headache and eosinophilia. In heavy infestation, cardiopulmonary schistosomiasis and calcification have also been noticed.

Prevention and control. (1) There is no important reservoir hosts for *S. mansoni* so control measure is relatively simple.

(2) The sanitary disposal of human excreta and urine may prevent from schistosomiasis but practically it is not easy in the society of poor economic status.

(3) Various methods regarding the control of snails should be applied to reduce the population of secondary host.

(4) The antimony compounds are used for the treatment of schistosomiasis.

Enterobius vermicularis

Phylum ..... Nemathelminthes
Order ..... Oxyuroidea
Genus ..... *Enterobius*
Species ..... *vermicularis*

It is commonly known as '**Pin-worm**' which is most common parasite of man. The distribution is worldwide and more common in America, Europe, Africa and Canada. The pin worm is an intestinal parasite but is also found in the appendix, caecum and the neighbouring parts of the intestine. Its infection is more in children. Sometimes its incidence has been reported in chimpanzee also. It is a small and white coloured worm. The female is longer (12 mm) than the male (4 mm). The sexes are separate and sexual dimorphism is distinct. The anterior end is provided with three lips and a pair of cephalic expansions. The posterior end of the male is blunt and curved whereas that of the female is long and pointed (Fig. 10).

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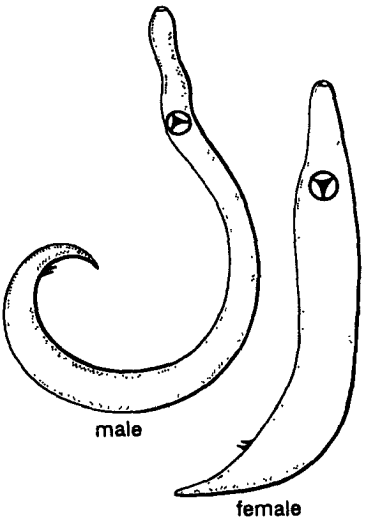

Fig. 10. *Enterobius vermicularis.*

Life cycle. The life cycle is direct and is completed without intermediate host. The gravid female migrates to the rectum and deposits the egg in the anal region. The migration of female causes itching at the anal and perineal regions. These embryonated eggs, laid on the anal region, become associated with the fingers and nails at the time of scratching the affected region and then enter into the gut with the food. Sometimes the eggs come out with the faeces and reach the gut of the host with the contaminated food and water. On reaching the small intestine the eggs hatch into the larvae. The larvae moult twice and attain adult stage. The adult live in the host for about one month and come out with the faeces.

Pathology. The worms attached to the wall of the appendix or caecal area may cause multiple focal inflammation of an acute or chronic nature or by the necrosis of the caecal mucosa and exposure of sympathetic nerve endings, the reflex nervous symptoms appear. When the worms emerge from the rectum and crawl over the perianal and perineal skin, and almost intolerable pruritus appears as the first symptom. If the itching is followed by scratching with scarification of the area, the bacteria may enter the lesion. In women, the worms may enter the genital tract and become encapsulated within the fallopian tubules, or wander into the peritoneal cavity and become encapsulated on the peritoneum.

The common symptoms in children are restless sleep, tiredness during day time, nycturia in boys and nymphomania in girls. There may be a slight anemia and low grade eosinophilia. The nervousness, appendicitis, hysteria and inflammation of mucous membrane may occur.

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Prevention and control. (1) Personal and group hygiene and control the transmission.

(2) Small children should be provided with closed sleeping garments so that their fingers may not come directly in contact with the perianal skin.

(3) The nails of the finger should be short.

(4) Satisfactory results with chemotherapeutics can be obtained only in case when all infected persons in the family are treated simultaneously.

(5) The administration of gentian violet medicinal, piperazine hexahydrate, phenothiazine, diphenan and egressin are effective in controling the pin worm.

Heterodera

The species of this genus are commonly known as **Cyst nematode** Fig. 11. The formation of cysts containing egg is the characteristic feature of this nematode. The well known species in this genus are the **sugar beet nematode** (*Heterodera schachtii*), the **golden nematode of potato** (*Heterodera rostochiensis*) and the **oat cyst** (*Heterodera avenae*) nematode. This genus is cosmopoliton in distribution. The woody perennial plants are not infected by *Heterodera* species. In India, more than 50% of crops is damaged by this nematode in Rajasthan.

Structure. There is profound sexual dimorphism in which male is elongated and cylindrical while female is stumpy, globular, short and pear shaped. The mouth is situated at anterior end and surrounded by 6 lip like structure. The buccal cavity is adapted to puncture the plant tissues and sucks the tissue sap of plants. The intestine is narrow and cylindrical in male while swellen sac like in case of female. The reproductive system is consisting of paired testis in male and paired ovaries in female.

Life cycle. In *Heterodera*, cross fertilization is common feature but reproduction without male has also been observed in certain species i.e. through parthenogenesis. The eggs are barrel shaped and resistant against unfavourable environmental conditions. The egg contains developing embryo in various stages of the development. The hatching takes place and second instar larvae are released free in the soil. Certain secretions, from the root of host plants, stimulate the hatching of *Heterodera* eggs. The breaking of egg capsule is purely mechanical phenomena which does not involve any physiological change in egg membrane. The second instar larva is infective stage and its duration is maximum as compared to other larval stages. Further, larva enters into the host plant tissues and starts feeding where it gets more favourable condition. It is believed that the chemicals oosing out of the plant root attracts the infective larval stage. With the help of hydrolytic enzymes secreted, the second instar larva moves into the plant tissues, digests the plant tissues and sucks in the form of juice. No larva undergoes second moult and attains the third larval instar stage and

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again starts feeding on plant tissues. The third instar larva undergoes third moulting and enters into fourth instar stage in which stage, the male and female can be distinguished easily. The development of male and female now proceeds on different lines. After fourth moulting, the adult male is liberated within the plant tissues, whereas, the mature female is in the form of cyst. Various ecological conditions affect the activity of the soil nematodes therefore, combined effect of soil moisture, soil aeration and soil temperature determines the activity of nematodes in the soil.

Damage. The major effect of *Heterodera* on the plant tissue is because of the host reaction. The host tissue react to the parasites including the proliferation division of the product cells surrounding the parasites. These cells divide rapidly and certain cells enlarged and called as '**giant cell**'. The cell wall of certain cortex cells dissolves as result syncitial masses of tissues are also developed in the infected area of host plant. The '**giant cells**' and syncitial masses surround the parasite and in advanced phase of infection the affected area of plant swells which is called as '**Galls**'. The giant cells and syncitial masses sometimes choke the xylem and phloem vessels of the plant stopping conduction of water and nutrients respectively thus, resulting in the wilting and death of the plant. The parasite also sucks food through their buccal stylet from the infected host plant tissue thus, causing deficiency of various essential nutrients to the plants.

Management of *heterodera*. Though the prevention and control of *Heterodera* is rather difficult, yet certain measures are taken :

Chemical measure. Some chemicals like methyl bromide, dichloro ethane and ammonia water have been reported to be nematicides but extreme care should be taken while using these chemicals. The nematicides to be used, should be chemically stable so that it does not break down soon within the soil. The chemicals being used, should not be injurious to the host plants.

Physical measure. ***(a) X-rays treatment.*** Radiation with x-rays has been found to be harmful to *Heterodera* but it is restricted to the laboratory only. It can not be used commercially.

(b) Heating. This method involves the treatment of soil with steam to increase the soil temperature which may be harmful to parasites. But during this treatment, care should be taken that the level of temperature should only be harmful to the parasites and not to the plants.

Agricultural practices. ***(a) Trap crop.*** This is an old practice in which trap crop is cultivated before the host crop so that *Heterodera* may be attracted towards trap crop. Further, the trap crops containing *Heterodera* larvae should either be removed from the field or be destroyed. This method requires extreamly careful planning and knowledge of the life cycle of parasite.

(b) Crop rotation. *Heterodera* having high degree of specialization can be controlled by crop rotation. In this method, a gap of 4-6 years is provided

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between two successive host crops. During this gap period the infecting larvae do not find the host, so ultimately die.

Biological control. The phytoparasitic nematodes are attacked by a number of parasites and predators. The parasites and predators include the groups of organisms like fungi, protozoa, insects etc. The fungal hyper parasite like *Dactylaria* is being used to control the *Heterodera.* The use of hyper parasite is rather difficult and requires many precautions. The hyper parasite being used should only parasitise the nematode and not the host plant. The hyper parasite should be capable to survive in the soil environment.

Confused and red flour beetle

Class ..... Insecta
Order ..... Coleoptera
Family ..... Tenebrionidae

Tribolium confusum Duval
Tribolium castaneum (Herbst)

About 85% of all the insects in flour mills are flour beetles (Fig. 12) which are cosmopolitan in distribution. Confused flour beetle is dominating over red flour beetle in flour mills. Although they severely attack wheat flour but flour of all starchy materials, peas, backing powder, nuts, drugs and many other food materials are also attacked by these beetles. Larval and adult both the stages are found infesting and causing damage.

The adult of *T. confusum* is elongate reddish-brown about 3 to 4 mm in length. Its larvae are found crawling over infested seed. They are brownish-white, flattened and six legged and known by millers as 'bran bugs'.

The adult of *T. castaneum* is reddish-brown, about 3 to 3.5 mm in length. Its larvae are reddish-yellow, about 6 mm in length and found crawling on the grains.

Damage. These beetles cause serious damage is monsoon period. They heavily damage flour in the mills but sometimes damage the grains in store which are already damaged partly by other pests. Both the adult and the larva are infective stages. After severe damage the flour changes into greyish colour and becomes unfit for human consumption.

Life cycle. The adults are very active and survive in moderately cold winters in unheated buildings and often live for 2 years or more in adult stage during which period the fertilized female produces 1,000 eggs in the flour or grains. After 4 to 10 days of incubation period the eggs hatch into larvae which after 6 to 7 moultings in 22 to 25 days get changed into pupae and settle in the flour. After 5 to 9 days of pupal period, adults emerge. The whole developmental period takes 26 to 30 days under favourable conditions.

Prevention and control. (1) All precautionary steps should be taken before storage of the grains.

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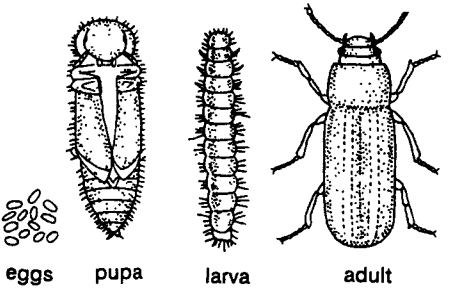

Fig. 11. Life history of *Tribolium castaneum.*

(2) Flour mills should be kept clean and dry.
(3) Modern sanitation procedures should be practised by millers.
(4) The infested portion of the flours should be removed.
(5) The adults or its other life stages should be removed from stores or godowns.

IMPORTANT QUESTIONS

» ***Long answer type questions***

1. Give an account of the pathology, prevention and control of *Leishmania tropica, Leishmania brasiliensis* and *Leishmania donovani.*
2. Give an account of the pathology, prevention and control of *Trypanosoma rhodesiense, Trypanosoma gambiense* and *Trypanosoma cruzi.*
3. Give an account of the nature of damage, prevention and control of *Tribolium* and *Heterodera.*
4. Give an account of pathology, prevention and control of *Schistosoma* and *Enterobius.*

» ***Short answer type questions***

1. Give an account of the pathology of *Trypanosoma rhodesiense, Trypanosoma gambiense* and *Trypanosoma cruzi.*
2. Give an account of the pathology of *Leishmania tropica, Leishmania brasiliensis* and *Leishmania donovani.*
3. Give an account of the nature of damage of *Tribolium* and *Heterodera.*
4. Give an account of the pathology of *Schistosoma* and *Enteribius.*

» ***Very short answer type questions***

1. Give short account of the transmission of *Leishmania* spp.
2. Give short account of the transmission of *Trypanosoma* spp.
3. Give an account of the infective stage of *Heterodera* and *Tribolium.*
4. Define Anthrophilus and Zoophilus.
5. Give short account of transmission of *Schistosoma.*

» ***Objective type questions***

1. Which of the following disease is caused by *Leishmania tropica ?*
   (a) Oriental sore (b) Espundia (c) Kala-azar (d) Sleeping sickness

(Z–37/Eco. Zool.)

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2. Which of the following disease is caused by *Leishmania brasiliensis ?*
   (a) Sleeping sickness (b) Espundia (c) Oriental sore (d) Kala-azar
3. Which of the following disease is caused by *Leishmania donovani ?*
   (a) Kala-azar (b) Oriental sore
   (c) Sleeping sickness (d) Espundia
4. Which of the following disease is caused by *Trypanosoma rhodesiense* ?
   (a) Chagas disease (b) Gambian trypanosomiasis
   (c) African sleeping sickness (d) Espundia
5. Chaga's disease is caused by :
   (a) *Trypanosoma gambiense* (b) *Trypanosoma rhodesiense*
   (c) *Leishmania tropica* (d) *Trypanosoma cruzi*
6. Which of the following is vector of *Leishmania ?*
   (a) *Anopheles* (b) *Culex*
   (c) *Glossina morsitans* (d) *Phlebotomus argentipes*
7. *Giardia lamblia* belongs to class :
   (a) Amoebina (b) Trichostomatida (c) Polymastigina (d) Protomonadina
8. The common name of *Schistosoma mansoni* is :
   (a) Whipworm (b) Blood fluke (c) Pinworm (d) Intestinal fluke
9. Which of the following larval stage inters in the body of human ?
   (a) Redia (b) Miracidia (c) Cercaria (d) Cysticercus
10. The common name of *Enterobius vermicularis* is :
    (a) Hook worm (b) Pin worm (c) Whip worm (d) Hydatid worm

Answers

1. (a), 2. (b), 3. (a), 4. (c), 5. (d), 6. (d), 7. (d), 8. (b), 9. (c), 10. (b)

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4

Household Insects

Insects cover more than 3/4th of the entire world fauna and are the biggest enemy of human-beings as they destroy stored grains, sizable part of crops, house-hold goods and live-stock. It is roughly estimated that the annual loss due to the various pests affecting our crops is about 15,00 crores. Consequently, their effect as carrier of diseases is in no way less than their attack on crops and orchards. Many efforts have been made to control the insect population but so far none have proved effective in exterminating them. The house-hold insects can easily be controlled, if proper method is employed because insects have already reached a resistant stage and are very well suited to wage a defensive war. A large number of house-hold insects like beetles, moths and bugs attack the grains and grain product in farmer's 'bins', mills, warehouses and stores. The house-hold insects may be grouped into 3 categories according to their mode of damage.

(1) Insects affecting human health,
(2) Insects damaging food products,
(3) Insects damaging other house-hold goods.

Insects Affecting Human Health

1. Cockroaches

Class ..... Insecta
Order ..... Dictyopetra
Family ..... Blattidae

Periplaneta americana (Linne')
Shelfordella tartara Adel
Blattela germanica (Linne')
Blatta orientalis (Linne')

Cockroaches (Fig. 1) are world wide in distribution but more prominent in tropical and sub-tropical countries. They are nocturnal and found to be present

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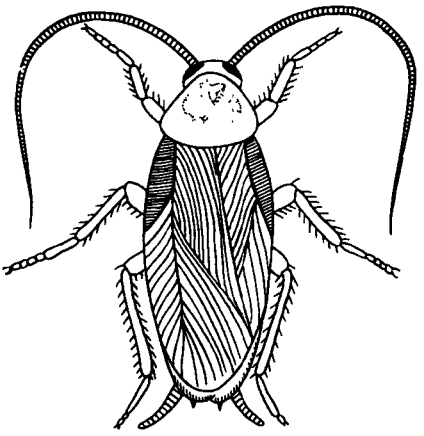

Fig. 1. Cockroach (*Periplaneta americana*).

in dark and humid places such as store rooms, bakeries, kitchens, boards, pictures, cracks, round sinks etc. In day light they hide behind cup-boards and heating pipes.

Adult and nymphal stages both cause damage. *P. americana* is commonly found in South India. It is about 3.5 cm in length and brown in colour. *Shelfordella tartara* is commonly found in northern states of India. It is about 3 cm in length and shining black in colour. The cockroaches are provided with one pair of very long antennae which function as tactile organ.

Damage. The cockroaches touch and pollute every thing which is palatable and prefer to feed on potatoes, vegetable, bread, chocolate sugar, honey, fat, oil, old damped books, leather material etc.

They may spread diseases viz, tuberculosis, cholera, leprosy, dysentary and typhoid.

Life cycle. Cockroaches breed continuously in warm house even in winter. They look more active in hot and humid regions. The fertilized female of *P. americana* lays eggs which are enclosed in a bag like structure called 'Ootheca'. One fertilized female can lay 15 to 90 capsules having 16 eggs in each capsule. After interval of 35 to 100 days of laying, 16 nymphs come out of each ootheca which take 10 to 16 months and 13 moults to attain adult stage. The female of *S. tartara* lays cigar-shaped eggs in bag-like capsules. After 2 days of laying, nymph emerges from egg but in winter it takes a few weeks. After one month nymphs attain adult stage.

Prevention and control. (1) As cockroaches are annoying, immediate steps should be taken to control them.

(2) Prompt removal of food remnants and cleanliness is essential measure to control.

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(3) Spraying of 2% oil solution or emulsion of chlordane is very much effective.
(4) Spraying of sodium fluoride with pyrethrum powder containing 0.5 to 1% pyrethrin may be very effective.
(5) Spraying of 0.5% dieldrin in liquid formulation and 1% in dust formulation is also effective.
(6) The spraying of malathion 0.2% or malathion/carbaryl 1.5% is found most effective.
(7) Fumigation of houses or hospital building with HCN may provide immediate relief.

But care should be taken that food materials and other articles are not contaminated/affected with spraying of insecticides.

2. House flies

Class ..... Insecta
Order ..... Diptera
Family ..... Muscidae

Musca nebula Wiedemann
Musca domestica Linnaeus
Musca vicina Linnaeus

Although house flies (Fig. 2) are cosmopolitan in distribution yet they are found in abundance in more dense population in hot and humid climatic conditions. They are found at all the places where human beings and unhygienic conditions are available. They harm human-beings by transmitting micro-organisms of some diseases and serve as intermediate host of Helminthes.

The adult fly is about 7 cm in length, dull coloured, and provided with plumose antennae and sponging type of mouth-parts.

Damage. The house flies are most important mechanical vectors of a number of human disease like epidemic diarrhoea, amoebic and bacillary dysentery, cholera, typhoid fever etc. They carry germs and diseases either by mouth-parts, foot-parts, wings or in the alimentary canal and transfer them on wounds by simple touching or regurgitation or by faeces.

Life cycle. After 24 hours of adult emergence copulation takes place and the fertilized female lays 100 to 150 eggs a time on decaying organic material and forms such 7 batches in her whole life span. After the incubation period of 12 hours to 12 days (varies according to climatic conditions) eggs emerge into larvae called as maggots which after 5 to 14 days undergo pupation for about 3 to 10 days and look like a barrel-shaped structure. After this pupation period adults are emerged. The life span of adults varies from 20 to 23 days and commonly 10 to 12 generations have been noticed in summers in hot climatic conditions.

Prevention and control. (1) Presence of house-flies indicates a defective sanitation, therefore, agriculturists should plan to dispose off the dung,

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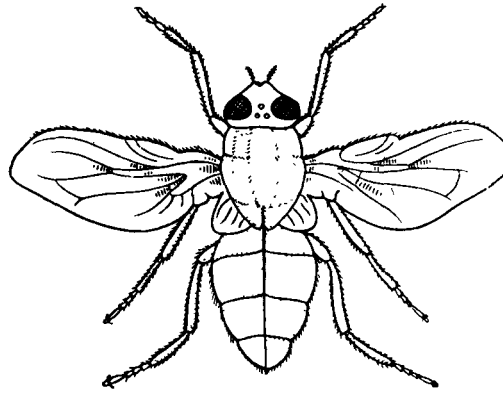

Fig. 2. House fly (*Musca domestica*).

manure and other fly-breeding materials quickly to proper places as far as practicable. The stored dung should be mixed with a mixture of one pound borax in 16 gallons of water at the rate of 16 cubic feet area.

(2) Houses should be cleaned and food materials should be kept at fly-proof places.

(3) A mixture of castor oil and rosin (5 : 8 w/w) is heated and flypaper are prepared by painting the mixture on it.

(4) Fumigation by neem leaves or carbolic acid is also helpful.

(5) Fly traps can be made by baits prepared from fermenting oil- cake soaked in water, sugar syrup, vinegar, milk and rotting bananas.

(6) Anti-fly candles can be prepared by mixing pyrethrum, saw dust, wheat flour and potassium nitrate (5 : 1 : 2 : 2 w/w) and rolled in the form of candles.

(7) The spraying of 2% malathion/diazinon, 1% lindane/chlordane and 0.5% dieldrin is very much effective for killing the flies.

(8) Fly-swatters are used to kill and knock off the house flies.

3. Mosquitoes

Class ..... . Insecta
Order .... .Diptera
Family ..... Culicidae

Anopheles quadrimaculatus Say
Culex pipiens quinquefasciatus Say
Aedes aegypti (Lenne')

Mosquitoes (Fig. 3) are cosmopolitan in distribution, nocturnal in habit and found in abundance in damp, marshy lands, near stagnant water etc. They are very noxius in tropical and subtropical regions. Only female mosquitoes are adapted to suck the blood of human-beings and functions as carrier of viral, bacterial and protozoan diseases. Out of 45 species of *Anopheles* only

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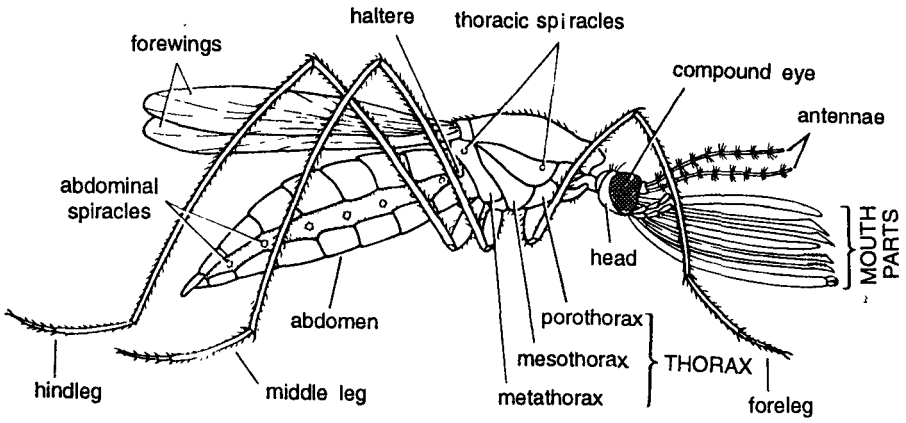

Fig. 3. Mosquito (*Culex-female*)

nine are vector of human malaria and carry the sexual stages of malarial parasite. *Culex* mosquito transmits filariasis by carrying the protozoan micro-organisms. *Aedes* spp. is carrier of viruses of yellow fever and other diseases. Females contain specialised mouth-parts for piercing while the males are devoid of having such type of elongated mouth parts. At the time of rest, abdomen of *Anopheles* is held at an angle of 45° to the surface while that of *Culex* is held parallel to the surface.

Damage. The female of *Anopheles* functions as the carrier of malarial parasite and causes malaria in human-beings. *Culex* spp. transmits filaria and *Aedes* spp. transmits yellow fever in human-beings. Thus, the mosquitoes are very dangerous for human health.

Life cycle. The breeding of mosquitoes continues throughout the year in warm and humid places. The fertilized females of *Anopheles* and *Culex* lay eggs in single and masses containing several hundred eggs respectively in dirty stagnant water. Eggs, after 2 to 3 days of incubation, hatch into larvae which are purely aquatic in habit and are known as 'wrigglers'. The abdomen of the larvae is provided with tubular siphon adapted for air breathing. The larvae by 4 moultings undergo pupation after 2 days to 2 weeks and from pupae the adult mosquitoes emerge after 2 to 3 days.

Prevention and control. ***(a) Elimination of breeding places.*** It is better to check the mosquitoes before full development because mosquitoes depend on aquatic habitat for larval development. The most fundamental means of control lies in the elimination of breeding places by draining, filling, pumping or temporary dewatering.

(b) Destruction of larvae and pupae. The water surface is covered by spraying kerosine oil, petroleum, paraffin oil, crude oil, so that the larvae die due to suffocation. Larvivorous fishes as *Gambusia* may be employed to keep

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the pools and ponds mosquito free. Larvicide dusts as oil emulsion on DDT, Y- BHC and toxaphene are used. Dragon flies, a natural enemy of mosquitoes, should be encouraged.

(c) Destruction of adult mosquitoes. Adults should be driven out of the houses or killed by fumigation with pyrethrum, sulphur etc. Spraying of 2% malathion, or 0.5% dieldrin, kills the mosquitoes.

(d) Defence against mosquito bite. Houses should be mosquito proof. Mosquito nets should be used atleast during sleeping period. The exposed part of the body should be protected by gloves, veils, boots or by repellents. Mixture of Dimethyl- phthalate, indalone and 2-ethyl-1, 3-hexanediol (3 : 1 : 1) and Dimethyl-phthalate, 2-ethyl-1. 3-hexanediol and dimethyl carbate (4 : 3 : 3) have been proved as good repellents when applied on the exposed body parts.

4. Wasps

Class ..... Insecta
Order ..... Hymenoptera
Family ..... Vespidae

Vespa orientalis (Linnaeus)
Polistes herbraeus (Fabricius)

Wasps (Fig. 4) are another menace to dwellings if they begin to prepare their nests over walls, ceilings and trees near human habitats. The adult inflicts pain to human beings by stinging.

The adults of *P. herbraeus* are smaller and yellowish in colour whereas those of *V. orientalis* are larger and deep brownish. Both are found on the plains. Adults are provided with chewing types of mouth parts. The tapering end of female abdomen possesses a sting whose infliction is dangerous and painful to human-beings. Another species. *v. magnifica* Smith is largest wasp of India. It prepares its nests on the ground and is dark brown in colour. It feeds on the honey bees hence, is found hovering over the beehives, snapping them with greatest ease.

Damage. Wasps inflict the human-beings by their sting and cause pain. They feed on fruits damage the honey combs.

Life cycle. Wasps are found outside in summer season and hibernate in winter. If nests are damaged by any agency they can further form new nests. Fertilized queen lays eggs in cells. The larvae come out of eggs and remain in the cell where they are reared. The young larvae are fed on masticated animal tissues and sugary food. Larvae change into pupae inside the cells and emerge out in the form of adult worker wasp. The last brood which comes up in the beginning of autumn, comprises of males and females which after mating get ready as fertilized queens for wintering over. Thus in winter all workers and males die and only queens are found living till next spring.

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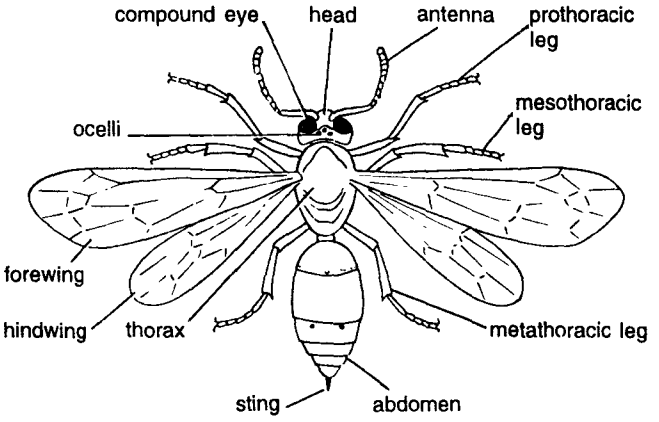

Fig. 4. Wasp (*Vespa orientalis*).

Prevention and control. (1) When wasps start to make comb they should be brushed off. Wasps never prefer to make new comb second time in the same locality.

(2) Before removal of large comb a spray of water should be directed towards it to wet the wings of workers which soon fall down and can be crushed.

(3) 10% solution or emulsion of DDT is recommended to kill the wasps.

(4) In heavy infestation period, fumigation by HCN is also recommended.

(5) Simple smoking is helpful to control the wasps.

5. Sand flies

Class ..... Insecta
Order ..... Diptera
Family ..... Psychodidae

Phlebotomus argentipes Brunetti

Sand flies (Fig. 5) function as vector of a number of diseases. Not only that, but they also bite a number of warm blooded animals. Adults are 2.0 mm in length, dark coloured and devoid of cross veins on the wings. Each segment of the larvae bears numerous spines. They are very active at night.

Damage. The adult female fly inflicts a painful bite for the sucking of the blood from human body. They prefer to bite on ankles, dorsum of feet, inner elbows and wrists of human-beings. After bitting, itching and swelling starts. *P. argentipes* is a vector of protozoan parasite causing very serious disease like Kala-azar.

Life cycle. The adults are seen active throughout the year. The fertilized female lays eggs in dark and damp places. After 7 days of inoculation larvae emerge out and get matured after 30 days, feeding on decaying matter. After maturation they undergo pupation and from the pupae adults emerge out after

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10 days. The life span of fly is about 8 to 10 days and two months are required to complete the life cycle.

Prevention and control. (1) The cleanliness of human habitat reduces the breeding of sand flies.

(2) The spraying of 5% DDT/BHC easily kills the flies.

(3) The pyrethrum ointment used on exposed part of body works as repellant.

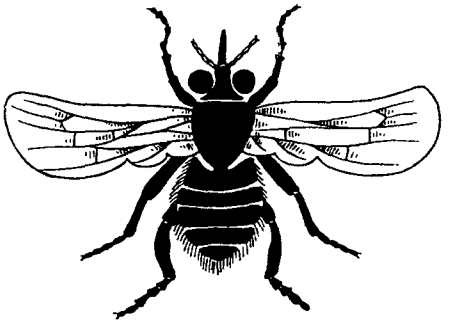

Fig. 5. Sand fly. (*Phlebotomus*).

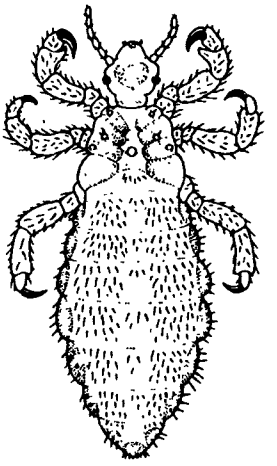

Fig. 6 Human Louse (*Pediculus humanus capitis*).

6. Human louse

Class ..... Insecta
Order ..... Anoplura
Family ..... Pediculidae
Pediculus humanus capitis De Geer
Pediculus humanus corporis De Geer

Louse (Fig. 6) is the blood sucking ectoparasite of man and cosmopolitan in distribution. They are found mostly in military barracks, prisons, orphanages and common houses etc. *P. humanus capitis* is a head louse found in head hair, *P. humanus corporis* is a body louse found in hairs of the arm pits, clothes and garments and *Phthirius pubis* Linneaus is a crab louse found in the hairs of pubic region of human-beings.

The adults are greyish-white, wingless, flattened and 1.5 to 4.00 mm in length. They are provided with piercing and sucking type of mouth-parts. Body louse is comparatively larger than the head louse.

Damage. They suck the blood, cause annoyance, itching, irritation and transmit germs of certain diseases viz. relapsing fever, typhus fever etc.

Life cycle. Louse breeds throughout the year in warm dwellings. In case of head louse, eggs (nits) are laid on hairs of head while body louse lays eggs

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on seams of clothes. The fertilized female lays 8 to 10 eggs per day and 50 to 100 eggs are laid by head louse while 200 to 300 eggs are laid by body louse. Egg after a week hatches into a very tiny louse which at once begins feeding about 2 to 6 times per day for the next 1 to 4 weeks. The life span of an adult is about one month.

Prevention and control. (1) One should have clean clothes, regular bath and avoid very close contact with infested persons.

(2) A drop of mercury is put in a little mustard oil and rubbed with a piece of coin for effective delousing.

(3) The surest and safest method of killing the body louse from the clothes is the vacuum fumigation with HCN or by methyl bromide fumigation.

(4) The DDT-benzyl benzoate formulation emulsion is very much effective for body louse and head louse both.

(5) Powder containing 2% malathion or 1% lindane is useful for delousing.

(6) A proper shampoo should be used to clean the hair.

7. Bed bug

Class ..... Insecta
Order ..... Hemiptera
Family ..... Cimicidae

Cimex lectularius Linne
Cimex hempipterus Fabricius

Every one of us must have bitter experience of this uninvited night guest at the time of sound sleep. It is cosmopolitan in distribution and inhabits hotel rooms, old buildings, houses, poultry sheds, barns, sleeping cots and mats. Although this is nocturnal but comes out often during the day. They also attack mice, rabbits, pigs, horses, cattle, poultry etc. They suck the blood by their piercing and sucking type of mouth-parts and carry blood infesting diseases.

The adult bed bug (Fig. 7) is wingless, brown coloured and 3 to 5 mm in length. They are having distinct offensive odour. Before feeding they are very active but when fully fed become sluggish.

Damage. They always disturb the human-beings at the time of sleeping. They bite by piercing mouth-parts causing itching and irritation. They are carriers of micro-organisms of a number of diseases viz., kala-azar, plague, typhoid and tuberculosis. However, no direct proof has been advanced that bed bugs are common vectors of diseases.

Life cycle. Bed bugs breed throughout the year although it is affected by the climatic conditions and the availability of the blood meal. After fertilization, female lays about 75 to 500 eggs at the rate of 3 to 4 eggs daily in safe places like cracks of furniture, cots and behind the base boards. After 6 to 17 days of incubation eggs are hatched into young nymphs. The life cycle is completed in about 2 to 10 months' time depending upon the climatic conditions. It has also

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been noticed that four generations may occur in a year. It is very interesting that the adult bug can live without food for a long time which may be up to one year.

Prevention and control. (1) The walls and floors should be white- washed and houses should be fumigated by HCN, methyl bromide or methyl formate.

(2) Spraying of 5% toxaphene or 1 to 2% chlordane, Y-BHC controls the bed bugs.

(3) The crude oil emulsion or kerosene oil or benzene emulsion are used for spraying and repeated after 3 to 4 days.

(4) Tick-20 is also used for their control.

(5) Boiling water is also poured on the furniture which reduced infestation.

The insecticide should be selected keeping in view the articles, particularly the furniture in the room.

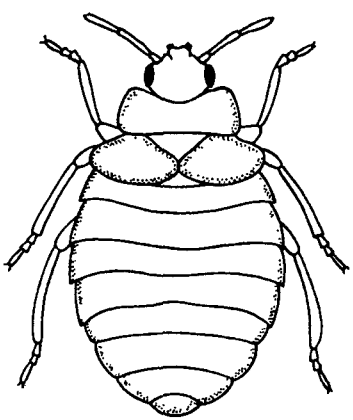

Fig. 7. Bed bug (*Cimex lectularius*).

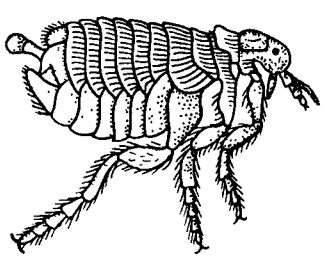

Fig. 8 Flea (*Xenopsylla cheopis*)

8. Fleas

Class ..... Insecta
Order ..... Siphonaptera
Family ..... Pulicidae

Xenopsylla cheopis (Rothschild)
Pulex irritans (Linni)

Fleas (Fig. 8) are cosmopolitan in distribution. They are blood suckers. Thus, cutaneous feeder in general, they act as a vector of a number of diseases. The rat flea *X. cheopis* is the transmitter of the bubonic plague caused by the bacterium (*Pasteurella pestis*) among human-beings. *P. irritans* attacks men, cats, dogs, rats and horses.

The adult of the rat flea is very hard-skinned, spiny and provided with piercing and sucking type of mouth-parts. The legs of the rat flea are very large, adapted specially for jumping.

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Damage. The adults of the rat fleas are vectors of micro-organism of the bubonic plague and murine endemic typhus. The biting of fleas causes irritation and itchy skin lesions.

Life cycle. Although breeding takes place throughout the year but it is less in cold season. The fertilized female lays eggs in dirt on dust which after, incubation period of 2 to 14 days hatch into legless and eyeless young larvae which feed on excreta of the adult flea with their chewing type of mouth-parts. Larvae after 7 to 35 days form cocoon from which adults emerge out after 7 to 35 days depending upon the climatic conditions.

Prevention and control. (1) Destruction of rats and other rodents and treatment of cats, dogs, hogs or other infested animals to kill the adult flea.

(2) Dusting of 1 to 2% chlordane,or 2% Y-BHC is very much effective in the elimination of fleas.

(3) In living house a light spray of the above or fumigation of HCN is recommended.

(4) Personal protection from flea can be obtained by treating trouser legs and socks with 2-phenyl-cyclohexanol or benzyl benzoate.

(5) Application of 5% DDT is recommended for spraying at the time of the spread of typhus and plague in all the areas.

Insects Damaging Food Products

9. Rice weevil

Class ..... Insecta
Order ..... Coleoptera
Family ..... Curculionidae

Sitophilus oryzae (Linne)

The rice weevils (Fig. 9) are the most destructive grain insects causing 50% damage of stored grains throughout the world.

Although it is a serious pest of rice but it also feeds upon maize, jowar, wheat, barley, bajara, corn, sorghum etc. They prefer humid condition and multiply rapidly in stores if undisturbed. Adults feed upon whole seeds or flour, but the larvae feed only on seeds or pieces of seeds or cereal products. The major damage to stored grains is due to larvae. Another species called as *S. granarium* (Linne) is also found damaging grains.

The adult is a reddish-brown 3 mm in length and bearing 4 yellowish spots on its back. The head region is provided with well defined rostrum. Larvae are white coloured, 5 mm in length and legless creatures called grubs. The adult males are smaller than females.

Damage. It is a serious pest of rice, maize, barley, jowar and sorghum in humid conditions. They also feed on cotton seed, corn, bajara and oats. The larval stage is found to be more destructive although its adults and larvae both

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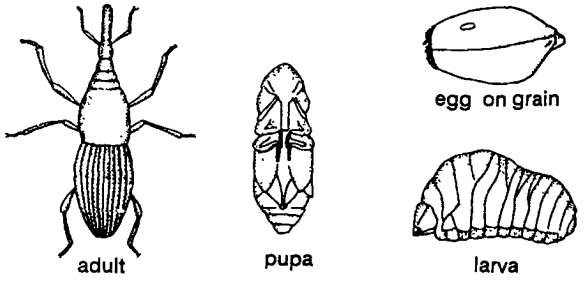

Fig. 9. Life History of *Sitophilus oryzae.*

destroy the grains. Maximum damage occurs between August to October and least in summer.

Life cycle. The female weevil in the months of April to October lays about 400 eggs in the holes of seed made by her mandibles. After 6 to 7 days of incubation eggs are hatched into larvae. The larvae feeding on the grains pupate and attain dark brown colour. The pupa, after 6 to 14 days of life, emerges into adult weevil. The life span of the adult weevil varies from 4 to 5 months and thus 3 to 4 generation have been observed in a year.

Prevention and control. (1) The dried and pest free grains should be stored in clean, insect-proof and dry granaries and examined constantly.

(2) Godowns should be heated up to 15°F for 10 hours and infested grains dried in sun light.

(3) Fumigation of granaries, containing grains, by 0.25 to 5% HCN for 18 hours or by carbon-di-sulphide for 24 hours or by methyl bromide for 48 hours is recommended. Fumigation by kiloptera is found to be very useful to control the weevils.

(4) Godowns should be sterilized by burning coke and spraying of 2 gallons of 2.5% methoxychlor per 1,000 sq. feet area.

(5) Surface infestation can be controlled by aerosols as pyrethrum aerosol and with Dichloro-difluoromethane which is highly effective.

10. Rice moth

Class ..... Insecta
Order ..... Lepidoptera
Family ..... Galleriidae

Corcyra cephalonica (Stainton)

It is a major pest of rice (Fig. 10) but also feeds on gram, sorghum, maize, ground-nut and cotton seed. It is distributed throughout Asia, Europe and North America. As stored grain pest, it causes serious damage to wheat in India and Pakistan.

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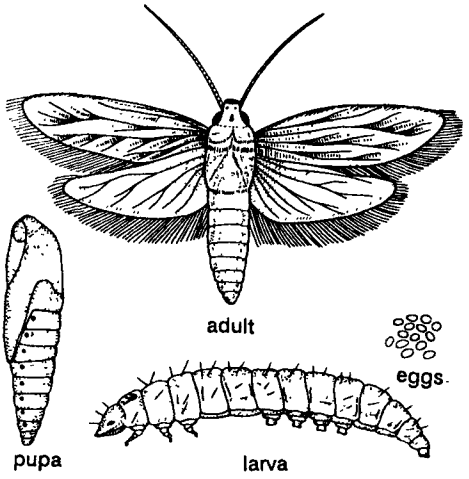

Fig. 10. Life history of *Corcyra cephalonica.*

Damage. Larvae are responsible for damage to grains of rice and maize. After strong infestation the whole of the stored stock is converted into a webbed silken mass and characterised by an unpleasant smell.

Life cycle. The most favourable condition for breeding is warm climate. The fertilized female moth lays 30 to 350 eggs, which, after 2 days or 2 weeks of incubation period, are hatched into larvae. Larvae feed on the grains and attain full grown stage in about 30 to 35 days and pupate in the form of cocoon. The pupal stage is of about 4 to 35 days after which adult moths emerge. Under favourable conditions the whole life cycle takes 5 to 6 weeks.

Prevention and control. (1) Seed and grains should be sterilized before storage.

(2) Godowns should be heated for 12 hours at 165°C.

(3) Fumigation by carbon tetrachloride and carbon bisulphide before and after storage is also useful.

(4) Stores should be clean, dry and devoid of cracks.

(5) The part of grains which are affected by pest should be removed quickly.

11. Wheat weevil (Khapra beetle)

Class ..... Insecta
Order ..... Coleoptera
Family ..... Dermestidae

Trogoderma granarium Everts

It is a major pest of wheat in Indian subcontinent but has also been reported from USA, England and Germany. In India, Uttar Pradesh, Haryana, Punjab, Bihar and Rajasthan are the areas where stored wheat is badly damaged by

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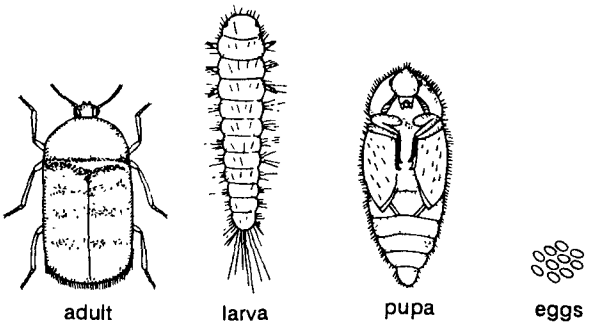

Fig. 11. Life cycle of *Trogoderma granarium.*

this pest. Other than wheat, rice, maize, oat, jowar, barley, gram and pulses are also attacked by this pest. The infective stage is only the larval stage.

The adults (Fig. 11) are dark brown coloured, 2 to 3 mm in length and the whole body is covered over with fine hairs. The females are large than the males and light coloured. Snout is well developed in the male weevils. The full grown larva is brown coloured having brown-yellow transverse bands across the body.

Damage. Only larval stage causes damage to wheat and other grains. They attack the superficial layer of grains. The maximum attack is in between July and October. The destruction of the embryo is the major damage by this pest but on heavy infestation every part of the grain may be destroyed. They are generally found attacking the upper 50 cm layer of the stored grain.

Life cycle. After emergence of 2 to 3 days of the adults, copulation takes place and the fertilized female lays eggs at the rate of 13 to 85 eggs in 1 to 7 days. The eggs after 3 to 5 days of incubation hatch into larvae which attain full grown stage in 20 to 30 days in case of the male and 24 to 40 days in the female and after that period they pupate. After 4 to 6 days of pupation adult weevils emerge. Four to five generations have been reported in a year. The breeding period is from April to October.

Prevention and control. (1) All preliminary precautions should be taken as mentioned in earlier cases of stored grain pests.

(2) Mostly, attack is superficial, so infested portion of grains should be removed completely and treated adequately.

(3) During severe infestation the adults and larvae can be trapped by spreading gunny bags over the grains resulting into clinging of the adults and larvae to the bags from which weevils should be collected and destroyed.

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12. Confused and red flour beetle

Class ..... Insecta
Order ..... Coleoptera
Family .... Tenebrionidae

Tribolium confusum Duval
Tribolium castaneum (Herbst)

About 85% of all the insects in flour mills are flour beetles (Fig. 12) which are cosmopolitan in distribution. Confused flour beetle is dominating over red flour beetle in flour mills. Although they severely attack wheat flour but flour of all starchy materials, peas, backing powder, nuts, drugs and many other food materials are also attacked by these beetles. Larval and adult both the stages are found infesting and causing damage.

The adult of *T. confusum* is elongate reddish-brown about 3 to 4 mm in length. Its larvae are found crawling over infested seed. They are brownish-white, flattened and six legged and known by millers as 'bran bugs'.

The adult of *T. castaneum* is reddish-brown, about 3 to 3.5 mm in length. Its larvae are reddish-yellow, about 6 mm in length and found crawling on the grains.

Damage. These beetles cause serious damage is monsoon period. They heavily damage flour in the mills but sometimes damage the grains in store which are already damaged partly by other pests. Both the adult and the larva are infective stages. After severe damage the flour changes into greyish colour and becomes unfit for human consumption.

Life cycle. The adults are very active and survive in moderately cold winters in unheated buildings and often live for 2 years or more in adult stage during which period the fertilized female produces 1,000 eggs in the flour or grains. After 4 to 10 days of incubation period the eggs hatch into larvae which after 6 to 7 moultings in 22 to 25 days get changed into pupae and settle in the flour. After 5 to 9 days of pupal period, adults emerge. The whole developmental period takes 26 to 30 days under favourable conditions.

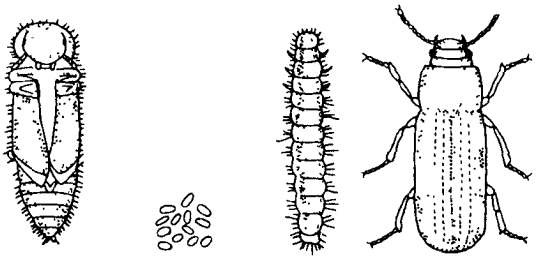

Fig. 12. Life cycle of *Tribolium castaneum.* *(Z–37/Eco. Zool.)*

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Prevention and control. (1) All precautionary steps should be taken before storage of the grains.

(2) Flour mills should be kept clean and dry.

(3) Modern sanitation procedures should be practised by millers.

(4) The infested portion of the flours should be removed.

(5) The adults or its other life stages should be removed from stores or godowns.

13. Pulse beetle

Class ..... Insecta
Order ..... Coleoptera
Family ..... Bruchidae

Callosobruchus chinensis (Linne)

It is a serious pest of stored gram and cowpea but also feeds on beans, lentil, arhar and other pulses. It is distributed in India, Burma, China, Japan, Africa, USA and Philippines. Only grubs are found to be infective stage for the stored grains and the maximum damage is reported from April to October. The holes on grains are the first evidence of infestation. The intensity of infestation is dependent upon humidity and temperature.

The adult beetle (Fig. 13) is reddish-brown in colour, 3 to 4 mm in length and provided with elongated serrated antennae. The full grown larva is 6 to 7 mm in length and is whitish and has light brown coloured head.

Damage. The heavy infestation is reported by the larvae in the months of April to October. The infestation of pulses due to this insect is on the top and almost all the grains of the infested store are damaged by this pest suddenly i.e. in no time. The infested grains become useless for human consumption.

Life cycle. Adults just after emergence copulate and fertilized female lays oval scale like eggs which are attached with the grains. The egg laying rate is 1 to 37 per day and thus single female can lay 34 to 113 eggs in total. The eggs after incubation of 7 to 14 days are hatched into larvae which bore into the grains and complete their development inside. The larva after 10 to 12 days, in August and September, gets changed into white coloured egg shaped pupa. The pupa, after 4 to 28 days, emerges by cutting a circular hole in the seed coat. The life span of the adult beetle varies from 5 to 20 days according to the climatic conditions.

Prevention and control. (1) All preliminary precautions, before storing, should be taken as mentioned earlier in case of other beetles.

(2) Two inch thick sand layer should be spread over the grains surface to check the egg laying.

(3) In winters the grains should be mixed with 4 times its weight hydrated lime, pyrethrum or derris powder and covered with one inch layer of fine dust of lime in the bins or drums.

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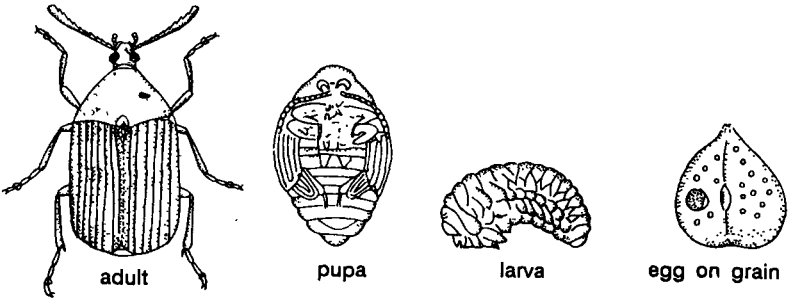

Fig. 13. Life history of *Callosobruchus chinensis*.

14. Mung dhora (Pulse beetle)

Class ..... Insecta
Order ..... Coleoptera
Family ..... Bruchidae

Callosobruchus analis (Fabricus)

It is a pest of mung, mash, peas, cowpeas etc. and distributed in India, Burma and Germany. The adult and larval both the stages cause damage to these pulses. The adult male is chocolate coloured while the female is also chocolate coloured but with black area in the centre of elytra towards outer margin. The larva is creamy-white coloured with oval body. The other species of the pulse beetle in India are *C. maculatus* (Fabricius), *C. phaseoli* Gyll; *C. quadrimaculatus* Fabr., *C., affinis* Frol.

Damage. In the months of April to August this beetle causes maximum damage because all stages are active during this period. The larvae feed inside the grain and make the seed hollow which gives unpleasant smell.

Life cycle. The male and the female emerge in the month of March, copulate and the female starts egg laying after 72 hours of mating. The female lays 11 to 50 eggs which, after 3 to 6 days in May to August, 3 to 13 days in November and 18 days in December, of inoculation period, hatch into young larvae which bore into the grain and feed there to attain full grown larval stage. The full grown larvae get pupated which ultimately emerge into adults. Experimentally, the duration of the larval and pupal stages at 25, 30, 35, 37°C is 15.8, 10.2, 19.9, 26.1 days and 10.4, 5.6, 6.1, 7.9 days respectively. The insect completes its life cycle in about 9 to 19 overlapping generations.

Prevention and control. (1) All preliminary precautions for keeping seed in the store, should be taken into consideration.

(2) Egg laying should be checked by 5 cm thick sand layer spread over the grain surface.

(3) Badly infested seeds should never be shown even after killing the beetles.

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(4) The fumigation of bins by a mixture of carbon tetrachloride and acrylonitrite (1 : 1) is recommended.

(5) The spraying of chloropicrin on the closed bins has proved better for the control.

15. Angoumois grain moth

Class ..... Insecta
Order ..... Lepidoptera
Family ..... Gelechiidae

Sitotroga cerealella (Oliver)

It is cosmopolitan in distribution. This small moth (Fig. 14) causes severe damage to stored paddy and jowar but is also reported to damage wheat, barley and maize. They also attack wheat in the field. Only adult stage can be observed from outside.

The adult moth is grey-yellow or brown coloured, 10 to 12 mm in length with wing expanse. The larva is white coloured, 5 mm in length and its head is characterized by yellow-brown colour.

Damage. In monsoon period maximum damage has been observed. The larvae feed on the grain and make hole. They have been reported to cause 30% damage to the grain but sometimes they completely destroy the grain. It is also observed that mostly the upper layer of the grains kept in the stores is severely attacked.

Life cycle. The moths after 24 hours of emergence start mating and after fertilization the female lays, on an average, 150 eggs within a week. It was found that at 20, 25, 30, and 35°C eggs hatch in 8.5, 6.0, 4.1, 4.6 days respectively. The young larvae feed on seeds for about 3 weeks and get changed into pupae

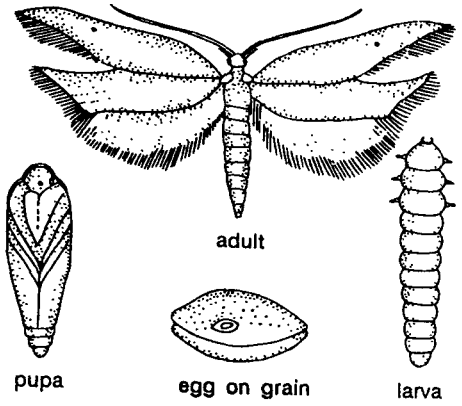

Fig. 14. Life history of *Sitotroga cerealella*.

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of reddish-brown colour which ultimately emerge into adults. It was found during experiments that at 20, 25, 30, 35°C the duration of larval and pupal stage is 23.5, 20.2, 19.4, 22.2 days and 12.5, 9.1, 6.5, 12.2 days respectively. The male has smaller life span than the female. The whole life cycle takes 28 to 37 days.

Prevention and control. (1) Before the storage, seeds and grains should be sterilized and dried well and other care should also be taken as stated earlier.

(2) Infested grains, eggs, larvae and pupae should be removed from the granaries.

(3) After infestation, godowns and granaries should be heated up to 60°F for 5 minutes.

(4) Fumigation by carbon tetra-chloride and carbon -di-sulphide before and after storage is also useful.

(5) Spraying of chloropicrin on the closed bins gives excellent results.

16. Potato tuber moth (Aloo ki surhi)

Class ..... Insecta
Order ..... Lepidoptera
Family ..... Gelechiidae

Gnorimoschema operculella (zeller)

It is a serious pest of potato distributed in Mediterranean regions, South France, East Indies, Australia, China, Tasmania, U.S.A. and India. It causes severe damage in godowns.

Adult moth (Fig. 15) is dark brown coloured having a fringe of hairs at the posterior margin of the hind wings. Larvae are elongated and provided with smaller spines throughout the body surface.

Damage. The larvae of this moth voraciously feed on green tissues of tuber resulting into infection of bacterial and fungal diseases. This moth is also reported damaging tobacco, tomato and some other solanaceous plants.

Life cycle. The female moth after emergence gets fertilized and lays over 80 oval eggs on the eyes of potato. Eggs hatch into caterpillars which feed on the mid-rib of leaves or bore into the tuber when they are present in the fields or the godowns respectively. The caterpillars feeding on the tuber get pupated after 10 to 15 days. The pupa is yellow brown, 5.5 to 7 mm in length and emerges into the adult moth. The time taken to complete the life cycle is known to be 25 to 35 days and 13 broods are found every year.

Prevention and control. (1) Good variety of potato seed, free from infection, should be sown at a depth of 12 cm and covered with soil.

(2) Affected tubers and other solanaceous weeds should be destroyed atonce.

(3) Just after digging, potato tubers should be kept in treated (1% DDT solution in xylene) bags immediately and examined twice a month.

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(4) Proper ventilation of godowns will reduce the temperature and render it fit for storage.

(5) Fumigation of stored tubers with CS_2 for 24 to 48 hours, petrol for 24 hours or methyl bromide for 3 hours are quite effective.

(6) Plants in the field should be spread with 1-2% DDT dust or 0.1% spray and uniformly covered with insecticides.

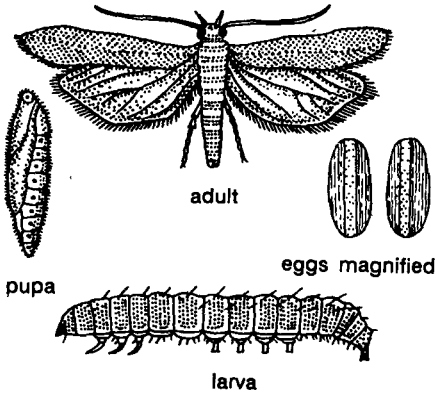

Fig. 15. Life history of *Gnorimoschema operculella*.

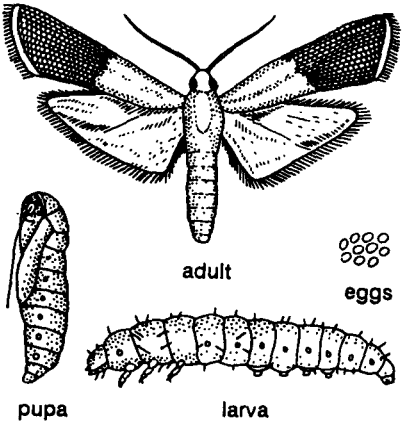

Fig. 16. Life history of *Plodia interpunctella*.

17. Indian meal moth

Class ..... Insecta
Order ..... Lepidoptera
Family ..... Phycitidae

Plodia interpunctella (Hubner)

This moth (Fig. 16) is cosmopolitan in distribution and attacks on grains, meal, seeds, soybeans, dried fruits, nuts, dried root, herbs, dead insects, museum specimens, powdered milk etc. It also causes severe damage in candy factories. They are also found to be very active in darker places.

The adult moth is about 13 to 20 mm with wing expanse and provided with coppery lusture on the outer two thirds of their fore wings. A cone-like beak is characteristic of this moth. The larva is greenish or pink coloured provided with light brown head. It is 8 to 13 mm in length.

Damage. The caterpillars cause severe damage to the grains or other food materials. The infested materials are webbed together and mixed with dirty silken masses containing the excreta of the larvae. Adult moth spreads the infestation by reaching from one to the other bins.

Life cycle. The moths after emergence copulate and the female after fertilization lays 30 to 350 eggs either in cluster or separately. The eggs after incubation period of 2 days to 2 weeks are hatched into larvae which feed on

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grains and other food materials as the case may be and after 30 to 35 days they pupate into cocoon. The pupa after 4 to 35 days emerges into an adult moth. About 4 to 6 generations are noticed every year.

Prevention and control. (1) Stores should be clean, dry and free from cracks.

(2) Dead spaces should be treated with oils.

(3) Heat or cold treatment proves to be a very much effective control measure.

(4) Fumigation by carbon-di-sulphide, carbon tetrachloride (1 : 4), ethyl dichloride, carbon tetra-chloride and ethyl-di-bromide (1 : 9 : 1) is quite effective.

(5) Fumigation by HCN liquid formulation, methyl bromide and ethyl oxide is also much effective.

18. Cheese skipper

Class ..... Insecta
Order ..... Diptera
Family ..... Piophilidae

Piophila casei (Linne)

This is world-wide in distribution and feeds on cheese and smoked cured meals.

The adult (Fig. 17) insect is about 5 to 6 mm in length. It is two winged fly and shiny in look. The larva is known as maggot and is legless, tapering towards the head end. The maggots are yellowish-white in colour and about 10 mm in length.

Damage. Damage is caused by small, naked maggots crawling in and over cheese or meat or jumping upto short distances by bending their body and then suddenly strengthening them.

Life cycle. The fertilized female lays about 500 eggs either in clusters or separately. After 24 to 36 hours of incubation, eggs are hatched into small fleshy maggots. These larvae after 7 to 60 days get changed into brown puparium and remain in this stage for about 7 to 10 days. The whole life cycle takes 18 to 20 days.

Prevention and control. (1) Infested part of cheese should be cut away or chopped off and then burnt.

(2) The places where cheese is kept should be maggot free either by closing the door tightly or by using 30-mesh screen.

(3) Cheese should be examined properly to see that no infestation is going on in the store.

(4) After serious infestation in store rooms, they should be fumigated with hydrogen cyanide gas at 20 ounces per 100 cubic feet.

(5) Synergized pyrethrins aerosols also control the adult infestation.

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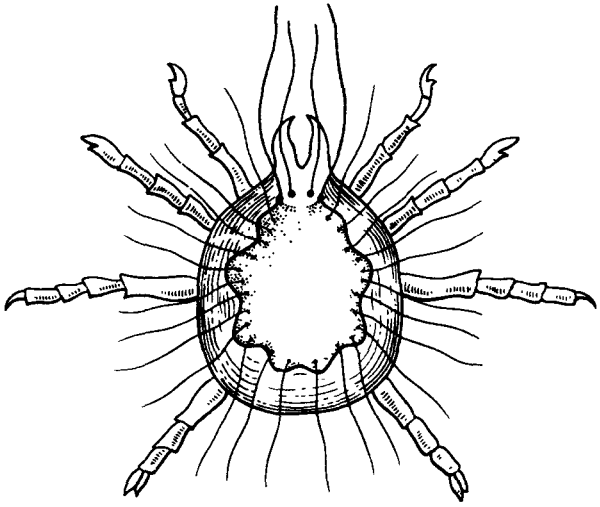

Fig. 17. *Piophila casei.*

(6) The heating of the store up to 125° F for 1 hour also kills the larvae and pupae.

(7) The cheese and meat kept below 43°F in the store will not be infested by this pest.

Insects Damaging other House Hold Goods

19. White ants (Termite) or Dimak

Class ..... Insecta
Order ..... Isoptera
Family ..... Termitidae

Microtermes obesi Holmgren

Odontotermes obesus (Rambur)

Termites (Fig. 18) are social insects and their colony comprises of six castes viz., winged adults, queen, king, complementary castes, workers and soldiers. The main food of termites consists of cellulose rich materials like wood-work, mango, sugarcane, potato etc. They are found commonly living under the ground but their earthen mounds are visible above the earth surface.

Social organisation. The colony of termites is well managed by division of labour and comprises of reproductive castes and sterile castes.

(a) Reproductive castes. It comprises of 4 types.

(i) Colonizing adults. They are produced in good number in rainy season and are winged males and females. Both male and female individuals go on nupital flight, copulate there in the sky and the female after fertilization may have a new colony separately.

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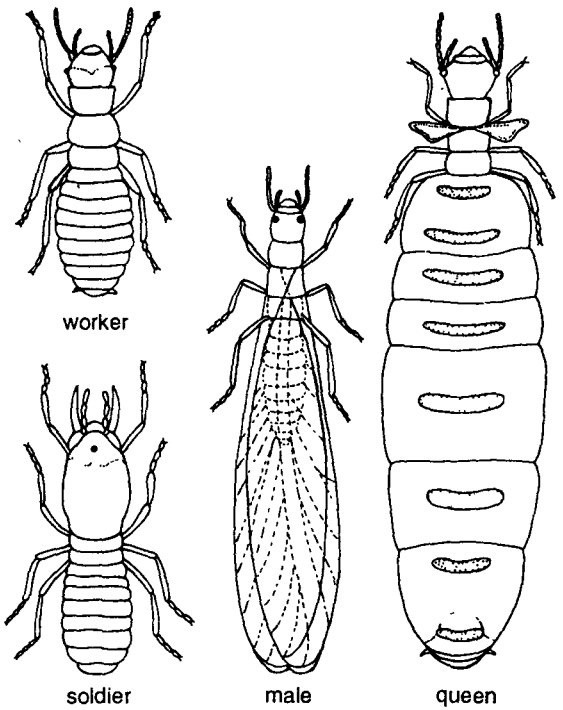

Fig. 18 White ant (*Microtermes obesi*).

(ii) Queen. Queen is either developed from above mentioned colonizing adults or from the wingless individuals (complemental) of a colony. The queen of *M. obesi* is 5 to 7.5 cm in length. The sole function of the queen is egg laying which lays 70,000 to 80,000 eggs in 24 hours. The life span of a queen is recorded to be 5 to 10 years. The queen lives in Royal chamber of the nest and feeds on Royal jelly. The queen is well served by the workers.

(iii) King. King is the father of the colony living with the queen in the Royal chamber. It is developed from an unfertilized egg by feeding on nutritive diet. It fertilizes the queen repeatedly to produce fertilized eggs for the hatching of the colonizing forms and workers. Life of the king is shorter than the queen. So the king is replaced by a new one.

(iv) Complementary castes. These are comprised of both the sexes and may function as king or queen in emergency after feeding on special diet to activate their reproductive function according to the need of the colony. This is governed by the workers.

(b) Sterile castes. *(v) Workers.* The workers are developed from the fertilized eggs. They are provided with well developed mandibles to feed on woody substances. The food of the workers consists of wood, sugarcane, paper, books and other cellulose containing articles. All the duties of the complicated colony,

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except reproduction and defence, are performed by notorious workers. The destruction of the material which they attack is caused by the workers.

(vi) Soldiers. They are developed from unfertilized eggs and characterised by big head and highly chitinized sickle-shaped mandible. Two types of soldiers are found: (i) The mandibulate type of soldiers having well developed jaws for fighting. (ii) The nasute type of soldiers, having median frontal rostrum, spray smell of obnoxious type.

Damage. Termites cause heavy damage to wood work, fancy, wooden poles within soil and a number of house-hold goods. Mango, apple, coconut, sugarcane, cotton, potato, wheat, tea and coffee crops are also damaged by this insect. Firstly they attack on dead bark then pith of the plant. Timber is totally tunnelled and consumed up. Sometimes they cause destruction of buildings and railway yards by making tunnels below them.

Life cycle. The colonising adults swarm, copulate in air and come down on the earth surface for egg laying. The queen firstly lays few eggs and performs all duties of the new establishing colony. Eggs after 7 days of incubation are hatched into larvae which form different castes viz., workers and soldiers according to conditions within 6 months. The reproductive capacity of the queen is very high and she can produce millions of eggs in her life. The queen now starts to live in the royal chamber.

Prevention and control. (1) In an established colony it is very difficult to eradicate the termites so it is better to find out the queen and kill her.

(2) At the time of plantation the pit should be treated with 0.2% dieldrin.

(3) For protecting the trees, spraying of 1% dieldrin is quite effective.

(4) Alternatively 10% BHC dust at the rate of 20 to 25 kg per hectare should be raked.

(5) Sugarcane at the time of planting should be dipped in 0.25% BHC suspension or 0.5% DDT suspension or treated with 5% BHC dust or 0.25 aldrin, dieldrin, chlordane, BHC etc.

(6) BHC 0.2% or dieldrin when poured in mound becomes a very effective control measure.

(7) The wooden structures should not directly touch the soil so they should be on cement layer. Application of a mixture of dieldrin and BHC is very effective to protect from termite attack.

(8) Woodwork should be painted with solignum and dusted with BHC after a few days.

20. Black ants

Class ..... Insecta
Order ..... Hymenoptera
Family ..... Formicidae

Monomorium indicum Forel
Monomorium gracillinum Smith
Camponotus compressus Fabricius

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Although black ants (Fig. 19) are world-wide in distribution but are more destructive in tropical and subtropical countries. It forms its nests in walls, floors and roofs of the buildings.

Ants are also socially organised insects and the colony consists of queen, male and workers. In monsoon after swarming the queen and the male go for nuptial flight and copulate in the air.

Damage. The workers cause damage and feed on anything edible which comes in their way. They use to take away grains out of store. They prefer to feed on sweets but they also attack wooden materials and make holes. Sometimes they make holes in the roofs of the houses which causes leakage in rainy season.

Life cycle. After fertilization the queen goes and settles into the nest and lays eggs after one month of nuptial flight. Eggs hatch into grubs. The grubs feed on the salivary secretion of the mother and after some time the grubs pupate, then the first batch of workers comes out in the newly established colony. They take many years to establish their well planned colony. It is observed that the life span of a queen is about 15 years.

Prevention and control. (1) To check the establishment of an ant colony is easier than the eradication of a full grown colony.

(2) The queen should be destroyed for permanent control of ants.

(3) BHC emulsion should be poured in the nest to destroy queen and other members of the colony.

(4) Houses should be kept clean, specially sugar should not be kept open here and there.

(5) By BHC dust, any area may be protected from ant attack.

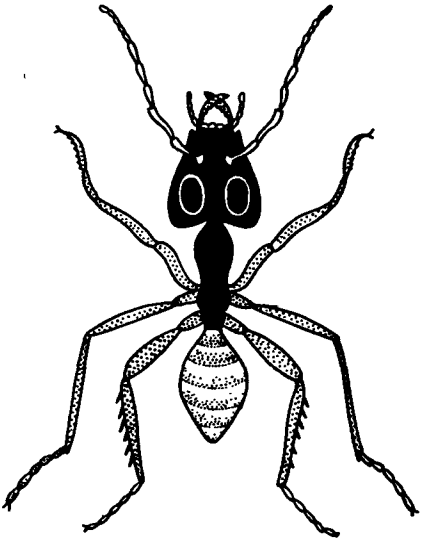

Fig. 19. Black ant (*Monomorium indicum*).

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21. Wax moths

Class ..... Insecta
Order ..... Lepidoptera
Family ..... Gallenidae

Achiora grisella (Febricius)
(Lesser Wax Moth)
Galleria mellonella Linnaeus
(Greater Wax Moth)

Greater wax moths cause severe damage to bee-keeping industries in plains and lower hills of India. Lesser wax moths also attack the honey-comb but in lesser number.

The adult moth (Fig. 20) is brownish grey in colour and 25 to 40 mm across the spread wings. The caterpiller is dirty grey in colour and 30 mm in length. These caterpillars attack the bee-colonies.

Damage. The caterpillar stage only causes damage to honey-combs because they feed on wax. At the time of severe attack the honey-comb looks like a mass of webbings which interferes with the rearing of the brood in chambers. The caterpillars also feed on old comb, propolis, pollen, larval skin and other proteinaceous ,materials.

Life cycle. The adult moths emerge in months of March-April and mate outside the bee-hive. The fertilized female lays about 1,000 eggs inside the bee-hive within 15 days of her life span. After an incubation period of 7 to 18 days eggs hatch into caterpillars which feed on gnawed pieces of honey-comb. After about 4 weeks they pupate inside silken cocoons. After one week of pupal life adults emerge from the cocoon. For the complete life cycle 6 to 7 weeks are required.

Prevention and control. (1) All cracks and crevices in the bee- hive should be covered with moulding-clay.

(2) The main enterance of the artificial hive should be reduced for easy watch of the entering wax moths by worker bees.

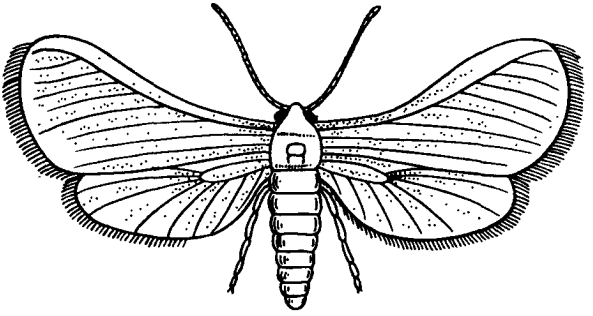

Fig 20. Wax moth (*Galleria mellonella*)

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(3) Any caterpillar when found should be removed out of the comb.
(4) Stocks should be in air tight boxes.
(5) If store is attacked, fumigation by EDCT and aluminium phosphide proves to be very useful for control.

22. Book louse

Class ..... Insecta
Order ..... Psocoptera
Family ..... Psocidae

Liposcellis transvallensis Enderlcin

It is cosmopolitan in distribution (Fig. 21) and is active gregarious insect found in bindings of books, paper boxes, cards and papers attached to the wall.

They are small, pale coloured, soft bodied and apterous insects. They are provided with chewing type of mouth-parts, long legs and antennae.

Damage. Although the outlooking infestation is not so much but they cause significant damage when present in large numbers as they specially damage old books. So, the loss of old literature by this pest can never be compared in terms of monetary loss.

Life cycle. They multiply rapidly but grow very slowly according to the climatic conditions. In favourable warm conditions they may breed throughout the year. The young emerged nymphs are similar in structure to the adults but smaller in size.

Prevention and control. (1) The room, almirahs should be ventilated and cleaned and the room floor and furniture should be washed with kerosene or creosote.

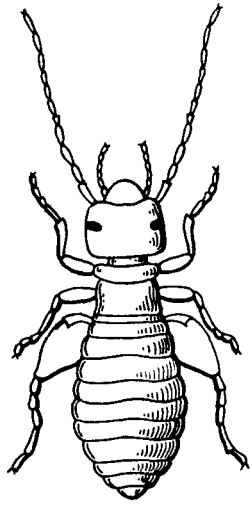

Fig 21 Book louse (*Liposcellis transvallensis*)

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(2) Naphthalein and camphor can also be used to control.
(3) Sodium fluoride mixed with flour (1 : 8) is a very effective poison bait.
(4) A mixture of 5 gm mercuric chloride, 60 drops of creosote, 2 pints of spirit and one ounce of carbolic acid is highly toxic.
(5) Fumigation of library, house and mounds with about 3 pounds for every 1,000 cubic feet of space closed for 24 hours has been proved to be very effective control measure for book louse.

23. Silver fish

Class ..... Insecta
Order ..... Thysanura
Family ..... Lepismidae

Lepisma saccharina Linnaeus

It is cosmopolitan in distribution (Fig. 22) and mainly found living in moist warm places and in old books etc. It is whitish, wingless insect of about 13 mm in length and found to be very active. They are found active throughout the year in warm climate.

Damage. Silver fish mainly attacks old books and magazines but also infests starched clothes, rayon fabrics, book labels or bindings whenever glue has been used.

Life cycle. The female lays eggs in warm places which, after incubation period of 6 to 10 days, hatch into young nymphs which are just like the adults but smaller in size than the adult silver fish. After 7 to 9 months it matures and is ready for further breeding.

Prevention and control. (1) Books should not be kept in damp places.
(2) After sometime books should be exposed to sunlight specially if they are not under regular use.
(3) Poisioned glue, pasted over the paper, should be kept with the books which would cause mortality to silver fish. This bait should be prepared by mixing wheat flour, sodium fluoride, powdered sugar and powdered common salt (200 : 16 : 10 : 5 parts)
(4) The dusting of 5% malathion has proved to be effective control measure for heavily infected cases.

24. Clothes moths

Class ..... Insecta
Order ..... Lepidoptera
Family ..... Tineidae

Tinea pellionella (Linne) (case making clothes moth)
Tineola bisselliella (Hummel) (Webbing clothes moth)
Trichophaga topetzella (Linne) (Carpet cloth moth)

Clothes moth (Fig. 23) is cosmopolitan in distribution and attacks the materials left undisturbed for sometime or stored in dark places. The adult moth is buff-coloured, 1.25 mm in length across the wings and found running on the

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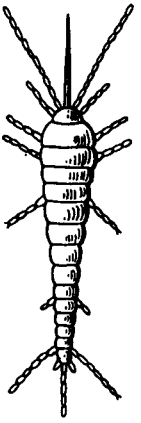

Fig. 22. Silver fish *Lepisma saccharina.*

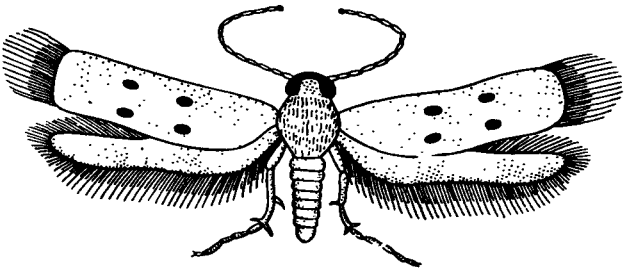

Fig. 23. Clothes moth (*Tinea pellionella*).

surface of infested goods. They are not attracted towards light. It is notable that adult never takes food. The larva is white coloured about 1.5 to 2 mm in length which varies according to the supply of the food.

Damage. Only larvae are infective stage. They feed on wool, hair, feather, fur, upholstered furniture, milk powder and nearly all animal product. But adult moth never takes food so are harmless.

Life cycle. The female moths after fertilization lay 100 to 150 eggs singly on the materials on which larvae can feed. After 5 days of incubation period eggs are hatched into larvae which feed on regularly. The growth is related with the supply of the food materials. Larvae after full growth (from 6 weeks to 4 years) get pupated in cocoons. From the pupae, after 1 to 4 weeks, emerge out the adult moth. The complete life cycle takes two months in normal conditions but sometimes it takes four years.

Prevention and control. (1) In tightly closed boxes naphthaline flakes at the rate of 0.5 to 1 pound in 15 cubic feet space is much effective.

(2) At the time of storage the furniture, clothes and papers should be free from moths.

(3) Pyrethrum powder, if fresh, is highly toxic for the larvae.

(4) Frequent dusting, brushing and vacuum cleaning of the clothes and leather is effective control measure.

(5) Fumigation by para-dichlorobenzene crystals over papers, furniture, and clothes in the boxes or rooms and to vacate for more than one month, is much effective to control clothes moth.

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25. Carpet beetles

Class ..... Insecta
Order ..... Coleoptera
Family ..... Dermestidae

Anthrenus scrophulariae (Linne)
Anthrenus flavipes Le Conte
Attagenus piceus (Olivier)

Carpet beetles (Fig. 24) attack woollen goods, cotton goods, leather, bristles, feather, hair, silk etc. They are also reported feeding on grains and insect specimens.

The adult is small blackish, hard-shelled beetle, sometimes flecked with white or reddish scales and never infects any article. The larvae are 6 mm long and are voracious feeders and attack all the materials as mentioned above. They bear cluster of hairs on their whole body surface.

Damage. Holes are made in fabrics like, clothing, furniture, curtains, specially those containing wool, fur, hair, feather and brushes of animal bristles. Most severe attack of this beetle has been observed on the materials kept undisturbed for a long time. They also feed on stuffed animals, flour, grains and many other animal and plant products.

Life cycle. Breeding may take place throughout the year in uniformly heated buildings. Female after fertilization lays about 50 eggs on the food materials of the larvae or in dark secluded places as upon clothes and cracks. After 7 to 10 days of incubation, eggs are hatched and young larvae come out and start feeding voraciously. After 5 to 11 moults, which require 1 to 3 years to complete its growth depending on the climatic conditions and supply of food material, larvae get pupated and after 1 to 4 weeks the adult beetle emerges out in the months

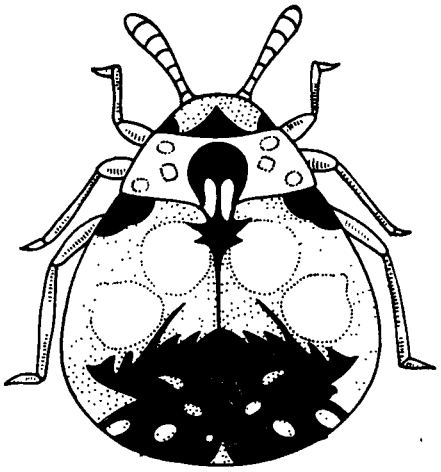

Fig 24. Carpet beetle (*Anthrenus scrophulariae*).

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of May to June. The life span of adult is about two weeks to several months but they never damage the house-hold goods.

Prevention and control. (1) Brushing, dusting and beating give little opportunity to establish the carpet beetles.

(2) On heavy infestation, fumigation of the room by HCN or CS_2 is recommended.

(3) Use of DDT, chlordane, Y-benzene hexa chloride and pyrethrum is highly toxic.

(4) Flakes of naphthaline of para-dichlorobenzene between the sheet of paper using one pound for 20 to 100 cubic feet.

(5) Heating to 135° F for 6 hours, kills all stages of carpet beetles.

26. House crickets

Class ..... Insecta
Order ..... Orthoptera
Family ..... Gryllidae

Gryllodes sigillatus Linnaeus
Achela domesica Linnaeus

A large number of cricket species are found in the different regions of the world but *A. dometica* is commonly known to houses.

They make very shrilling noise by their stridulating organs. They are found living in various crevices in the wall, floor, ceiling, books etc. They feed on plant foliage but are practically carnivorous, eating other insects and small invertebrates. They are found very active in monsoon.

The adult cricket (Fig. 25) are yellow-brown in colour with long antennae, tarsi 2 to 3 segmented and modified hind legs for jumping. The nymph is quite similar to the adult crickets but smaller in size and without wings.

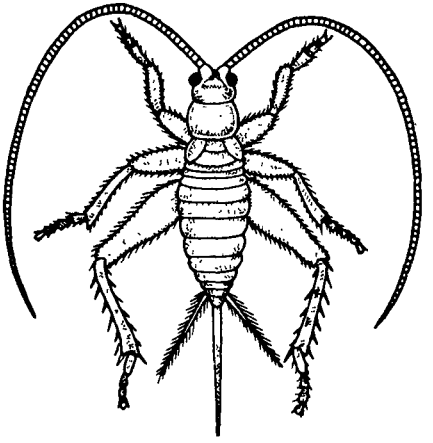

Fig. 25. House crickets (*Gryllodes signillatus*). *(Z–37/Eco. Zool.)*

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Damage. They produce high pitched shrilling noise and disturb the night. They feed on different food materials in the house and pollute them. It has also been observed in the field that crickets destroy some plant parts viz., roots and fruits by their chewing type of mouth-parts.

Life cycle. Fertilized female lays her eggs in the summer either in the soil or at other places. After about 7 to 8 days the eggs hatch into nymphs which are very much similar to the adults except that they are smaller in size and are wingless. After a period of 3 to 4 months, depending upon the climatic conditions, the nymphs attain the adult stage.

Prevention and control. (1) The control of crickets is very difficult job but they can be checked to some extent by baiting or by trapping.

(2) Poison baits are prepared with barium, sodium fluoride, chlordane, and gamexene.

(3) The spraying of 10% Parathion and 5% Carbaryl in the houses can suddenly control the crickets.

(4) Chinese eat crickets as food and use them in hotels to make noise, so the population of crickets in China has been reduced.

IMPORTANT QUESTIONS

» ***Long answer type questions***

1. Give short account of the household insects of economic importance.
2. Give an account of the household insects effecting human health as carrier of diseases.
3. Give an account of the household insects damaging food products.
4. Give an account of the household insects damaging stored grains.
5. Give an account of the nature of damage and control measures of termite, black ants, wax moth, clothes moth and carpet beetles.

» ***Short answer type questions***

1. Enumerate the nature of damage and control measures of house fly, mosquitoes, wasp and sand flies.
2. Enumerate the damage caused and control measures of human louse, bed bug and fleas.
3. Describe the nature of damage and control measures of rice weevil, rice moth, confused and red flour beetles and pulse beetle.
4. Enumerate the damage caused and control measures of termite, book louse and silver fish.

» ***Very short answer type questions***

1. Give an account of the diseases caused due to transmission by house fly, mosquitoes, human louse and fleas.
2. What are the sterile castes of termite ?
3. Mention the nature of damage caused by clothes moth and carpet beetle.

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» ***Objective type questions***

1. The common name of *Phlebotomus argentipes* is :
   (a) Potato tuber moth (b) Angoumois grain moth
   (c) Tse-tse fly (d) Sand fly
2. *Xenopsylla cheopis* belongs to family :
   (a) Cimicidae (b) Pulicidae (c) Psychodidae (d) Culicidae
3. *Cimex lectularius* belongs to family :
   (a) Pulicidae (b) Psychodidae (c) Culicidae (d) Cimicidae
4. *Pediculus humanus capitis* belongs to order :
   (a) Hemiptera (b) Siphonoptera (c) Anoplura (d) Hymenoptera
5. The common name of *Sitophilus oryzae* is :
   (a) Wheat weevil (b) Rice weevil (c) Pulse beetle (d) Mung dhora
6. The common name of *Trogoderma granarium* is :
   (a) Khapra beetle (b) Rice moth (c) Rice weevil (d) Pulse beetle
7. *Corcyra cephalonica belongs* to family :
   (a) Dermestidae (b) Tenebrionidae (c) Bruchidae (d) Gelleriidae
8. The common name of *Piophila casei* is :
   (a) Indian meal moth (b) Cheese skipper (c) Potato tuber moth (d) Mung dhora
9. Silver fish belongs to family :
   (a) Lepismidae (b) Tineidae (c) Dermestidae (d) Formicidae
10. The common name of *Monomorium indicum* is :
    (a) Wax moth (b) Book louse (c) Black ant (d) Clothes moth

Answers

1. (d), 2. (b), 3. (d), 4. (c), 5. (b), 6. (a), 7. (d), 8. (b), 9. (a), 10. (c).

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5

Mites and Ticks and their Control

Arachnids are terrestrial and air-breathing arthropods which include a number of parasites and pests. Three orders of this class are of economic importance viz., Acarina, Araneida and Scorpionida. Ticks and Mites belong to the order Acarina and infest a number of plants and animals. These are small-sized and oval having compact bodies without clear differentiation of prosoma and opisthosoma. Mouth-parts are well adapted for biting, sucking and piercing. Chelecerae and pedipalps are small chelate and associated with the mouth-parts. The segmentation in the posterior part of the body is greatly reduced and sometimes is altogether absent. The number of legs are variable in larval, nymphal and adult stages. The legs are 3 pairs in the larva and nymph while 4 pairs in the adult stage. The respiration is performed by the trachea but in its absence cutaneous respiration takes place.

Mites are major agricultural pests and of considerable biological importance. They are smaller than the ticks and are predaceous, parasitic and scavengers. Some of them are microscopic in size. They are found inhabiting almost every habitat suitable for animal life viz. in fresh water, in sea-water, in hot water, in soil, on vegetation, in plant galls, under stones, in debris, on dead animals etc. Some species are parasites of insects, farm animals, birds and even on man. Some mites and ticks of economic value have been mentioned here in detail.

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Mites

1. Mangemite : *Sarcoptes scabiei* (DeGeer)

Phylum ..... Arthropoda
Class ..... Arachnida
Order ..... Acarina
Family ..... Sarcoptidae
Genus ..... *sarcoptes*

The mangemite infects men, horses, goats, buffaloes and sheep. A number of varieties have evolved which are confined to the specific host viz., *S.s. hominis* on man; *S.s. equi* on horses, donkeys and mules; *S.s.caprae* on goats and horses and *S.s. dromedarii* on camels (Fig. 1).

General appearance. The female mites are about 0.06 mm in diameter, whereas males are half the size of females. Four pairs of short stubby legs are found of which the third pair in the male and third and fourth pair in the female end in the form of bristles which are as long as the body. The skin is pale coloured and striated. The eye and tracheae are absent. Just after mating the female digs the skin of the host and forms tunnels of 2.5 cm length and a diameter of about 0.08 mm.

Life history. The female after mating enters the galleries made in the skin and lays about 24 eggs. Six-legged larva hatches out from the egg and is gradually changed into eight-egged nymphal stage which feeds inside the galleries and attains the adult stage which can survive for about 10 days and may infest new hosts on contact.

Damage. The burrowing, especially the feeding, of mites causes extreme itching which the main symptom of the disease. The tunnels are parallel to the skin surface and can be observed as delicate grey thread lines beneath the skin, between fingers and toes, on external genitalia, behind knee and in prolonged cases, all over the body except the head. Sarcoptes mange causes different types of damage if different hosts viz., on buffaloes and cattle in the perineal region and the neck, on horses in thin skinned area, on pigs around the eyes and ears, on camels in the groin, flanks, belly, legs, head, back and neck. The hard pin-headed pamples provided with yellow fluid are formed on the affected part which after scratching cause the formation of large sores and scabs. The entrance of venom and nervous strain caused due to the feeding of the mites depresses the host resulting into weakness.

Prevention and control. (1) The infected individuals must be isolated from the rest of the house-hold.

(2) The body of the infected animals should be treated with a dilute mixture (1 part to 5 parts water) of benzyl benzoate (68 parts), DDT (6 parts), benzocaine-ethyl p-aminobenzoate (12 parts) and Sorbiton monooleate

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polyxyalkalene derivative (14 parts). The mixture must not be used on the head region.

(3) The treatment with 1 per cent lindane or 10 per cent sulphur ointment is also effective.

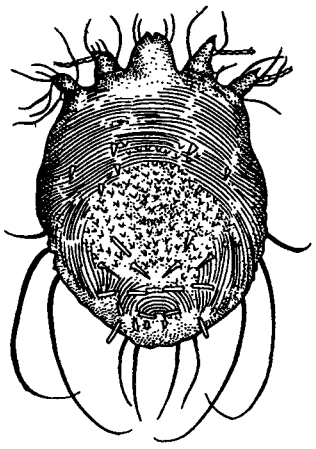

Fig. 1. *Sarcoptes scabiei.*

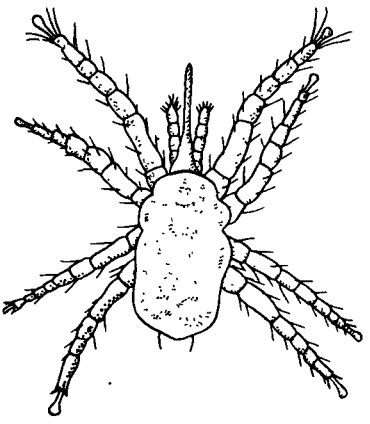

Fig. 2. *Dermanyssus gallinae.*

2. Chicken Mite : *Dermanyssus gallinae* (DeGeer)

Phylum ..... Arthropoda
Class ..... Arachnida
Order ..... Acarina
Family ..... Dermanyssidae
Genus ..... *Dermanyssus*

The chicken mites attack preferably chickens. The other poultry is not likely to be affected badly if chickens are available. In the infested houses it causes irritation to persons or other animals. They are cosmopolitan in distribution and cause more trouble in dry and warm countries. They live in walls, floors, cracks, ceilings of the houses during day time and at night they crawl upon the fowls. They feed normally on the blood of fowls (Fig. 2).

General appearance. The adult chicken mites are grey coloured and 0.1 mm to 0.15 mm in length. When they are replete with blood they look bright red to black in colour. They have sharp piercing type of mouth parts. It is found that adults feed on alternate days.

Damage. The chicken mites feed on the blood of fowls by sharp piercing mouth-parts at night. They never stay on poultry, so it is very difficult to know the infection of mites in primary stages. The mites are found in abundance where the roost timbers rest on their support. Affected fowl becomes droopy, listless and becomes unable for egg laying and ultimately dies.

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Life history. The number of chicken mites is greatly reduced during cold weather. With the advent of spring, their activity gets increased and female lays pearly-white elliptical eggs in cracks or in dry manure under the roosts. Within a period of a few weeks 25 to 35 eggs are laid and hatching occurs after 2 to 4 days producing young, six-legged nymphs. The nymphs become 8 legged when they search for a fowl and feed on blood. After third moulting the nymph becomes adult. The time taken for development from egg to an adult is about 10 days.

Prevention and control. (1) Poultry houses should be without cracks and cleaned thoroughly.

(2) Poultry houses should be simple, ventilated and with natural light.

(3) Poultry houses should be sprayed by 1 per cent malathion at the rate of 1 to 2 gallons per 1,000 square feet.

(4) The birds should be sprayed by 0.5 per cent malathion at the rate of one gallon per 100 birds.

3. Sheep Scabe Mite : *Psoroptes equiovis* (Herring)

Phylum ..... Arthropoda
Class ..... Arachnida
Order ..... Acarina
Family ..... Sarcoptidae
Genus ..... *Psoroptes*

This mite attacks sheep and other cattle particularly goats and horses. It is cosmopolitan in distribution. It causes scabies which is one of the serious diseases of sheep. It feeds on the surface of the skin like the mangemite. The eggs, young ones as well as the adult swarm together with the scab from an infested animal (Fig. 3).

General appearance. The adult scab mite is 0.1 mm in diameter and greyish in colour. The mouth-parts are sharp and of biting and sucking type.

Life history. The female lays 1 to 2 dozen eggs in small clusters at the base of the hair. The eggs, after 2 to 10 days laying, are hatched into six legged nymphs which develop an additional pair of legs. After 1 to 2 weeks time the nymphs grow into adults. The female adult may survive for 1 month and deposits 100 eggs.

Damage. In the infected sheep the scabies is identified by 'tagging' and rubbing of the body by animals. The mite punctures the skin of the sheep with its mouth-parts. Just after puncture, the blood starts flowing over the skin, hardens and forms a scab containing mites beneath it. The mite continuously feeds on the skin with the result of that successive layers of scabs are formed which cause the removal of hair by the roots. The loss of blood and irritation and introduction of irritating poison due to feeding of mite, sheep becomes weak and if not properly cured dies after a few days.

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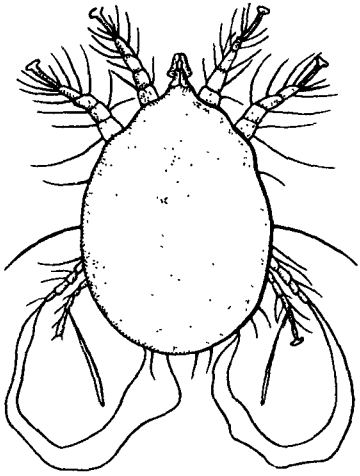

Fig. 3. *Psoroptes equiovis.*

Prevention and control. (1) The quarantine measures should be practised.

(2) The dipping of individuals for 2 min. in Lime-sulphur at a dilution of 1 part to 15 parts of water is most effective to eradicate the mites. At least two dippings are necessary in case of heavy infestation after 10 to 14 days interval.

(3) The dipping of infested sheep in nicotine, lindane and toxaphene is also effective.

4. Straw Itch Or Harvest Mite : *Pyemotes ventricosus* (Newport)

Phylum ..... Arthropoda
Class ..... Arachnida
Order ..... Acarina
Family ..... Pediculoididae
Genus ..... *Pyemotes*

This mite attacks only men and insects, and is most troublesome. The persons engaged in handling cotton, beans or small grains, and usually sleeping on straw-filled mattresses are mostly attacked. The symptoms produced are much like chiggers. It is predaceous in nature and preys on rice and granary weevils, and Angoumois grain moth (Fig. 4).

General appearance. This mite is microscopic and the normal size of female is 0.03 mm long which, after mating, becomes 0.25 mm in length.

Life history. The fertilized female contains 200 to 300 eggs. The eggs hatch inside the abdomen of the mother and the nymphs develop into adult stage within the abdomen of mother itself. The adults are born viviparously.

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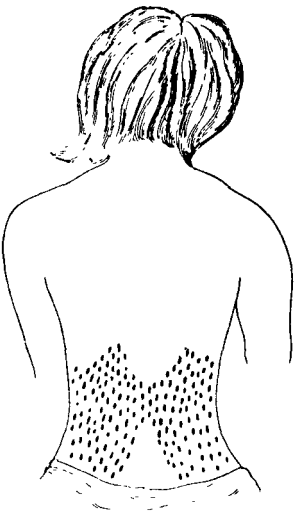

Fig. 4 *Pyemotes ventricosus.*

Just after birth the adults mate and start new generation which is completed within one week. Thus a single female produces 200 to 300 adults mites.

Damage. This mite bites the individuals and hive-like eruptions appear on the body which cause itching for about a week. This also causes headache, vomiting and fever. Only adults are responsible for this infection.

Prevention and control. (1) People should keep themselves away from infested straw stubbles or seedstores.

(2) Before working among infested materials free use of sulphur dust in clothing should be done and work clothes should be changed soon.

(3) Fumigation and heating at 130° F for 6 hours protects the mattresses and other things from infestation.

(4) The application of cooling ointments provides slight relief from irritation to infected persons.

5. Chiggers : *Eutrombicula alfreddugesi* (Oudeman)

Phylum ..... Arthropoda
Class ..... Arachnida
Order ..... Acarina
Family ..... Trombidiidae
Genus ..... *Eutrombicula*

Chiggers attack on men, poultry, domestic animals, snakes, frogs, squirrels, rabbits etc. It is distributed in peculiar way because some areas are badly attacked, while other areas apparently similar and far distant are free. The infective stage is 6 legged larva and not the adult (Fig. 5).

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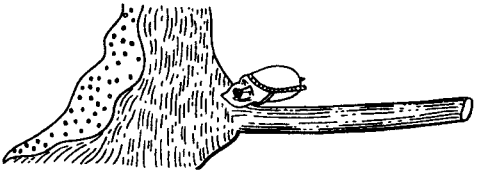

Fig. 5. *Eutrombicula alfreddugesi.*

General appearance. The adults do not attack men and are scavengers on the excrement of other arthropods or on decaying wood. Small 6 legged mite is about 0.025 mm in diameter and can not be seen by naked eyes. They are oval, orange coloured and run very fast.

Life history. After fertilization female lays eggs which hatch into 6 legged larval mite. The eggs are laid in the overlapping scales of snakes and turtles. The 6 legged larval stage of this mite attacks the man and causes irritation due to feeding by inserting its sharp mouth-parts in the skin. After being full fed, this 6-legged larval mite drops off from man in September and settles into the loose soil during the winter. Further, it attains the nymphal stage which after 2 to 3 weeks moults and attains adult stage and remains in its earthen cells in the soil until spring. Only one generation has been recorded per year.

Damage. The 6-legged larval mite causes the appearance of scattered red blotches of varied size followed by itching for about a week. The human-being become nervous resulting into his illness. This mite injects a poisonous substance which causes irritation.

Prevention and control. (1) Clothes should be treated with dimethyl phthalate, dibutyl phthalate or benzyl benzoate.

(2) Dusting of 5% benzil on arms and legs and opening of clothings is quite effective to prevent the attack.

(3) The application of cooling ointments viz., ammonia or salicylic acid in alcohol with a little olive oil prevents the infection.

(4) The spraying or dusting with lindane at 0.25 to 0.5 pound, dieldrin at 0.5 to 1 pound, or chlordane or toxaphene at 2 to 4 pound per acre is quite effective in infested premises.

Ticks

Ticks are large in size in comparison to the mites. They also belong to the order Acarina and attack animals like cattle, sheep, goat, horse etc. Unlike insects whose body is divided into 3 parts (head, thorax and abdomen) the head and thorax of ticks are fused. Some of the common ticks of economic importance are given here.

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1. Cattle Tick : *Boophilus microplus* (Canestrini)

Phylum ..... Arthropoda
Class ..... Arachnida
Order ..... Acarina
Family ..... Ixodidae
Genus ..... *Boophilus*

The cattle tick mainly attacks the cattle but is also found on horses, mules, deer, goats and sheep. All the stages viz., larva, nymph and adult suck the blood from the host. They spread cattle fever, tick fever, texas fever from sick individuals to healthy ones. The symptoms of tick fever are high fever, reddish discoloration of urine, enlargement of spleen, loss of flesh, arched back and dropping ears. The protozoan, *Boophilus annulatus* (Say) is responsible for this disease which destroys the red corpuscles of the blood. Thus, this disease is caused by a protozoan parasite but only the ticks are responsible for the spread of this disease. The germs of texas fever are carried through the eggs of diseased ticks which infect the new individual (Fig. 6).

General appearance. After maturity the female cattle tick attains a length of about 0.1 mm. It is olive-green to bluish grey in colour. They are bean-shaped with hard and wrinkled skin. The larvae are smaller provided with 3 pairs of legs, whereas, nymphs and adults have 4 pairs of legs.

Life history. The female after mating lays eggs in the soil, cracks and crevices of buildings. A single female lays about 2000 eggs in clusters. The eggs hatch into six legged larva after 2 to 6 weeks. The larva attaches itself on a host. These larvae start feeding, get changed into young nymphs which attain adult stage feeding on the same infested cattle. Now mating takes place on the host's body and adults drop to the soil surface to lay eggs for another generation. Four stages viz. eggs, seed tick, nymph and adult are found in this parasite. The adults exist in two phases i.e. parasitic and nonparasitic phase. Part of the life time of an adult female, egg stage and most of the seed tick (larva) stage comes under nonparasitic phase whereas a portion of the seed tick stage, complete nymphal stage and a part of adult female life is parasitic phase. Single life cycle needs about 60 days and 4 generations have been recorded in one year.

Damage. The soft parts of host cattle is attacked by cattle tick. Mostly they attack the skin of ear and under and base of the tail. The ticks insert their heads into the skin and suck the blood due to which a number of diseases are transmitted.

Prevention and control. (1) Ticks should be removed by hand picking and killed immediately.

(2) The animals affected by ticks should be sprayed by lindane dust or carbaryl/malathion 1 per cent.

(3) Rotating pasture lands should be planned due to which all seed ticks will starve and die.

(4) Dairy cattle should be dipped in 0.175 to 0.19 per cent arsenic trioxide.

(5) The quarantine activities should be maintained by the Government.

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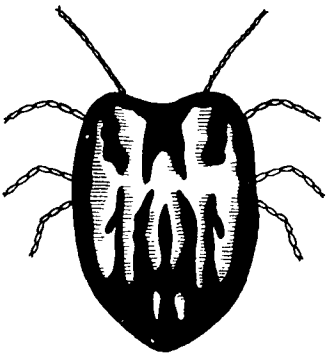

Fig 6. *Boophilus microplus.*

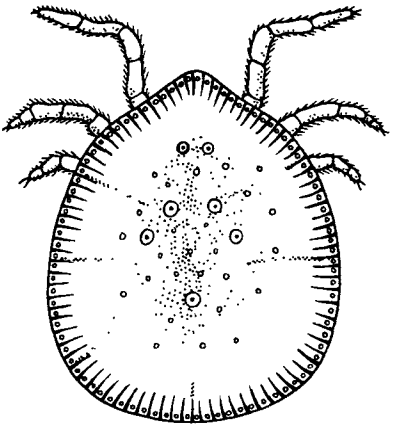

Fig. 7. *Argas persicus.*

2. Fowl Tick : *Argas persicus oken*

Phylum ..... Arthropoda
Class ..... Arachnida
Order ..... Acarina
Family ..... Argasidae
Genus ..... *Argas*

This tick is cosmopolitan in distribution and transmits spirochaetosis. Apart from fowls, the ducks and pigeons are also attacked by this tick. The feeding period for the nymphs and adults is only the night but larvae feed continuously till they are fully developed. The domestic mammals and men are rarely attacked by this tick (Fig. 7).

General appearance. The adults are flattened, leathery and egg shaped. They are red to blue-black in colour and about 0.5 cm in length.

Life history. This tick breeds throughout the year but best breeding period is the hot dry weather.The female lays about 500 to 900 eggs in batches of 30 to 100 in cracks and crevices of fowl houses. The eggs are hatched into-6 legged larvae after 10 to 90 days of laying. The larva feeds for 3 to 10 days on fowl and attains first nymphal stage provided with 4 pairs of legs. Now nymph feeds on fowl body by sucking the blood only at night, hiding itself in cracks and crevices during the day time. Further it moults and changes into second instar nymph which again sucks the fowl blood, drops to the soil surface and after 15 days moults and changes into adult. Female can lay eggs only after taking the meal of bloods from the host. The adult can survive for about 3 years without food. The complete life cycle takes 35 to 45 days.

Damage. The poultry mites attack the skin of neck, breast, thighs, under wings and suck the blood which causes weakness of legs, pale comb, droopy

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wings, cessation of egg-laying and death due to severe loss of blood. A highly fatal poultry diseases called as fowl spirochaetosis is causes by this tick through the transmission of *Spirochaeta anserina.*

Prevention and control. (1) The poultry houses should be sprayed by 3% malathion, 2% carbaryl on walls, floor and ceilings.

(2) Roosts should be suspended by wires from the ceilings so that they do not touch the walls.

(3) Poultry should be established only at those places where treatment of insecticides can be performed.

(4) The entrance of a new fowl into the flock should be with the precaution that it is tick-free. It may be treated with 0.5% chlordane before entry.

IMPORTANT QUESTIONS

» ***Long answer type questions***

1. Give an account of mites and ticks and their control measures.
2. What are the mites ? Give an account of the life history, damage caused and control measures of the mites infesting human beings.
3. Give detailed account of the parasitic mites of economic importance.

» ***Short answer type questions***

1. Give short account of the nature of damage and control measues of the mites and tics of economic importance.
2. Write note on mange mite or chicken mite or sheep scabe mite or straw itch mite or chiggers.
3. Write note on cattle tick or fowl tick.
4. Give an account of the life history, damage caused and control measures of cattle tick and fowl tick.

» ***Very short answer type questions***

1. Describe the nature of damage caused by mange mite or chicken mite or sheep scabe mite or straw itch mite or chiggers.
2. Describe the nature of damage caused by cattle tick or fowl tick.
3. Differentiate between mites and ticks.
4. Enumerate the host of mange mite, chicken mite, sheep scabe mite, straw itch mite and chiggers.

» ***Objective type questions***

1. The generic name of mange mite is :
   (a) *Pyemotes ventricosus* (b) *Sarcoptes scabiei*
   (c) *Dermanyssus gallinae* (d) *Psoroptes equiovis*
2. The generic name of straw itch mite is :
   (a) *Psosoptes equiovis* (b) *Eutrombicula alfreddugesi*
   (c) *Sarcoptes scabiei* (d) *Pyemotes ventricosus*

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3. The generic name of chiggers is :
   (a) *Eutrombicula alfreddugesi* (b) *Psoroptes equiovis*
   (c) *Pymotes ventricosus* (d) *Sarcoptes scabiei*
4. The generic name of sheep scabe mite is :
   (a) *Pyemotes ventricosus* (b) *Psoroptes equiovis*
   (c) *Sarcoptes scabiei* (d) *Dermanyssus gallinae*
5. The generic name of chicken mite is :
   (a) *Dermanyssus gallinae* (b) *Psoroptes equiovis*
   (c) *Sarcoptes scabiei* (d) *Eutrombicula alfreddugesi*
6. Mange mite belongs to family :
   (a) Dermanyssidae (b) Pediculoididae (c) Sarcoptidae (d) Trombidiidae
7. Chicken mite belongs to Family :
   (a) Dermanyssidae (b) Trombidiidae (c) Pediculoididae (d) Ixodidae
8. The common name of *Boophilus microplus* is :
   (a) Fowl tick (b) Cattle tick (c) Chiggers (d) Harvest mite
9. The generic name of fowl tick is :
   (a) *Boophilus microplus* (b) *Argas persicus*
   (c) *Spirochaeta anserina* (d) *Dermanyssus gallinae*
10. Cattle tick belongs to family :
    (a) Trombidiidae (b) Ixodidae (c) Argasidae (d) Sarcoptidae

Answers

1. (b), 2. (d), 3. (a), 4. (b), 5. (a), 6. (c), 7. (a), 8. (b), 9. (b), 10. (b).

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6

Apiculture

Man had started the use of animal products since time immemorial even at the cost of animal's life. Honey has been under use in human civilization since prehistoric period as mentioned in our religious literatures like Vedas, Purans, Ramayan, Mahabharat and Charak Sanghita. Some foreign travellers like Fahiyan and Whenson had also discussed the use of honey as medicine. People were very much dependent upon honey for medicines and essential nutritive elements of the diet.

The highly evolved social organisation of bees had been established before the existence of human race. Bees teach us the lesson of work-work and work with co-operation. We can easily imagine about the hard-working of the bees by the simple fact that for one pound of honey, a single honey bee travels about double the distance of the circumference of the earth's globe. Previously, the method of extraction of honey from the honey comb was very much crude but after the invention of artificial hive by Longstroth (1951), it became scientific and commercial. The bee keeping in United States, Canada, Australia and New Zealand has achieved out-standing success. In India people do not take interest in bee keeping from commercial point of view but only for their routine use. Since honey is produced by the honey bees, a detailed study of the biology of the bees is essential for successful implementation of apiculture programme.

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Honey Bee

Phylum ..... Arthropoda
Class ..... Insecta
Order ..... Hymenoptera
Family ..... Apidae
Genus ..... *Apis*

Habit and habitat

Honey bees are highly organised social insects reported from all over the world. Although they are active throughout the year but in winter season they do little work and do not rear the brood. In spring seasons *i.e.,* at the time of flowering they prepare a strong colony with honey rich combs.They exhibit polymorphism. and good division of labour. The bee hives with thousands of individuals are observed hanging down from the branches of the trees and ceilings of houses. The workers communicate informations for the location of the food sources through the 'Waggle Dance', a phenomenon called as 'Language of the bees', by the eminent biologist Karl Von Frish. He has mentioned that the rate of dance is directly proportional to the distance of the food.

Species of Honey Bees

Four species of honey bees are reported.

1. ***Apis dorsata F.*** (Rock bee). This the largest bee, about 20 mm. in length, so named as GIANT HONEY BEE. SARANG and BOMBARA are other names of this bee which yields maximum amount of honey in comparison to other species. A single comb may yield 60 pounds of honey which is the maximum amount for a comb. The workers are very smart and active which may pollinate 12,000 flowers daily. But due to its ferocious and irritable nature, specific hive and migratory habit it is very difficult rather practically impossible to domesticate them for the bee keeping industry.

2. ***Apis indica F.*** (Indian bee). Commonly found in forest and plain regions of India. This is slightly smaller than *A. dorsata.* They prefer to live in dark places and construct several parallel combs about one foot across the protected places like cavities of tree trunks, mud walls, earthen pots, thick bushes, wells and walls of the buildings. This species is very gentle in nature, so can be domesticated easily. The production of honey is much less *i.e.,* 6 to 7 pound per comb.

3. ***Apis florea F.*** (Little bee). This is smaller than *A. indica* and yields very small amount of honey. The bees are not of gregarious nature and form a single comb. Due to its docile nature and rare stinging behaviour the combs can be removed easily for the honey extraction.

4. ***Apis mellifera F.*** (European bee). Although this bee produces less honey yet it is found to be the best species from the commercial point of view. Due

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to their docile nature they can be domesticated easily and can be improved by breeding for several hundred years. Out of its several varieties, the Italian variety is reared every where in Europe and America in artificial hives for honey.

Social Organisation of Honey Bee

A highly organised division of labour is found in the colony of honey bees. A good and well developed colony of bees had 40 to 50 thousand individuals consisting of 3 castes *viz.,* QUEEN, DRONE and WORKER. The queen after fertilization lays fertilized and unfertilized eggs both. From unfertilized eggs male bees emerge which are known as DRONES whereas from the fertilized eggs worker bees are produced. The workers when feed on ROYAL JELLY, develop into QUEEN.

Queen. It is a well developed fertile female provided with immensely developed ovaries. Commonly one queen is found to be present in each hive and feeds on Royal Jelly. She is the queen in real sense as the Mother of the Colony, guarded by a number of attendants and never alloted any duty except egg laying. Egg laying is the sole function of the queen throughout her active life span. The queen is 15 to 20 mm in length and can be easily distinguished by her long tapering abdomen, short legs and wings. Structurally she is unable to produce wax or honey or gather pollen nector. By the combination of ovipositor-cum sting, a structure is developed which aids in egg laying. It is said that the queen gets mated only once in her life but in a single chance of mating, drone releases 2 crore sperms which are sufficient for the fertilization of the eggs at the time of laying by the female throughout her life span. In recent researches in U.S.A. it has been reported that out of 110 queens only 55 mated twice before egg laying. It is also a fact that queen lays fertile and unfertile eggs both in accordance to her will but the factors governing such selective activity are still not known. One queen lays about 1,500 to 2,000 eggs in a day depending upon the seasonal variation and other ecological factors. The total weight of 100 eggs is equal to her body weight. In the whole life span of two to five years a queen lays about 15,00,000 eggs. When the queen in a colony looses its eggs laying capacity, another worker of the same colony starts feeding on queen's diet *i.e.*, Royal Jelly and develops into a new queen and is provided with the facilities of real queen. At the same time old queen may be driven out but sometimes some workers object that as tc why the mother of the colony be driven out so ultimately they also come out with the mother. Sometimes when 2 to 3 queens are developed in a colony, only one takes the position of the real queen and the others come out with some workers to establish new colonies.

Workers. Although the workers are the smallest of the three castes but they function as the main spring of the complicated machinery like honey bee colony. Like the queen, they are also produced from the fertile eggs laid by the queen and live in a chamber called as 'WORKER CELL'. It takes 21 days in the development from the egg to the adult and the total life span of a worker

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is about 6 weeks. The workers are atrophid female which sacrifice themselves for the well-being of the colony. The total indoor and outdoor duties of the colony are performed by the workers only. That is why they are provided with some special structures for particular work.

(1) Long proboscis for sucking the nectar.
(2) Strong wings for fanning.
(3) Pollen baskets for the collection of pollen.
(4) Powerful sting to defend the colony against any attack.
(5) Wax gland for wax secretion.

The workers which are engaged in outdoor duties, collect the nectar, pollen, gum and water which are received and stored properly by the house bees. The indoor workers are further sub-grouped for specific duties. Some of them which are very sincere, attend the queen while some others look after the nursery called as NURSERY BEE. Some produce wax for the formation of the new hive and are known as BUILDER. The repairing of the comb is done by the REPAIRERS. The dead body and other impurities are removed from the hive by the CLEANERS. The fanning in the hive is performed by the wings of the FANNERS. Several other functions like honey storage and ripening are also done by the workers. The guard bee always watches at the gateway. It is said that upto half of the life period workers perform indoor duties and later on become engaged in outdoor duties.

Drone. The drone is the male member of the honey bee colony which fertilizes the queen so called as KING of the colony. They take 24 days to develop from the egg to the adult stage. The sting and the wax glands are absent but in the males the reproductive organs are very well developed. They are reared from an unfertile egg in large DRONE CELL. Drone are totally dependent on the workers and have been seen begging for honey from the workers. The sole duty of the drone is to fertilize the virgin queen. At the time of swarming the drone follows the queen, copulates and dies after copulation.

Life History

After mating the queen generally lays one egg in one brood cell. The eggs are pinkish coloured, elongated with cylindrical body generally attached to the bottom of the cell. Larvae emerge out from both the fertilized as well as unfertilized eggs. Thus, the larvae from the unfertilized eggs form the drones while the workers are developed from the larvae of the fertilized eggs. Amongst the larvae of the workers one is fed on the royal jelly, a special diet secreted by the young workers in the colony, and becomes the queen of the colony. The royal jelly consists of digested honey and pollen, mixed with a glandular secretion into the mouth of the workers. After 5 days of feeding the cell is sealed and the larvae undergo pupation. It spins a thin silken cocoon and pupates completely. Emergence of the young ones takes place after three weeks and they get busy in the indoor duties for about 2 to 3 weeks. Later on they

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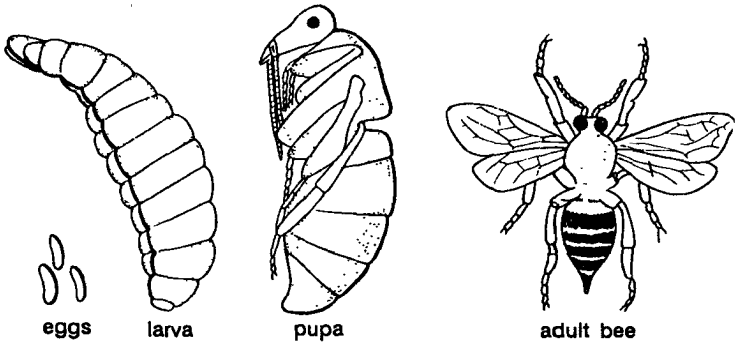

Fig. 1. Life history of *Apis indica.*

are sent for the outdoor duties. All the bees pass through a complete metamorphosis with the various changes in the life-cycle taking place within the comb (Fig.1).

Swarming. The process of leaving off the colony by the queen termed as swarming. It happens towards the end of spring or early summer but the real cause of swarming is still not well known. In summers when plenty of food is available and hive is overcrowded by the bees, the queen leaves the hive on a fine fore-noon with some old drones and workers and establishes a new colony at some other place. Now in the old hive a worker is given Royal Jelly and is converted into a new queen of the colony. This new empress of the colony never tolerates her successor, as a natural law in the hive, so she orders to kill the other sisters, if any, in the hive.

Supersedure. When the egg laying capacity of the old queen is lost or it suddenly dies, a new young and vigorous queen takes the position of the old queen and is called as supersedure.

Absconding. The migration of the complete colony from one place to another takes place due to some unfavourable conditions of life, such as destruction of the comb by termites or wax-moths and scarcity of nectar producing flowers around the hive. This phenomenon is quite different from that of swarming.

Nuptial or marriage fight. The first swarm is led by the old queen but the second swarm is led by the 7 days old virgin queen which is followed by the drones and is called marriage flight. One of the drones starts copulating with the queen in the sky and fertilizes the queen and dies during the course of copulation. The queen receives spermatophores and stores in the spermatheca. Along with the queen, died drone falls on the ground and the queen reaches the hive.

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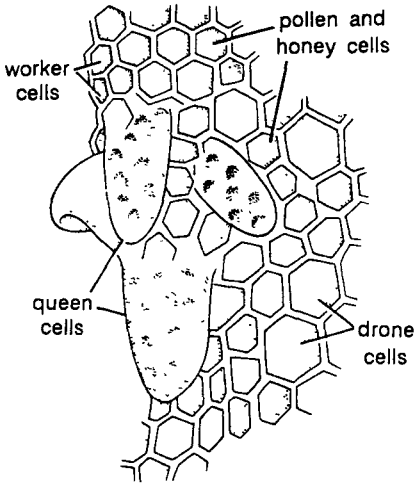

Fig. 2. Hive of *Apis indica* showing various cells.

Hive

The house of honey bees is termed as hive or comb. It consists of hexagonal cells made up of wax secreted by the worker's abdomen. These hives are hanging vertically from rock, building or branches of trees. Each hive has thousands of hexagonal thin walled fragile cells arranged in two opposite rows on a common base. The resins and gums secreted from the plants are used for the repairing of the hives. The young stages are generally occupying the lower and central cells in the hive which are the 'BROOD CELLS'. In *A. dorsata* broad cells are similar in shape and size but in other species brood cells are of 3 types *viz.*, WORKER CELL for workers, DRONE CELL for drones and QUEEN CELL for the queen. The queen cell can not be used again while the rest are used a number of times. There are no special cells for lodging the adults which generally keep clustering or moving about on the surface of the comb. The cells are mainly intended for the storage of honey and pollen specially in the upper portion of the comb while those in lower part are for brood rearing (Fig. 2).

Flora for Apiculture

Although honey bees can collect nectar and pollen from quite a long distance but the flora for apiculture is also important. The flora may be of wild or cultivated type. The more nectar yielding plants are neem, jamun, soapnut etc. The other plants like maize, rose and sorghum are good sources of pollen. Some plants like plum, cherry, apple, sheesham, coconut, guava, mustard etc., are good sources for nectar and pollen both.

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Selection of Bees for Apiculture

For running a good apiary, selection of honey bee is of much importance, so the following should be kept in mind at the time of selecting honey bees for apiculture :

(1) Honey bees should be of gentle temperament.
(2) Honey bees should have capability to construct strong colony.
(3) It should have ability to protect from enemies.
(4) Honey bee should have energetic and industrious workers.
(5) Workers can suck juice from numerous varieties of plants.
(6) Bees on the whole can produce more and more honey from its comb.
(7) Bees can from their comb easily at any place.

The apiculture scientists engaged in genetics are trying to find out such cross races which would not be of ferocious nature but be a good honey producer. In India, *Apis indica* is the best bee for apiculture industries due to its gentle nature and having efficient and prolific workers.

Methods of Bee Keeping

The ultimate aim of bee keeping is to get more and more honey in pure form. The old method commonly used by old apiculturists is very crude, cruel and of unplanned type. This old method is called as Indigenous method.

Indigenous method

1. Hive. Two types of hives are used in indigenous method of bee keeping *e.g.* wall or fixed hive and movable hive.

(a) Wall or fixed hive. It is purely natural type of comb because the bees themselves prepare the hive at any space on the wall or trees. There is an opening on one side through which bees come out of the hive.

(b) Movable hive. It comprises of hollow wood logs, empty boxes and earthen pots etc. placed in varandas of houses. There exist two holes, one is for entrance and the other for exit of the bees. The swarmed bees usually come to the box on their own accord. Some bee keepers use to take the clusters of the swarms from a tree and keep them in the hive.

2. Extraction of honey. For honey extraction, burning fire is brought near the bee hive at the night as a result of which bees are either killed or they escape off. Further the hive full of honey is being removed, cut into pieces and squeezed to get honey. Sometimes smoking is done so that the bees may escape from their hives.

3. Drawbacks of indigenous method. The indigenous method of bee keeping suffers from a number of drawbacks due to which it is not recommended by present day panel. These drawbacks are :

(i) Honey becomes impure because at the time of squeezing, the brood cells, pollen cells, honey cells and larvae are also extracted. (ii) The colony

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becomes weak due to killing of the eggs and the larvae at the time of squeezing. (iii) Formation of new hive by the escaped bees requires extra energy which effects the yield. (iv) The activities of the bees can be controlled. (v) The hivation of bees on the same place is only matter of chance. (vi) The honey robbers, like, rat, ant, wasp and monkeys may affect the hive easily. (vii) The race improvement programme may not be applied, so no possibility for the selection of the best bee is there. (viii) The hazards created by climatic factors can not be controlled.

Modern method of apiculture

To overcome the drawbacks of indigenous method an advanced method based on scientific facts has been developed. It has opened a new era for the cottage industry in India and has also given an opportunity for lakhs of unemployed persons to keep them busy in this business. From this cottage industry programme the routine agricultural work may not suffer. First of all care was taken to improve the texture of the hives and during this race hive patterns were introduced in India. The Newton model with 7 to 10 frames (21×14.5 cm) in the brood chamber with a shallow super (21×6.5 cm sized frames) has been most popular in south, east and central India. Longstroth hive containing 10 frames (44.8×23 cm) has been used as a standard hive in Himachal Pradesh, Jammu and Kashmir, and Punjab. In Uttar Pradesh another type of hive has been in use which was evolved at Jeolikote apiary and contained 8 frames (30×18 cm). After gaining experience from the above mentioned hives, Indian Standard Institute has standardized the hives of small and big sizes accommodating frames 21×14.5 cm and 31×20.4 cm respectively.

Now-a-days a typical type of movable hive is constructed which is capable of expansion or contraction according to the requirement of the place, season and climatic conditions.

Appliances for Modern Method

(1) Typical movable hive.
(2) Queen excluder.
(3) Honey extractor.
(4) Uncapping knife.
(5) Other equipments.

1. Typical movable hive. An artificial movable hive is constructed by wooden box based on bee space theory (Fig. 3). The size and number of frames are variable from hive to hive according to the need. A small space is enough to permit the entrance and exit of workers and drones but queen once placed in hive never comes outside the hive. The perforation size on zinc sheet is only of 0.375 cm but the thorax of the queen is 0.43 cm to 0.45 cm, so the queen

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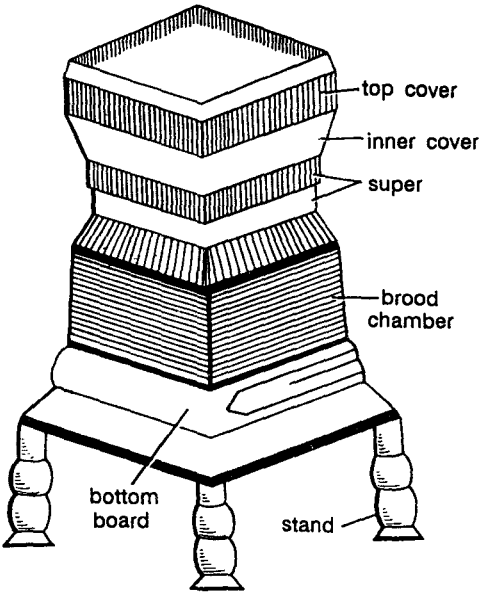

Fig. 3. Typical movable hive.

can never pass through this pore. This typical hive consists of 6 parts as given below :

(a) ***Stand.*** It is the basal part of the hive on which the whole hive is constructed. The stands are adjusted to make slope for the hive. Due to this slope rain water comes down quickly.

(b) ***Bottom board.*** It is situated above the stand and forms the proper base for the hive having two gates in the front position. One gate functions as an enterance while the other as exit.

(c) ***Brood chamber.*** The bottom board carries the brood chamber which is the most important part of the bee hive. It is large in size provided with 5 to 10 frames. In each frame a wax sheet bearing haxagonal frames is held up by a couple of wires in a vertical position. Along with the margin of every hexagonal mark, the bees start making wall and ultimately the cells. Here every sheet of the wax is known as COMB FOUNDATION which attracts the bees and provides the base for the comb preparation on both the sides. The frames are kept vertically in brood chamber which is covered over by other frames having a wire meshing through which the workers can easily pass. The comb foundation helps in obtaining a regular strong worker brood cell comb which can be used repeatedly. The Central Bee Research Station at Pune arranged the manufacture of a comb foundation mill which manufactures, different cell sizes required in several regions of the country. The brood chamber is covered by another chamber known as super.

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(d) ***Super.*** It is also without cover and the base. Super is provided with many frames containing comb foundation to provide additional space for expansion of the hive.

(e) ***Inner cover.*** It is a wooden piece used for the covering of the super. It has many holes for proper ventilation.

(f) ***Top cover.*** It is meant for protecting the colony from rains. It is fitted with zinc sheet which is plain and sloping.

2. Queen excluder. It consists of a wire-gauze, extrans guards and drone traps with individual wires placed 0.375 cm apart. It readily permits the workers to pass through it but keeps back the queen in the brood chamber.

3. Honey extractor. It is used for the extraction of the honey from the comb and functions on principle of centrifugal force. When combs are centrifuged by this device the pure honey is thrown out without any damage to the comb.

4. Uncapping knife. When all of the combs are filled with honey they are sealed by capping with the wax. So, before such capped combs are placed in the honey extractor, the wax sealing has to be removed with the help of an uncapping knife heated by steam before use.

5. Other equipments. Most of the useful equipments for the successful management of the bee are locally manufactured which are very cheap. As they are made locally, they may not be exactly similar to those made at other places. Thus, Indian Standard Institute has standardized some very common equipments for the production of uniform and interchangeable articles. Some materials like protective garments, gum cages, gloves, net veil, bee net, brush etc. are required for easy and well planned handling of the bees.

Advances of Modern Method

In the modern method of bee keeping there are several advantages which encourage the well planned bee keeping.

(1) A proper watch on the activities of the bees can be had.
(2) A strong colony can be developed by providing sugar, syrup, pollen substances to honey bees.
(3) Swarming of bees is checked by modern hive.
(4) The same hive is used again and again so the workers pay their attention more for the honey and not for the hive formation.
(5) Under adverse climatic conditions the hive can be transferred from one place to the other for the protection of the bees.
(6) Comb can be protected from the enemies.
(7) Pure honey in large quantity can be obtained.

Precautions. For the proper management of bee keeping programme following precautions should be taken :

(1) The hive should not be kept more than half a mile away from the place from where the bees have to collect the nectar and the pollen.

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(2) People must know about the bee keeper for proper contact.
(3) The boxes must be kept under shade at cool places.
(4) Industry should be near the road for proper transport facilities.
(5) Fresh water reservoir should be near the hive.
(6) Good flora for the collection of pollen and nectar should be there.

Products of Bee Keeping

The chief products of bee keeping industry are : (i) honey and (ii) bees wax.

Honey

It is truly an insect product of high nutritive value. The food value of honey may be estimated by the presence of about 80% sugar in it.

Production of honey. One should not be confused that honey is a direct plant product because the nectar, pollen and cane-sugar bearing secretions of flowers are ingested by honey bees, get mixed with the saliva and undergo certain chemical changes due to enzyme action. At this stage cane-sugar (sucrose) is converted into invert sugars *i.e.* dextrose and levulose. At this very time some ingredients of bees are also added to the mixture and reduce the water content. The whole mixture is then collected in the honey sac (crop) until the honey reaches the hive. As the honey bee reaches the hive this compound is regurgitated in the hive cell and is known as the honey. Now honey is concentrated by a strong current of air produced by the rapid beating of worker's wings, crawling over the cells.

Honey is very much sweet in taste and white to black in colour with variable smell in accordance with the juices collected from different flowers.

Chemical composition of honey. Honey is sugar rich compound having the following constituents :

(1) Levulose	—	38.9%
(2) Dextrose	—	21.28%
(3) Maltose & other sugars	—	8.81%
(4) Enzymes & pigments	—	2.21%
(5) Ash	—	1.0%
(6) Water	—	17.20%

Storage of honey. After long duration in the stored condition, the honey may be granulated and fermented.

(a) Granulation of honey. The stored honey becomes granular after long duration. Such type of granulation property is the best evidence of pure honey. It is considered that 10 parts of dextrose combine with one part of water, hence forms crystals. Due to less solubility levulose is not crystalised and gives cloudy appearance. Crystallization is mainly accelerated by the presence of minute air bubbles, colloids and pollens.

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*(b) **Fermentation of honey.*** After crystallization honey is subjected to fermentation. Due to crystallization of dextrose 9% moisture is released, which dilutes the remaining levulose of the honey and the action of yeasts present in air, flowers and soils takes place on levulose and dextrose resulting in the fermentation of honey.

$$C_6H_{12}O_6 \rightarrow 2C_2H_5OH + 2CO_2$$

Economic importance of honey. Honey is used by human beings in different ways of which the most important is as food and medicine.

*(a) **Food value.*** It is estimated that 200 gm of honey provides as much nourishment as 11.5 litre of milk or 1.6 kg creamor 330 gm meat. 2.1 gm of honey provide as much as 67 K. cal of energy. Its sugars, minerals, vitamins and other vital elements are readily absorbed by the systems. Honey may be taken by healthy men as well as those who are ill. It can be taken at any time in any season and by persons of all ages even those just born. It is used in the preparation of candles, cakes and bread. In illness it is preferred over milk because more than half of the body energy is provided burning of dextrose.

*(b) **Medicinal value.*** Honey is mildly laxative, antiseptic and sedative, generally used in Ayurvedic and Unani systems of medicine. It is quite helpful in building up of the haemoglobin of the blood and also used as preventive against cough, cold and fever, as blood purifier and as a curative for ulcers on tongue and alimentary canal. Its regular use is recommended after severe cases of heart attack for malnutrition, indigestion and diabetes. It is also found that typhoid germs are killed by honey within 48 hours, those of branchio-pneumonia in 4 days and of dysentry in 50 hours.

*(c) **Other uses.*** Other than food and medicine, honey is used in numerous ways. It is used in the preparation of bread, cake and biscuits. It enhances their preserving quality. Much amount of honey goes in making alcoholic drinks. In poultry and fishing industries honey is widely used. In laboratory, honey is used to stimulate the growth of plants, the bacterial culture, inoculation of seeds of cloves, in insect diet and in the preparation of poison baits for fruit flies.

Beeswax

Beeswax is a very useful by-product of bee keeping industry. It is yellowish to greyish brown in colour and insoluble in water but completely soluble in ether. Commonly it is a wrong impression to suppose that honey bees convert the pollen into beeswax because beeswax is also a natural secretion of the worker bees and is poured out in thin delicate scales or flakes. Chibnall (1934) has reported that all insect waxes are complex mixture of varying proportions of :

(1) Even numbered alcohols ranging from C_{24} to C_{36}.
(2) Even numbered normal fatty acids from C_{24} to C_{34}, and
(3) Odd numbered normal paraffins ranging from C_{23} to C_{37}.

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The various beeswaxes differ only due to change in the proportions of these constituents. Large quantities of beeswax produced and exported, come from *Apis dorsata* bees. Indian Standard Institutions have fixed standards for pure beeswax in order to facilitate its export.

Economic importance of beeswax. Beeswax is used in the manufacture of cosmetics, for Catholic churches, face cream, paints, ointments, insulators, plastic works, polishes, carbon paper and many other lubricant. It is also used in the laboratory for microtomy with the common wax for block preparation of tissues.

Bee Enemies

Enemies of the bees harm the colony in different ways so they have attracted considerable attention in the different regions of the country. The wax moths (*Galleria mellonella and Achroia grisella*), Wasp (*Vespa* spp. *and Palarus* sp.), black ants (*Componotus compressus*) and bee eaters (*Merops orientalis*) and Kingcrow (*Dicrurus macrocercus*) are common enemies of the honey bee's comb and honey. Man is the last but worst enemy of honey bees.

Before 1958 bees were considered to be free from the diseases though suspected cases of NOSEMA from Punjab and Kashmir were known. But a parasitic mite-*Acarapis woodi* Rennie caused Acarine disease in the adult honey bee in Kulu valley in Punjab in 1956. It was later reported from Himachal Pradesh, Uttar Pradesh and Jammu and Kashmir. This disease was controlled by the scheme in co-operation with the United States of America at the college of Agriculture Ludhiana, Punjab. Now-a-days Indian honey bees are commonly free from any such disease. A strict quarantine measure is being taken to check the spread of any disease from foreign countries. But in European countries bees are commonly attacked by microsporadian which is injurious to bees.

Bee-keeping Industry

Bee-keeping has gained a good position as an industry in U.S.A., Canada and Australia but in tropical countries it is not growing as per need of the people. Before 1953 attention to bee-keeping was paid only by the State Governments but in the same year, all India Khadi and Village Industries Commission, started to pay attention to it and it was controlled by Union Government itself. Due to the functioning of the central organisation, bee-keeping industry was spread in South India and in some northern states also. Now-a-days bee-keeping industry is nation wide and is a good source of cottage industry. Till now limited research and development work has been done in this field which indicates that 'Apiculture' can be raised to the status of a viable occupation in tropical climates provided appropriate scientific and developmental efforts are generated. Because the tropical countries are very rich in bee fauna, the scientific development of apiculture may be helpful in agriculture and may

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contribute for providing nutrition, and employment to rural population and may help in raising the economic status of the people.

Recent Efforts

An international conference on 'Apiculture in Tropical Climates', organised by the 'World Crops' in collaboration with the International Bee Research Association (IBRA) was held at London in 1976. In this Conference it was recommended that the research and development of apiculture should be taken on priority basis in the tropical areas. The Second International Conference on Apiculture in Tropical climates was organised by the Indian Council of Agricultural Research in Collaboration with the Khadi and Village Industries Commission, Department of Science and Technology and Indian National Science Academy at New Delhi in 1980. In this Conference Eminent National and International scientists and experts realised the importance of apiculture and suggested further research development as a device for raising the industrial status of apiculture.

IMPORTANT QUESTIONS

» ***Long answer type questions***

1. Give an account of the social organisation and life history of honey bee.
2. Describe the methods of bee keeping.
3. Give detailed account of the products of bee keeping industry.

» ***Short answer type questions***

1. Give short account of the species of honey bees.
2. Describe about the workers of honey bees.
3. Write short note about bee hive.
4. Enumerate precautions regarding the selection of bees for Apiculture.
5. Describe the typical movable hive in bee keeping industry.
6. Give short account of the economic importance of Honey.
7. What is Beeswax ? Give its economic importance.
8. Give short account of bee enemies.

» ***Very short answer type questions***

1. What is Waggle dance ?
2. Write short account of giant honey bee.
3. What is royal jelly ?
4. Define nuptial flight of honey bee.
5. Define swarming in honey bee.
6. Define absconding in honey bees.
7. Define honey extractor in bee keeping industry.
8. Define granulation of honey.
9. Define fermentation of honey.
10. Give medicinal value of honey.

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» ***Objective type questions***

1. The common name of *Apis dorsata* is :
   (a) Indian bee (b) Sarang (c) Little bee (d) European bee
2. The common name of *Apis florea* is :
   (a) Little bee (b) Indian bee (c) Bombara (d) Giant bee
3. *Apis* spp belongs to order :
   (a) Hemiptera (b) Homoptera (c) Lepidoptera (d) Hymenoptera
4. The length of honey bee queen is :
   (a) 15 to 20 mm (b) 2 to 5 mm (c) 5 to 10 mm (d) 40 to 50 mm
5. The number of sperms released by drone of honey bee during single mating is about :
   (a) 2 crore (b) 4 crore (c) 6 crore (d) 8 crore
6. The total number of eggs laid by one queen of honey bee in one day may be about :
   (a) 2000 (b) 4000 (c) 6000 (d) 8000
7. The total number of eggs laid by one queen of honey bee in her whole life is about :
   (a) 15 lakh (b) 25 lakh (c) 30 lakh (d) 35 lakh
8. Which of the following constituent is maximum in honey ?
   (a) Dextrose (b) Levulose (c) Maltose (d) Water
9. Which of the following statement is correct ?
   (a) Honey bees convert the pollen into beeswax
   (b) Bees wax is the natural secretion of honey bee
   (c) Bees wax is insoluble in ether
   (d) Bees wax is soluble in water
10. Which of the following statement is wrong ?
    (a) The stored honey becomes granular
    (b) Dextrose is maximum in honey
    (c) Honey is mildly laxative
    (d) After crystalization, honey is subjected to fermentation

Answers

1. (b), 2. (a), 3. (d), 4. (a), 5. (a), 6. (a), 7. (a), 8. (b), 9. (b), 10. (b)

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7

Lac Culture

Lac insects and their products have been known to naturalists since very early times. The lac has been referred in ancient Sanskrit works *viz.*, Atharva-Veda (Dave, 1950; Hora, 1952) and was called as 'Luxa'. It is mentioned in Mahabharat that 'Luxa Griha' was made up of lac which was prepared by Kaurava for Pandavas. Abul Fazal (1590) in his famous book 'Ain-i-Akbari' has mentioned in detail about the lac industry in India. Mahdihassan (1950, 1952), has referred about the lac insect and its products in China. The first scientific reference regarding the lac and lac insect is the report of Kerr and Glover in 1782. Subsequently, much work has been done by various workers on the organization, distribution, taxonomy, host plants, culture, production, enemies, chemistry and technology.

Three products from lac insects, viz., the lac-dye, lac-wax and lac (resin) have been items of trade and commerce.

Distribution

India has its monopoly on the production of lac. Other countries like Africa, Australia , Brazil, Burma, Sri Lanka, China, Formosa, France, W. Germany, Japan, Malaya, Nepal, Spain, Thailand, Turkey, U.S.A. and some others also produce lac. But in Thailand, Malaya, Burma and Nepal the lac producing industries are increasing day-by-day. Thailand has become the main competitor of India in export of lac. In India major lac producing places are Assam (Kashi Hills), Bengal (Kolkata, Jangipur, Murshidabad, Mathrapur, Malda), Jharkhand, Bihar (Manbhum, Palamau, Ranchi, Santhal Pragana), Delhi, Gujarat, Hyderabad, Kashmir, Chattis Garh, Madhya Pradesh (Damoh, Champa, Bilaspur, Rewa, Umaria), Chennai, Coimbatore, Mysore, Orissa (Cuttak,

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Mayurbhanj), Punjab (Hoshiarpur, Shahpur), Rajasthan (Indergarh, Kota, Jaipur, Jhallawar, Karauli), and Uttar Pradesh (Ghazipur, Mirzapur, Agra) etc.

Lac Insect (Lakh ka-kira)

Phylum ..... Arthropoda
Class ..... Insecta
Order ..... Hemiptera
Sub-order ..... Homoptera
Super-family ..... Coccidae
Family ..... Leciferidae
Genus ..... *Tachardia*
Species ..... *lacca*

Lac insect (*Tachardia lacca*) previously known as *Laccifer lacca* is a minute, resinous, crawling scale-insect which inserts its beak into plant tissues, sucks juices and grows, and secretes lac from the hind end of the body. Its own body ultimately gets covered with lac in the 'CELL'. Lac is actually secreted for its protection and not for the food of the insect. The commercial lac is produced in large quantities by female as a protective covering of its body which is injurious to the host plants.

Male. Male is red in colour and 1.2 to 1.5 mm in length. It secretes bright creamy lac. It has reduced eyes and ten segmented antennae. The mouth-parts are of piercing and sucking type. Thorax bears three pairs of legs and one pair of hyaline wings. The abdomen is eight segmented and terminates into a short, chitinous prominent general sheath containing penis. On either side of this genital sheath a white elongated caudal seta is found.

Female. Female is larger than males and measure about 4 to 5 mm in length. The pyriform body of the female is enclosed in a resinous cell. The head, thorax and abdomen are not clearly distinct. The mouth-parts are of piercing and sucking type. The antennae are clearly visible and degenerated. The posterior end of the body has a median and two lateral processes. The legs are in degenerated form.

Life History

Each mature female just after mating lays about 200 to 500 eggs in a cell in which she is enclosed. The oviposition takes place into the incubating chamber which is formed by the contraction of the body of the female in forward direction inside the lac cell. The eggs are laid in the months of October and November. After six weeks of laying, the eggs are hatched into first instar nymphs in the months of November and December. When nymphs emerge they are in quite large number. This mass emergence of the nymphs is known as 'SWARMING' (Fig. 1).

Nymph. At the time of emergence the nymphs are about 0.5 mm in length, red coloured and boat-shaped. The head bears paired antennae, ocelli and

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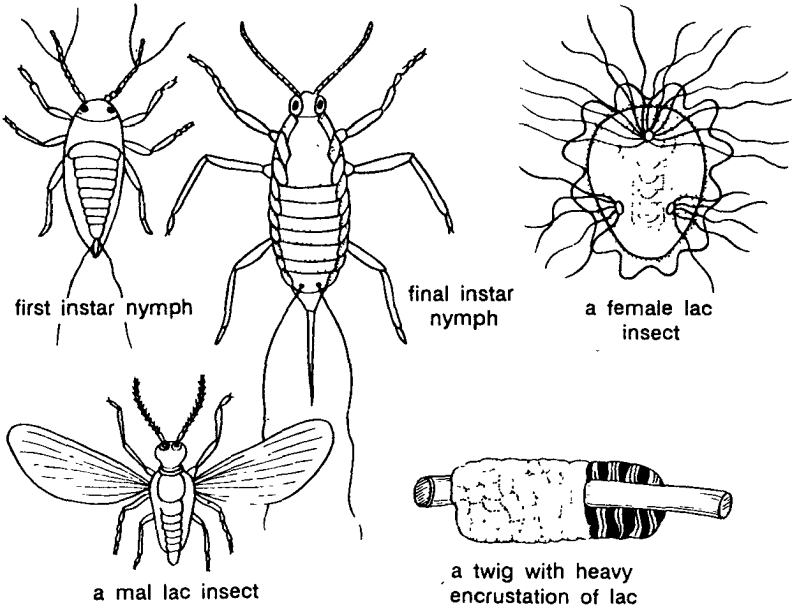

Fig. 1. Life history of *Tachardia lacca.*

ventrally situated piercing and sucking type of mouth-parts. The mouth-parts are provided with proboscis. The three segmented well developed thorax contains two pairs of spiracles and only one pair of walking legs. The abdomen contains two pairs of legs and terminates into a pair of long caudal setae. The active nymphs can crawl to a considerable distance so, just after emergence they start moving in search of food and reach their host plants, preferably on young and succulent shoots because the young nymphs are unable to settle and feed on hard twigs. These nymphs settle very close to each other on the twig of the host plant which further collapses completely and forms a continuous covering even on the lower surface of the twig. The number of nymphs that settle per square inch area is about 150 to 200. Settled nymphs suck the sap from the twig of the host plant and start to secrete the resinous substance by special dermal glands which are located all over the body. As the resinous secretion comes in contact with air, it soon becomes hard and forms a coating over the body of nymph and is called as 'CELL'. Within this cell various life processes like growth of the nymph, morphological changes and lac secretion take place.

The male 'Cell' is elongated and cigar-shaped having two holes *i.e.*, anterior and posterior. From the posterior hole which is covered by a flap or operculum, the male insect comes out by pushing open the operculum. After six to eight weeks of stationary life the nymphs are metamorphosed as a result of which some (30%) active winged males and maximum (70%) emerge in the form of

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females which are wingless. The females get fixed on the host plant in resinous mass. The males walk over the encrustations of females and fertilize them within their oval cells through anal opening. The males leave the parent cell after fertilizing the female. One male is capable to fertilize many females. The female nymph once settled never moves but undergoes 3 moults inside her cell loosing its eyes and legs, and with rudimentary antennae only. The fertilization of female is followed by a rapid growth of the female body till it begins to lay eggs in October and November. From these eggs male and female emerge in February to March. The male fertilizes the females of this generation and the fertilized female lays eggs in months of June to July and dies secreting lac all the time. Thus, the life cycle reoccurs twice in one year on the same host plant.

Due to short life period males do not take major part in the secretion of lac but female secretes lac throughout her life and its life span is longer than males. Major quantity of lac is secreted from females. The life cycle period depends mainly on ecological factors of the region.

Host Plants

The lac insects have more than one host plant. The selection of suitable host plant for the cultivation of lac is of much importance. To establish the lac industry one should know well about the topographic and climatic conditions for the growth of host plants suitable for that particular region. Brun (1958) has mentioned that 113 varieties of host plants are found in the geographical Indian regions including Pakistan and Burma. Out of these 113 host plants only 14 are very common in India which are as follows :

1. Kusum	—	*Schleichera oleosa*
2. Babul	—	*Acacia nilotica*
3. Ber	—	*Zizyphus mauritianas*
4. Palas	—	*Butea monosperma*
5. Ghont	—	*Zizyphus xylopyra*
6. Khair	—	*Acacia catechu*
7. Peepal	—	*Ficus religiosa*
8. Gular	—	*F. glomerata*
9. Pakapi	—	*F. virens*
10. Putkal	—	*F. globella*
11. Mango	—	*Mangifera indica*
12. Sal	—	*Shorea robusta*
13. Shisham	—	*Dalbergia sisso*
14. Fig	—	*Ficus carica*

The quality of lac is directly related with the quality of host plant. So far, no artificial product has been able to replace the lac. Khair, Kusum and Babul give better quality of lac when sown directly in the field. But Palas, Ber and Ghont give good crop when they are first sown in nursery and then transplanted to the lac growing field. Palas and Ber produce a particular type of lac which is called as 'KUSUMI LAC'.

(Z–37/Eco. Zool.)

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Cultivation of Lac

Lac cultivation is a complicated process, so the cultivators should know well about the inoculation, swarming period and harvesting of lac.

Inoculation

The first procedure in the lac cultivation is the inoculation of lac insect. Inoculation is the process by which young ones get associated properly with the host plant. Inoculation is of two types :

1. Natural inoculation. The inoculation taking place in normal routine or in natural way is very simple and common process during which the swarmed nymphs infect the same host plant again and start to suck the juices from the twigs. The natural incubation of swarmed nymphs has some drawbacks which are as follows :

(a) Incomplete nutrition. Lac insects with their piercing and sucking mouth-parts, pierce into succulent twigs and suck the cell sap of the same host plant for nutrition. If the cell sap of the same host plant is further sucked out by the swarmed nymphs of the second crop continuously, the growth of the host plant would be retarded. In this way lac insect may not be able to get enough nutrients from the same host plant. The lac insects due to lack of sufficient nutrients lose their proper development, thereby affecting the production of lac also.

(b) Irregular inoculation. During the natural inoculation it is not sure that uniform sequence of inoculation takes place. If inoculation is not of continuous fashion, a regular crop of lac may not be obtained.

(c) Unfavourable climatic conditions. At the time of swarming a number of factors like high intensity of sunlight, heavy rainfall, flow of wind etc. affect the proper inoculation of nymphs. These natural environmental factors may also affect the host plant at the same time and may cause a gap of inoculation resulting in irregularity of the lac crop.

(d) Multiplication of parasites and predators. Lac insects have certain enemies in the form of parasites and predators. If the crop is not harvested in time and lac is allowed to remain on the same twig, the multiplication of parasites and predators takes place which hampers the population growth of lac insects.

Thus, keeping in view the above drawbacks the natural procedure of inoculation is avoided and certain devices have been developed to ensure artificial method of inoculation.

2. Artificial inoculation. The main idea behind the artificial method of inoculation is to check all possible drawbacks of natural inoculation.

In this method first of all host plant should be pruned in January or June. The twigs bearing insect nymphs which are about to swarm, or just before swarming are cut in sizes ranging between 20 to 30 cm in length. Then the cut

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pieces of these twigs are tied to fresh trees in such a way that each stick touches the tender branch of the tree at several places which form bridges for the migration of the nymphs. After swarming, these twigs should be removed and separated from the host plant. The following precautions should be taken in artificial inoculation :

(i) One must ensure that the twigs, which are going to be tied on fresh host plant, are having good number of nymphs or eggs. It is also possible that from many of the twigs nymphs have swarmed out, thus inoculation would prove unsuccessful. (ii) The twigs provided with eggs or nymphs should be without any parasite and predator. (iii) The eggs or nymphs present on the twigs should be healthy and about to swarm so that one has not to wait for longer period and thus save time. (iv) For the uniformity of inoculation, 3 to 4 twigs should be utilised. (v) Host plants should be changed from time to time for the proper nutrition of the nymphs.

These insects are very small and if they move to a long distance there are chances of mortality of the nymphs. Due to maximum contact of twigs, swarming nymphs have not to move for long distance and find suitable places to establish on the host plant.

Inoculation period

In India two types of crops *viz.*, Rangini and Kusumi are grown in a year. The Rangini crop is of two types called as Kartiki and Baisakhi crop which produce Kartiki and Baisakhi lac respectively. The Kusumi crop is also of two types *viz.*, Agahani and Jethi which produce Agahani and Jethi lac respectively.

Thus, the inoculation periods of all the four types of crops are different. The inoculations of Kartiki, Baisakhi, Agahani and Jethi crops are recommended in months of June to July, October to November, July and January to February respectively. But if continuously four crops are taken, the plant would not get any rest which may cause less production of lac.

Swarming

It is very important phase in the life history of lac insect. So one should have accurate knowledge about the actual date of the swarming. At the time of swarming, the upper surface has yellow spot on the anal region. At this stage muscle contracts and insect gets detached from the place of attachment. Thus, it leaves a hollow cavity which later on gets covered with wax also. When these eggs are to be hatched out they become orange coloured. Thus, it is an indication that swarming has taken place. Thus, by trials and learning methods *i.e.*, by practice one could know about the exact date of swarming by looking at the colour of the eggs.

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Harvesting of lac

The process of collection of ready lac from host tree is known as harvesting. In common practice the harvesting is of two types.

1. Immature harvesting. The harvesting of the lac before swarming is called as immature type of harvesting and the lac thus obtained is known as 'ARI LAC'.

2. Mature harvesting. The collection of crop after the swarming is called as mature harvesting and the lac obtained is known as 'MATURE LAC'.

The harvesting of lac before the swarming has some drawbacks because the lac insects may be damaged at the time of harvesting which would affect the population of lac insects and ultimately result in great economic loss to the cultivators. But in case of palas lac (Rangini lac) it is found that Ari lac gives better production. Therefore, Ari lac harvesting is recommended in case of palas only. In all other cases immature harvesting should be discouraged. It is also found that in cold areas mature crop yields better quality of lac.

Harvesting period. The harvesting periods of different crops are quite different in accordance with the inoculation of crops. Kartiki crop is harvested in October to November whereas, Baisakhi crop in May and June. The other crops like Agahani and Jethi are harvested in January to February and June to July respectively.

Recent Plan for Lac Cultivation

With the increasing number of lac industries some advanced plans have been recommended for the better cultivation of lac crops. Two types of planning are used now-a-days.

1. Ceupe system. All the trees of host plants of a definite area are not used under continuous cultivations process of lac crop because if all host plants of a farm would be under continuous attack of lac insects, 100% plants may not get any rest and thus the production of the lac would be affected due to deficiency of nutritive cell sap to the swarmed nymphs and adults. So, the plants of a farm are numbered into 5 groups of plants. This artificial division or marking of trees is called as ceupe system of crop cultivation. In this system when one group of host plants is under the process of cultivation of lac, other groups of host plants would be under rest.

2. Alternation of plant. In this system the variety of host plant is changed after one crop. So, swarmed nymphs are inoculated on the tree of other variety of host plant. In this way every host plant can get enough rest resulting into better production of lac.

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Processing of the Lac Industry

When the crop matures fully most of the lac is harvested and some part is left on the host plant. For the proper cultivation, the host plant should be pruned in January every year.

The twig bearing the lac alongwith eggs is called a BROOD LAC STICK and lac is known as BROOD or STICK LAC. The processing starts with the scraping of the stick lac from the twig. The scraped lac is subjected to removal of many impurities like dead parts of the lac insects, eggs and colouring matter, and finally crushed by hand-operated mortars. Then the material is air dried and obtained in the form of granules which is known as SEED LAC. This seed lac is soaked in water, washed, dried in sun light, bleached and heated to melt on charcoal fire in cloth bag of 3 to 4 metre. At the time of heating the bag is twisted and the lac is squeezed out of the bag. The impurities of the lac are left out in the bag, and are called as KIRRI LAC. The squeezed lac is now allowed to cool and solidify around the button-shaped forms which is now called BUTTON LAC or PURE LAC. This pure lac when stretched into thin sheet is called as SHEET LAC. This sheet lac when dissolved in water, produces white or orange coloured lac which is called as SHELL LAC. Shell lac is, in fact, prepared by boiling the seed lac with yellow arsenic in a certain proportion. Thus the shell lac is most purified form of lac.

The quality of lac depends upon the host plant. Kusumi lac is said to be the best lac while Dhak is supposed to be the worst and cheapest one. The quality and colour of the lac is variable according to the presence of gum and resins in the host plants.

Composition of lac

Lac is a complex substance having large amount of resins, together with sugar, water and other alkaline substances. The percentage of various constituents are as given below :

(1) Resin	—	68 to 90%
(2) Dye	—	2 to 10%
(3) Wax	—	6%
(4) Albuminous matter	—	5 to 10%
(5) Mineral matter	—	3 to 7% and
(6) Water	—	3%

Properties of lac

(1) Lac is not soluble in water but easily soluble in alcohol. This property of lac has great value for insulation of electrical connections.
(2) Lac is easily fusible on heating.
(3) Lac has adhesive quality.

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(4) It has binding property when mixed with alcohol.
(5) Lac is also soluble in weak alkali like ammonia.
(6) Lac is a bad conductor of heat.

Enemies of Lac Cultivation

Lac cultivation is destroyed by biotic and abiotic factors :

1. Abiotic enemies. These are high intensity of light, high temperature, high humidity, heavy rainfall and flow of wind.

2. Biotic enemies. The main biotic enemies of lac cultivation are mammals and insects. Krishnaswami et. al. (1957, 59), and Gepulpure et. al. (1963), have reported that squirrel, rats, and monkeys cause great damage to the lac crop.

The insects are very powerful enemies of lac crop. Annual loss due to the insect enemies is to the tune of about four lakh maunds.The insects damage the crops in different ways.

1. Parasites. The lac insects are parasitised by eight species of chalcidoid parasites like, *Parenchthrodryinus clavicornis, Erencyrtus dewitzii, Tachardiaephagus tachardiae,Tachardiaephagus tachardiae* var. *somervilli, Eupelmus tachardiae, Coccophagustschirchii, Mariettajavensis* and *Tetrastichus purpureus.* These parsites lay their eggs into lac insects and parasitised 4.8 to 9.9% of lac insects per year and 1/3 of the parasitised cells are males. Thus, it may be concluded that parasitization is not a major cause of the damage to the lac cultivation.

2. Predators. Predators cause very severe damage to lac cultivation and 35% of the lac cells are damaged by two predators *viz., Eublemma amabilis* Moore (Lepidoptera : Noctuidae) and *Holocera pulverea* Meyr (Lepidoptera : Blastobasidae). Female lays eggs near encrusted twigs from where larva emerges and feeds on lac insects.

Precautions

(1) Twigs for inoculation should be cut just before the swarming to get healthy brood.
(2) Twigs used for inoculation should be free from predators and parasites.
(3) Twigs tied for inoculation should be removed from inoculated host plants after a maximum period of 20 days.
(4) Lac left on the host tree for swarming should be removed in October and November.
(5) The brood lac after swarming should be destroyed along with predators and parasites on it.
(6) The lac scraped from the tree should be taken away from the area of lac infected trees.
(7) Fumigation and water immersion of lac, before removing from twig, should be done.

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Lac Industry in India

India used to produce about 97% of the total lac output in the world but at present it has come down to 50-60%. The cultivation of lac has been good source as an earner of foreign currency. About 50% of the total lac produced in India is obtained from Chhotanagpur area. States like Orissa, Punjab, Chattis Garh, Madhya Pradesh, W. Bengal, Uttar Pradesh, Uttaranchal, Gujarat, Rajasthan, Assam etc. are increasing the production of lac now-a-days. On a very small level lac producing is also reported from Delhi and Kashmir. The average yearly yield of lac in India is about 15,000 metric tons. A lac research institute 'Indian Lac Research Institute' Namkum, Ranchi had been established in 1925 which is producing good quality of white lac. The Indian white lac is supposed to be better than red or other coloured lac because they produce stain or spots at places where they are kept. This is mostly small scale industry with around 350 factories, mostly located in Bihar and Jharkhand. In Mirzapur district alone there are about 40 factories. Out of total lac produced in India about 85 to 95% is exported specially to Britain, U.S.A., Russia and West Germany.

Economic Importance

In 19th century lac dye was in more use than lac resin. Presently due to availability of a better and cheaper annaline dyes the use of lac as a dye has been discarded. The manifest uses of lac is one of the Nature's standing gifts. The various used to which it is put are —

(1) It is utilized in the preparation of gramaphone records. Previously this industry utilized major part of the lac produced annually. But now a days to a great extent plastic is being used in this trade.
(2) It is of utility to Jewellers and Goldsmiths who use lac a filling material in the hollows in gold ornaments like bracelets, armlets and necklaces etc.
(3) It is an essential gradient used extensively for making polishes, paints and varnishes for finishing wooden as well as metal furnitures and doors etc.
(4) It is utilized for the preparation of toys, buttons, in pottery and artificial leather.
(5) It is used in the manufacture of photographic material, lithographic ink and for stiffening felt and hat materials.
(6) It is used as an insulating material for electrical goods.
(7) It is also used in confectionary trade as antifowling for applying on ship bottom, grinding stone industry and for ammunition and fire works.

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(8) Last but not the least used commonly as sealing wax.

Thus, it is of great use and considered to be as one of the cash crops for the cultivators and also to the Government as source of foreign exchange earners which amount to crores of rupees annually.

IMPORTANT QUESTIONS

» ***Long answer type questions***

1. Give an account of the life history of lac insect.
2. Give an account of the cultivation of lac.
3. Give an account of the processing, enemies and status of lac industry in India.

» ***Short answer type questions***

1. Enumerate host plants of lac insects.
2. Define natural inoculation of lac insect.
3. Define artificial inoculation of lac insect.
4. Give recent plan for lac cultivation.
5. Describe processing of lac industry.
6. Economic importance of lac.

» ***Very short answer type questions***

1. Explain swarming of lac insect.
2. Define immature harvesting of lac.
3. Define ceupe system in lac cultivation.
4. What is seed lac ?
5. Name the predators of lac insect.

» ***Objective type questions***

1. *Tachardia lacca* belongs to order :
   (a) Lepidoptera (b) Hemiptera (c) Thysanura (d) Diptera
2. Which of the following is not a host plant of lac insect ?
   (a) *Acacia nilotica* (b) *Zizyphus mauritianas*
   (c) *Ficus religiosa* (d) *Saraca indica*
3. Which of the following is most purified form of lac ?
   (a) Seed lac (b) Pure lac (c) Sheet lac (d) Shell lac
4. The raw lac obtained from the twig of host plant is called :
   (a) Shell lac (b) Sheet lac (c) Button lac (d) Brood lac
5. Which of the following is maximum in lac ?
   (a) Wax (b) Resin (c) Water (d) Mineral
6. Which is not the constituent of lac ?
   (a) Dye (b) Wax (c) Resin (d) Gum
7. *Tachardia lacca* secretes lac for :
   (a) Protection (b) Food
   (c) Reproduction (d) Attracting the microbes

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8. Which of the following is wrong ?
   (a) Lac is easily soluble in alcohol (b) Lac is easily fusible on heating.
   (c) Lac is a bad conductor of heat (d) Lac is not soluble in weak alkali
9. Which is greatest producer of lac in India ?
   (a) Chhotanagpur (b) Delhi (c) Kashmir (d) Gorakhpur
10. Which of the following is predator of lac insect ?
   (a) *Merops orientalis* (b) *Eublemma amabilis*
   (c) *Acarapis woodi* (d) *Componotus compressus*

Answers

1. (b) 2. (d) 3. (d) 4. (d) 5. (b) 6. (d) 7. (a) 8. (d) 9. (a) 10. (b).

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8

Sericulture

For more than 35 centuries countless generations of silkworms are continuously breeding, feeding on mulberry leaves, spinning their cocoons and dying, an everlasting sacrifice to the demand of human-beings for decoration. For the first time in 2697 B.C. Lotzu Empress of Kwang-Ti discovered the fancy origin of beautiful silk in the form of threads. Thus, the technique of cloth preparation from the cultivated silk was known to Chinese people for more than 2,000 years ago. The art of silk preparation was kept as top secret as national policy and any one, who attempted to send the eggs of silkworm out of the country, was hanged to death. It is said that silk was as valuable as gold and ultimately gold was flowing into China from all parts of the world. But in the year 555 A.D. this secrecy was opened and the eggs of silkworm and sericulture technique were smuggled by two monks sent as spies to China and thus, sericulture was introduced into Europe. Later on it was introduced in Mediterranean and Asiatic countries. Now-a-days sericulture has become one of the most important cottage industries in a number of countries like Japan, China, Rep. of Korea, India, Brazil, Russia, Italy and France.

The experimental and systematic study on sericulture was started in Japan in 1911 after establishment of the Sericulture Experiment Station and in 1979 the National Sericulture Experimental Station was set up in Tokyo.

In India first of all Lefroy (1905-1906) started investigation on the silkworm and sericulture at Pusa Institute, New Delhi. He set up a sericulture stall in an 'All India Exhibition' organised by the Government of Uttar Pradesh at Allahabad in 1901-1910 to draw the attention of scientists and general public towards the sericulture industry.

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Silk Moth

The silk producing machine is an insect called as silk moth locally in Hindi 'Resham-ka-kira'. Although a number of species are found producing silk but only few species are used for sericulture industry.

Systematic position

Phylum ..... Arthropoda
Class ..... Insecta
Order ..... Lepidoptera
Family ..... Bombycidae and Saturniidae

Species of Silkworm

1. Mulberry silkworm. *Bombyx mori.* It belongs to the family Bombycidae. China is the native place of this silkworm but now it has been introduced in all the silk producing countries like, Japan, India, Rep. Korea, Italy, France and Russia. Since the natural food of this worm is mulberry leaf, it is called as mulberry silkworm. The silk produced by this moth is white or yellow in colour.

2. Tasar silkworm. *Antheraea paphia.* It belongs to the family Saturniidae and common in India, China and Sri Lanka. The caterpillar feeds on ber, oak, sal and fig plants. The cocoon produced by this moth is hard and of hen's egg size which produces reelable brown coloured silk. Though it had been only a wild variety of silk moth since long, now, by cross breeding, it has been possible to produce such varieties which are reared any how and domesticated. But the domestication of tasar caterpillars is not so easy, so the cocoons have to be collected from the forest. The moths do not easily breed in captivity. Since breeding is not well controlled, the tasar silk industry has not reached up to mark as the mulberry silkworm industry.

3. Muga silkworm. *Antheraea assama.* It also belongs to the family Saturniidae and semi-domesticated in nature. The native place of this species is Assam where, it has now become a good source of cottage industry. The caterpillars of this worm feed on *Machilus* plant and the silk produced by this moth is known as Muga silk.

4. Eri silkworm. *Attacus ricinii.* It also belongs to the family Saturniidae and produces silk in East-Asia. In India sericulture scientists are trying to produce silk in East-Asia. Sericulture scientists are trying to produce such cross breeds which can provide good quality of silk and can be reared easily. It feeds on castor leaf. Cocoons cannot be reeled as in mulberry cocoons, therefore, it has to be spun. Its life history resemble with that of mulberry worms. The cocoons of this worm have very loose texture and the silk produced is called as 'Arandi silk' locally. The threads are not glossy but much durable.

5. Oak silkworm. *Antheraea pernyi.* It belongs to the family Saturniidae and is found in China and Japan. *A. roylet* of the Himalayas and *A. yamamai* of Japan have been reared for centuries. They produce good quality of silk.

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6. Giant silkworm. *Attacus altas.* It belongs to the family Saturniidae and is found in India and Malaysia. It is the largest of the living insects reaching upto eleven inches in wing-span.

Out of the above species only four are of common use for sericulture *viz., Bombyx mori, Attacus ricinii, Antheraea assama* and *Antheraea paphia.*

Mulberry Silkworm

The perusal of literature reveals that much advanced work has been done by sericulturists and scientists on *Bombyx mori* because of its total domesticated nature. Various varieties of silkworm are produced by genetical crossing and they are producing 2-7 generations in India but in some countries like Europe and Russia where the duration of winter is more than the summers only one generation is produced per year. The race of silkworm by which only one crop is taken in one year is called UNI-VOLTINE, producing two crops in a year is called BI-VOLTINE and producing more than two crops in a year is called MULTI-VOLTINE races. Now- a-days , for commercial purpose only approved races are reared by conducting national trial of silkworm races offered by various research institutions. Different crosses are generally chosen for spring and autumn rearing.

Life History of Mulberry Silkworm, *Bombyx mori* (L)

The adult of *Bombyx mori* is about 2.5 cm in length and pale creamy white in colour. Due to heavy body and feeble wings, flight is not possible by the female moth. This moth is unisexual in nature and does not feed during its very short life period of 2-3 days (Fig. 1).

Fertilization. Fertilization is internal preceded by copulation. Just after emergence, male moth copulates with female for about 2-3 hours and if not separated they may die after few hours of copulating with female.

Egg laying. Just after copulation, female starts egg laying which is completed in 1-24 hours. One moth lays 400 to 500 eggs depending upon the climatic conditions and the supply of food material to the caterpillar from which the female moth is obtained. The egg laying is always in form of clusters and covered with gelatinous secretion of the female moth which helps them in proper attachment.

Eggs. The eggs laid by the female moth are rounded and white in colour. The weight of the newly laid 2,000 eggs comes to about 1 gm. With the increase in time after laying, eggs become darker and darker day-by-day. Two types of eggs are generally found *viz.,* DIAPAUSE type and NON-DIAPAUSE type. The diapause type of eggs are laid by the silkworm inhabiting in temperate regions, whereas, silkworms belonging to subtropical regions like India lay non-diapause type of eggs. During diapause all the vital activities of the eggs cease.

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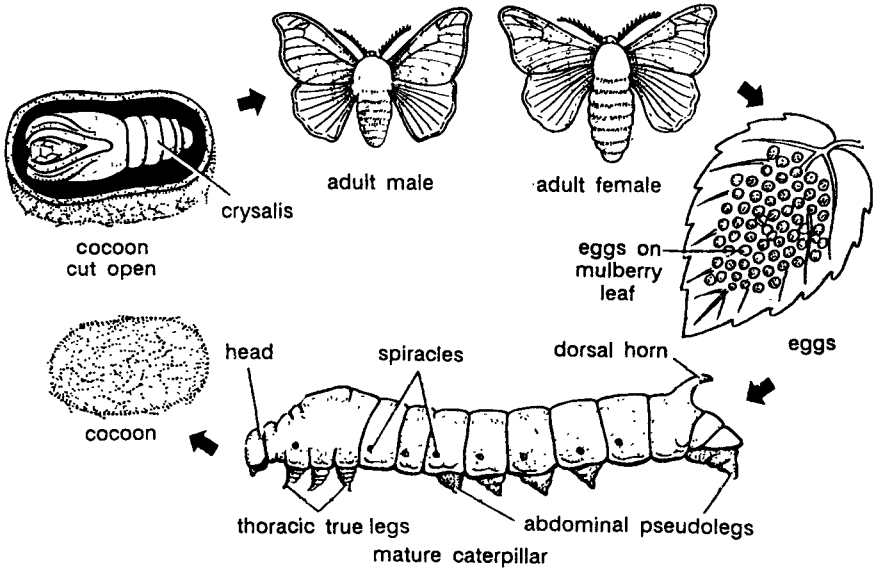

Fig. 1. Life history of *Bombyx mori*.

Hatching. The eggs after ten days of incubation hatch into a larva called as caterpillar. Hatching is the most important phase of silk moth's life. After hatching, caterpillars need continuous supply of food because they are voracious feeders. If proper supply of mulberry leaf is not possible the development of caterpillar would not be in proper course. Sometimes, due to lack of food material, young caterpillars die causing great loss to the sericulture industry. It is recorded that in uni-voltine race hatching of eggs takes one month after laying.

Caterpillar. The newly hatched caterpillar is about 0.3 cm in length and is pale, yellowish-white in colour. The caterpillars are provided with well developed mandibulate type of mouth-parts adapted to feed easily on the mulberry leaves. The caterpillar is twelve segmented and the abdominal region has ten segments having five pairs of pseudo-legs. It is also provided with a small dorsal horn on the anal segment. Because of its being very much tender, the Ist instar larva can feed only on very soft leaves of mulberry plants. As they are voracious feeders, they grow rapidly which is marked by four moultings. After Ist, 2nd, 3rd and 4th moultings caterpillars get changed into 2nd, 3rd, 4th and 5th instars respectively. It takes about 21 to 25 days after hatching. The full grown caterpillar is 7.5 cm in length. It develops salivary glands, stops feeding and undergoes pupation. The time taken for the full growth of the caterpillar from young to the well grown stage varies with regard to the temperature, humidity, food supply and type of race. Weight of the full grown caterpillar varies from 4 to 6 gm.

Pupa. The caterpillars stop feeding and move towards corner among the leaves and secrete a sticky fluid through silk gland. The secreted fluid comes

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out through spinneret (a narrow pore situated on the hypopharynx) and takes the form of long fine thread of silk which hardens on exposure to the air and wrapped around the body of the caterpillar in the form of a covering called as COCOON.

Cocoon. Cocoon is the white coloured bed of the pupa whose outer threads are irregular while the inner threads are regular. The length of continuous thread secreted by a caterpillar for the formation of cocoon is about 1000-1200 metres which requires 3 days to complete. The threads is wound around the cocoon in concentric manner. The binding of threads round the cocoon is very interesting and quick going phenomenon achieved by the constant round motion of the head of the caterpillar from one side to the other at the rate of 65 times per minute. Now the silkworm pupa is covered within a thick, oval white or yellow silken cocoon. It is estimated from the data obtained by practical application that one pound of silk can be obtained from 2,500 cocoons. The weight of one cocoon is about 1.8 to 2.2 gm and the weight of the cocoon shell only is 0.45 gm. The size of the thread is 2.0 to 2.8 denier. The pupal period lasts for 10 to 12 days and the pupae cut the cocoon and emerge into adult moths.

Emergence of imago. Due to active metamorphic changes during pupal period the abdominal pseudo-legs disappear and two pairs of wings develop. The silkworm within the cocoon secretes an alkaline fluid to moisten its one of the ends. As a result of this the moistened end becomes soft where the threads are cut open (hydrolysed) by the silkworm. Finally a hole is formed through which a feeble adult moth squeezes out of the cocoon.

Sericulture Industry

The production of silk from the silkworm by rearing practices on commercial scale is called sericulture. Although silk is very beautiful and fancy gift of nature but its commercial production is very much complicated and a tough job which requires heavy man power. Before going into the details of the sericulture industry it is essential to have an idea about the major steps and requirements of sericulture. Improved race of *Bombyx mori* and good nutritive type of mulberry plantation is the sole need for the industry. Other than these some of the other requirements are given below :

(1) Machana : The proper place for rearing the silkworms.
(2) Rearing trays : For keeping the laid eggs alongwith the mulberry leaves.
(3) Spinning or Chandrakis tray : For keeping the caterpillars at the time of full grown stage ready for pupation.
(4) Dalas : For fetching the mulberry leaves.
(5) Chopping knife : For cutting the mulberry leaves into smaller pieces.
(6) Baskets : For the distribution of mulberry leaves.
(7) Hygrometer : To know the % humidity in the atmosphere.
(8) Thermometer : To take the reading for the room temperature.

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(9) Oven : To regulate the different stages of life cycle at different temperatures.
(10) Freez : For the storage of eggs (seed) for next generation.

Selection of races of *B. mori.* Although a number of races have been developed for the purpose, care should be taken to select only those which would be fit for a particular locality keeping in view the climatic condition of that area. According to rearing season *viz.*, spring, early autumn and late autumn different crosses are chosen for successful rearing.

Mulberry. The whole sericulture industry is based on the best utilization of the mulberry leaves as it is the only food of this insect. In Japan more than thousand varieties of mulberry exist including as many as 130 natural species out of which only a few are in commercial use.

Mulberry is a deciduous medium sized tree belonging to the family Moraceae. Its species are given as below :

***(a) Morus alba* Linn.** It is of white type and locally called as Toot, Tootri etc. This is widely used for rearing the silkworm and also for fruits.

***(b) Morus indica* Linn.** It is locally called as 'shahtoot' and is Indian in origin. It is also used for fruits and for rearing of silkworms.

Climate. Although, mulberry is a plant of temperate zone but some varieties have been developed by cross breeding which can grow well in tropical and subtropical zones also. According to the climatic conditions different varieties of mulberry are being used throughout the world.

Soil. For a good crop and nutritive type of leaves, soil should be of loam type and not with stones etc. Soil with neutral pH is best suited for proper growth of mulberry plants.

Plantation. It is of two types as given below —

(a) Seed. In December and May seeds of mulberry are sown and the seedlings grow very quickly which can be transferred either as whole plant or a stump in months of June, July and November. Seed beds should be mixed with ash, lime and white arsenic.

(b) Cutting. Cutting should be done in months of July and August. The size of each cut piece should be 20 to 25 cm in length and 2 to 3 cm in thickness. The cut pieces should be planted in slanting position in the pits (50 × 50 × 50 cm) having 1 kg. superphosphate, 30 gm B.H.C. and 25 kg farm-yard manure.

The plantation is performed in December-January or July. The plantation is mainly of 2 types *viz.*, single row and multiple row plantation. (i) In single row plantation 400 plants can be placed around the boundary of one hectare plot at the distance of one metre from plant to plant. (ii) In multiple row plantation scheme the whole of the plot is used only for sericulture programme. About 10,000 plants are placed at the distance of 1 × 1 metre per hectare.

Weekly irrigation is most preferred for bumper growth of mulberry leaves.

Fertilizers. The months of December to January are the best time for manuring the crops. Although the real dose of any fertilizer can be fixed after

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proper soil testing and according to the fertility of the soil but a generalized recommended dose of manuring is given below (S.S. Sagwal and O.P. Katna, 1981).

Table. **Dose of manures and fertilizers per plant.**

Age of Plant (Year)	Farmyard manure (Kg.)	Kisan Khad (gm)	Super phosphate (gm)
1	10	500	250
2	20	1,000	500
3	30	1,500	750
4	40	2,000	1,000
5	50	2,500	1,250

Pruning and thinning. December and January are best suited months for pruning and thinning. After 4 to 5 years of plantation mulberry plants get ready for the rearing of silkworms.

The white mulberry *(Morus alba)* or Kashmir white or black mulberry or white Philippine early variety are preferred. In India white Philippine early variety is most preferred because this grows easily.

Rearing of Silkworm

The word rearing does not mean only the feeding of caterpillars as often understood but a continuous care from egg laying through aestivation, hibernation, incubation, early stage larval care, late stage larval care to the production of cocoon. So, for proper and step-wise study of rearing one should proceed from Grainage Technology.

Grainage management

The aim of the establishment of grainage is to provide good quality of seed to rearers and maintenance of original quality of races. For this purpose due care should be taken of the 'crop of silkworm' for seed production from the very beginning *i.e.* the caterpillar stage, by providing them with proper nutrition and protection from the attack of diseases. Keeping these points in view initial selection is made on the basis of percentage of dead pupae during normal development. If it is above the limit seed should not be purchased for seed production. First selection is made by separating out dead cocoons and next selection in the grainage.

After final selection, cocoons are subjected to sex separation by cutting one end of the cocoon either manually or through Nagahara (in Japan) cocoon openers. The Nagahara machine can cut 10,000 to 15,000 cocoons per hour. For the production of commercial eggs loose forms of cocoons are used and collective mother examination is done, either through mass pebrine detecting machine or general microscopic observations. They are then kept for mass emergence.

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1. Emergence of moth and fertilization. When kept for emergence at room temperature, mass emergence of adults takes place. As per their nature, just after emergence, male moth starts moving around the female. Males are very much active whereas the females which are loaded with eggs are incapable of flying. If not separated atonce in cages males start copulating with the females but the eggs obtained from this female mated from the male of the same stock is useless for the seed. So the males and the females just after emergence have to be separated into separate cages without their mating. Now one female of one lot is kept with the male of the other lot and atonce they form pair and copulate for about 3 hours. After completion of mating, males should be separated and may be used for the mating of other females. But one male can not mate more than two females. Now mated females are subjected to egg laying.

2. Egg laying. Just after mating, female starts egg laying and in the duration of 24 hours it completes egg laying process. The eggs laid by one female are about 400 to 500 varying according the different races. Female dies after egg laying. These eggs are called as SEED. These eggs are kept in sterilized trays and stored at 4°C under laboratory conditions or sometimes kept at hill stations in diapause conditions.

The stages of egg (seed) production is of 3 types *viz.*, production and supply of grand parent eggs, production and supply of parent eggs, rearing of parent eggs and production of commercial F_1 seed. The grand parent and parent eggs are produced by recognised and reputed organizations. This commercial seed is supplied to the rearers.

3. Hatching. This is an important phase of sericulture industry because as soon as the larvae are hatched they start feeding voraciously. So only those sericulturists who would be able to supply sufficient amount of fresh mulberry leaves to the young hatched larvae, could perform successful sericulture programme otherwise young ones will die resulting great loss to sericulture industry. This is why the hatching has to be controlled, accelerated or postponed by artificial treatments under refrigerated conditions. For proper hatching of seeds (eggs) advanced techniques have been developed in which eggs are collected and kept with mulberry leaves, working as stimulant for hatching in shady places on white sheet of paper in insect proof trays on a stool. For this purpose the legs of stool must be kept in water so that insects may not crawl and damage the hatching eggs. It is also notable that if the eggs are placed in the same position in which they are laid, hatching will not be 100%. So it is advisable that the eggs kept in trays should be moved with the help of feather. The group of caterpillars hatched at various stages should be kept separately. Thus, one should be careful that hatching must be coincided with the best season of the mulberry.

4. Experimental data of egg laying and hatching. (i) If after 120 minutes of oviposition eggs are kept at 10°C for 24 hours then transferred to the oven at 16°C for 4 days and further soaked in hydrochloric acid (15% at 46°C) for

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5 minutes, the diapause condition is broken easily. (ii) To get the homozygous stock of female silk moth, eggs are taken from 24 hour old moth and treated with hot water (46°C) for 18 minutes then kept at 15 to 17°C for 4 days, treated with acid at 46°C and then kept for incubation. When such eggs are reared carefully a homozygous stock is obtained. (iii) If the female moth is kept at 5°C for 24 hours just after mating and for egg laying at normal room temperature, 70% eggs are laid in the first hour after incubation and 20% eggs are laid in 2nd hour. This data is very much useful for grainage technicians from the point of view of uniform hatching of eggs.

Supply of seed to rearers and commercial rearing

After grainage management the next step is the supply of seed or caterpillars to the farmers. The supply is of two types depending on the knowledge of rearers *i.e.*, supply of eggs and 2nd instar larvae.

The old rearers who are well versed with the rearing technique may purchase eggs for the rearing but new and untrained rearers knowing nothing about the rearing should always be given 2nd instar caterpillars for this purpose. Much care should be taken for the rearing of 1st, 2nd and 3rd instar caterpillars and 4th and 5th instar caterpillars are mostly reared either on hanging trays often with nylon nets or on the floor.

It is essential to clean the bed of the caterpillars once in a day for 3rd, 4th and 5th instars.The principle of rearing should be the production of healthy caterpillars with uniform development.The mulberry leaves supplied to the 1st and 2nd instar larvae should be young and well chopped because they are very tender in nature. The 3rd instar larvae may feed even on chopped hard leaves but 4th and 5th in star larvae can feed easily on leaves also.

The taste of mulberry leaf is lost due to rapid loss of moisture, so rearer should be careful to stop or reduce the loss of moisture from the leaf after harvesting. For this purpose 60 to 70% humidity of the room is needed otherwise it affects the health of silkworm. So, it is advisable to keep the leaves wrapped in wet clothes. The overcrowding of worms causes under-nourishment and checks proper development. If a large number of rearers in the same village take the worms from same lot, spinning of silkworm of all the rearers starts on the same day if proper supply of mulberry leaves is there.

Now full grown 5th instar larva stops feeding, undergoes pupation and settles to a corner among the mulberry leaves and starts to secrete sticky fluid.

Thus, an improved technique of rearing of silkworm has resulted in the production of cocoons of good quality. The temperatures best suited for the rearing of 1st, 2nd, 3rd, 4th and 5th instar larvae are 27, 27, 25, 24 and 23°C respectively.

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Spinning of cocoons

This is the period when the caterpillar stops feeding and starts to secrete a pasty substance from the silk gland. In this condition worms should be picked up and transferred to the spinning trays and kept in a position of slope (slanting) to the sun for a short period. Within three days spinning is over and the cocoon is formed and this is the last phase of the rearing of silkworm.

Quality of cocoon. The quality of cocoon is dependent on the raw silk yield, filament length, reliability and splitting.

Marketing of cocoon. The price of cocoon is fixed during every season of the rearing. This price is, however, watched by the Government and cocoons are purchased by the rearers.

Post-cocoon processing

The method of obtaining silk thread from cocoon is known as post-cocoon processing. This includes STIFLING and REELING.

1. Stifling. The process of killing the cocoons is termed as stifling. Sericulturists should be very much careful that before the emergence of silkworm (The cocoons which do not have cut holes) good sized cocoons of 8 to 10 days old are selected for further processing and dropped into hot water or subjected to steam or dry heat, sun exposure for 3 days or fumigation. In this way pupae or cocoons are killed. The killing of the cocoon in boiling water helps in softening the adhesion of the silk threads among themselves and loosening of the outer threads to separate freely, facilitating the unbinding of silk threads.

2. Reeling and spinning. The process of removing the threads from the killed cocoon is called as reeling. Four or five free ends of the threads of these cocoons are passed through eyelets and guides to twist into one thread and wound round a large wheel from which it is transferred to spools. Thus the silk obtained on the spool is called as RAW SILK or REELED SILK. The waste outer layer or damaged cocoons and threads are separated, teased and then the filaments are spun. This spunned silk is called as 'SPUN SILK'.

The raw silk is further boiled, stretched and purified by acid or by fermentation and then carefully washed over again and again to bring about the well-known lustre on the thread.

The modernization of the reeling and spinning process by autolization and various labour saving process has opened a new way to this cottage industry in the world. One autolizer can yield 3.715 kg silk per basin in 8 hours in Japan.

Silk

Silk is a pasty secretion of the silkworm produced by the silk gland. The silk glands are actually modified salivary glands which are long and sac like. As this pasty secretion comes in contact with air, it becomes hard and forms

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strong and pliable silk strands. This secretion forms two cores of fibroin : (i) a tough elastic insoluble protein consisting of 75% of the fiber's weight and cemented together with sericin from the middle region of the silk gland at the time of secretion, and (ii) a gelatinous protein which is easily soluble in warm water. Some quantity of wax and carotenoid pigments are also detected. The diameter of the silk fibers is 0.0045 to 0.0082 cm. Its elasticity is found to be 20%.

Diseases of Silkworm

The Sericulture Industry suffers from a number of diseases in Tropical regions of South East Asia. The maggot disease, pebrine, polyhedrosis and flacherie are the diseases which cause severe damage to this industry. The poisoning by tobacco and Muscardines is also reported to be harmful but is not very common.

[I] Maggot disease

This disease is caused by *Tricholyga sorbillans,* a fly belonging to the order-Diptera and Family-Tachinidae. It is distributed throughout India, Japan, Korea, China, Vietnam and Thailand. The presence of milky white cylindrical eggs on the skin of silkworm larvae is a symptom of this disease. The number of eggs laid by the fly on a silkworm larva varies from several to more than fifty but usually they are two to three. After 30-40 hours of egg laying, maggot is formed inside the egg shell. Now this maggot makes a hole on the ventral side of egg shell and on the skin of the silkworm. Thus, maggot penetrates into the body of silkworm larvae and starts eating the tissues of larvae. When the maggot penetrates into the larval body, the big black mole is formed on that part of the skin. The segments in which maggot exists, swell up and bend as a result the attacked larva becomes inactive and loses appetite. Usually fourth and fifth stadia are attacked by the maggots. The larvae, attacked up to the fourth stadia die before making cocoon, whereas, those attacked in the fifth stadium make cocoons but usually do not attain the pupal stage.

A number of natural enemies like parasitic insects, fungi etc. are known to control the population growth of *T. sorbillans.* The avoidance of entry of this fly into the rearing room of silkworm is the only means for the prevention of this disease for which nets are fixed around the windows.

[II] Pebrine

This is one of the worst diseases of silkworm. Sericulture was once damaged by this disease in all the countries involved in this industry but some countries have overcome this disease and succeeded in getting pebrine-free-silkworm-eggs for reeling cocoons. *Nosema bombycis* Nageli, belonging to Microsporida, is the casual micro-organism of this disease. The infection takes place through the mouth of larvae at the time of feeding or through the mother's ovary.

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When new spores are formed in the tissues of alimentary canal of silkworm, they are discharged with the faeces and make a source of infection. When the spore enters into the digestive tract of silkworm, two nuclei, contained in the sporoplasm, are divided into four nuclei and at the same time the polar filament projects and penetrates into the cells of the alimentary canal. Further, they enter into the blood and swim in it. They are distributed throughout the host body, attacking various tissues, specially the fat bodies and organs, excluding chitinous tissues and nucleus of cells. When the hypoderm is attacked and its cells die, the affected part becomes black due to the formation of melanin. Inside the body, the milky white spots or marks are observed on the silk gland or on the surface of the alimentary canal. In case of severe infection of the eggs the whole of yolk nearly gets filled with the micro-organisms resulting in their (eggs) death. Whereas, in case of slight infection the eggs hatch but the larvae carrying infection die at the third moult without making cocoon.

The diseased larvae show little inclination towards food and exhibit irregular and differential growth resulting in the formation of small larvae of different sizes. They become tardy, shrunken or moult quite late and finally die.

Counter measures against pebrine. If the infection occurs at the embryo stage, the larvae die in the third moulting stage as already mentioned. So, during the rearing of reeling cocoons it is very important that the pebrine free eggs are used. The infection by pebrine should be strictly avoided at any stage of the life history of the silkworms for rearing seed cocoons in order to get the healthy eggs. Therefore, it is essential for the prevention of pebrine that the tools used and the rearing houses should be kept free from pebrine germs. The following measures may be applied.

1. Examination of mother moths. All the mother moths producing eggs should be carefully examined one by one, and eggs laid by healthy moths only be taken for further use. The unqualified eggs should be burnt away.

2. Forecasting and correcting examination. In order to make the pebrine examination more reliable, the forecasting and correcting examinations are carried out for the eggs of the seed cocoons.

The materials employed for forecasting examinations are the excrement of mature larvae, late moulting larvae, dead larvae, cocoons or pupae and moths accelerated to emerge out of cocoons. For the correcting examination a few eggs of each reproductive egg-batch are taken and incubated and thus, emerged larvae are used as the material for examination of pebrine germs.

3. Removal and disinfection of pebrine germs. The spores of pebrine may survive for a number of years in an ordinary type of rearing room if the environmental condition is humid. Therefore, rearing rooms, tools and other utensils should previously be cleaned and washed to remove the pebrine diseased eggs, carcases of infected larvae, pupae, moths and dead cocoons, faeces of diseased larvae and so on. The pebrine spores can be destroyed by treatment

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with 2% formalin for 30 minutes, 0.5% sublimate for 5 minutes, 5% chlorinated lime for 30 minutes, current steam for 30 minutes and sun shine in the summer for 7 hours.

4. Care on rearing silkworms. The tendency of the infestation by the pebrine spores has been observed to occur more when silkworms are reared in dry and cool conditions than in the hot and wet conditions. If the larval period becomes longer, the infection of pebrine is severe, so care should be taken on these points during the course of selection of the seed cocoons by the rearers.

[III] Polyhedrosis in silkworms

Three types of polyhedrosis are found in silkworms.

(1) Nuclear polyhedrosis.
(2) Intestinal cytoplasmic polyhedrosis.
(3) Intestinal nuclear polyhedrosis.

1. Nuclear polyhedrosis (Grasserie, Jaundice). It is caused by a kind of virus which forms polyhedra in the nuclei of the cells of fatty tissues, dermal tissues, muscles, tracheal membranes, basement membrane, epithelial cells of midgut and blood corpuscles. The polyhedra are commonly hexagonal and rarely tetragonal in shape, containing large number of virus in them. The polyhedra form the white pus after they are released into the body fluid. The virus present inside the polyhedra maintains its pathogenic power for a number of years in the rearing room but the isolated virus loses its pathogenic power in a period of short time.

The larvae infected by this virus become inactive and lose appetite, and the membrane between segments swell up. Further, the whole body swell up showing the loose skin. In the last phase of the disease the body becomes purulent and the skin becomes tender from which pus leaks out. The larvae in this phase crawl around up and down and finally die. The infection of grasserie occurs through the mouth of the larvae, the wounds of skin and induction under extremely adverse conditions (cold treatment, heat treatment, chemical treatment).

Countermeasures. (1) The rearing rooms, tools and utensils should be washed, cleaned and disinfected.

(2) The highly nutritive mulberry leaves should be given sufficiently to the infant larvae. The fresh air should be circulated in the rearing room especially in fifth stadium.
(3) The high temperature, low temperature and high moisture content should be avoided especially during the infant stages to maintain good health.
(4) The diseased larvae or dead bodies should be removed and the room disinfected completely by 2% formalin.
(5) The silkworms should be reared carefully, so that they may not suffer from the wound of skin.

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2. Intestinal cytoplasmic polyhedrosis. This type of polyhedra are formed in the cytoplasm of midgut cells but in a few cases they are formed in the goblet, too. The polyhedra of this disease contains plenty of virus. The infected cells of midgut rupture and polyhedra are released into the gut. Thus the faeces, excreted becomes whitish, containing plenty of polyhedra.

The symptoms of this disease are the occurrence of translucent cephalothorax and shrinkage of body size but in the advanced phase the larvae excrete white coloured loose faeces. The body fluid of the diseased larvae remains in the normal condition.

The mode of infection of this disease and countermeasures are similar to those of the nuclear polyhedrosis.

3. Intestinal nuclear polyhedrosis. In this disease the virus makes polyhedra inside the cytoplasm and nucleus of the midgut cylindrical cells. The polyhedra formed in this disease are large sized. The translucent cephalothorax, shrinkage of body and diarrhoea are the symptoms of this disease also. The mode of infection and countermeasures are similar to those of nuclear polyhedrosis.

[IV] Flacherie

Flacherie is the genetic name of some kinds of silkworm diseases, carcases of which rot due to the attack of bacteria. Flacherie may be divided as follows :

1. Infectious flacherie caused by a kind of virus. The various symptoms of flacherie are loss of appetite, translucent cephalothorax, vomiting and diarrhoea but the real diagnosis can be made after the microscopic observation of the virus.

The pathogen of this disease is a spherical virus which does not form polyhedra in the body of silkworm larvae. The virus multiplies in the tissues of midgut and is released into the gastric juice and is excreted alongwith faeces which is the source of infection. The virus infects the larvae of silkworm orally.

Countermeasures. (1) Resistant silkworm races should be selected.

(2) The rearing room, tools and utensils should be well disinfected.

(3) In order to maintain the good health of silkworm, high quality mulberry leaves should be provided.

(4) Favourable conditions like temperature and humidity should be maintained in rearing rooms.

(5) The faeces, diseased larvae and dead bodies should be piled in the compost.

(6) Some of the chemicals like hydrochloric acid, formalin, chlorinated lime may be used as disinfectants for this virus.

2. Gastric injury caused by physiological disturbance of silkworms followed by the multiplication of bacteria. Due to the supply of bad quality of mulberry leaves the digestive physiology of the silkworm is disturbed and multiplication of bacteria in the gastric cavity takes place. Thus, the combined

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action of physiological disturbances and bacterial activity in the gut are major causes of this disease. In unfavourable climatic conditions, the bacteria like *Streptococci* sp. *Coli aerogenous bacilli* or proteus group bacilli attack the weakened silkworms.

The control measures against this disease is to keep healthy conditions of rearing silkworms.

3. Bacterial intoxication. This disease is caused by a toxin of some bacilli, *Bacillus thuringiensis* Var. The larvae attacked by this toxin become unconscious, later soften, become darkish and finally rot off. The infection occurs orally and can retain the toxicity as long as for seven years in some cases.

The countermeasures are the disinfection of the rearing room and instruments.

4. Septicaemia. This disease is caused by infection of some bacteria as *Bacillus megatherium, B. proteus, B. prodigiosus, B. pyocyones* in the blood of silkworms. This disease is rare in the larval stage but it causes severe damage to the pupae and the moths during the period of egg production. The infection is caused through the wounds on the skin.

Countermeasures. (1) The rearing tools and rearing houses should be kept sterilized.

(2) The diseased cases should be kept away and put into the fermenting compost.

(3) During the period of egg laying the temperature and humidity of the room should be maintained in proper order specially at lower range of humidity.

[V] Green muscardine

It is a fungal disease of silkworms. There are a number of muscardine in silkworm but only green muscardine (*Spicaria prasina*) has been noticed to affect the larvae of silkworm in Vietnam.

The infection may be observed at the third and fourth stadia of silkworm. In the beginning stage a big black spot is observed on the ventral side.

The green-tubes of fungus develop into mycelia in the blood and bear cylindrical spores which are separated from mycelia and further form mycelia which bear cylindrical spores again. Thus, all the organs of silkworm are attacked by this fungus disturbing their normal functioning. As a result the diseased larvae do not moult and finally die.

Countermeasures. (1) The rearing room, tools and utensils should be disinfected.

(2) The diseased larvae and their faeces should be piled into compost to kill the germs.

(3) The rearing bed should be kept dry as much as possible to prevent the germination of conidia of fungus.

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Economic Importance of Silk

The raw silk is used in the manufacture of woven materials and the knitted fabrics for the preparation of garments, parachutes, parachute cords, fishing lines, sieve for flour mills, insulation coil for telephones and wireless receivers, and tyres of racing cars. Fabrics for garments in various weaves, plain, twill, stain, crepe, georgette and velvet, knitted goods such as vests, gloves, socks, stockings, dyed and printed ornamented fabrics for saries, jackets, shawls and wrappers are made out of this material.

Status of Sericulture Industry in India

At the root of the social, economic, cultural and political progress of India, there are 6.5 lacs villages where 75% of the population of the country lives. The real progress of our country is definitely on the development of these villages. For the economic independence of the villages it is most important to check the flow of ingenious people from the villages towards cities so that the villages also may get a chance for advancement and progress. Even today the main source of earning livelihood, in villages, is agriculture and agriculture based industry on which 70% of the population depends. Majority of the village population even today lives below poverty line. It is believed that small scale and cottage industries are only in small and under developed countries but this assumption is only partially correct because in developed countries like USA, Germany, France, Britain, Russia, Switzerland and Denmark cottage industries occupy a special importance in their economy. In such countries where there is derth of capital but ample labour power, small scale and cottage industries also have great importance. When we discuss the economic policy of India, one doubt always haunts our mind, wheather on the strength of small and cottage industries only, would it be possible for us to face the challenges in the international economic competition. Gandhi's economic philosophy provides solution to this doubt that small cottage industries and modern and large industrial units have to be free from mutual competition, then only, all round development of the nation can be possible.

In the back ground of the industrial growth of past few years and their popularity and distribution of cottage industries it is apparent that the silk industry has developed as a popular cottage industry in which all big, middle, marginal and small farmers in their own way in their limited resources can start silkworm rearing. Even the landless labours with the cooperation of farmers can get mulberry leaves and rear silkworms. This industry neither needs any large equipment, big capital nor specialized technical know how for its start. Although sericulture is practised in India since long even much before independence, yet because of more capital involved at that time and low quality production it could not achieve required success. In any region for achieving success in sericulture industry there are some basic factors which should be surveyed. It

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is most important to have additional knowledge of the climate, soil, previously developed small industry, if any, and economic and social structure of that region. In case the soil and the climate of the region is suitable for rearing of silkworms, proper arrangement for irrigation, availability of labour etc. have also to be thought of. In short it must be fully ascertained wheather this new industry of silkworm rearing would be definitely profitable in contrast to the traditional farming or other small and cottage industries, if any, prevelant in that region before embarking on this new project. The idea of the capital investment involved and the average income per acre should also be calculated so that the farmer be told that it would be profitable to them. If finally decided to undertake this venture then for selecting the race of silkworm for rearing, the climate, soil and irrigation facilities should again be kept in mind so that the rearers may not face any technical difficulty later on.

In the country due to the efforts of sericulture research and investigation cum training centres and other production programmes, there has been a good improvement in the production and quality both of the silk cloth during the last 25 years. In a number of regions new varities of mulberry with close spacing and proper instructions have proved to be much fruitful in some regions but a number of rearers are still unaware of the proper cultivation technique and use of fertilizers for the mulberry plants. By efforts of systematic researches it has been possible to improve the nutritive quality and growth of mulberry leaves from 15,000 to 35,000 kg per hectare. The new mulberry varieties K_2 and M_5 are giving 65% more yield than the local crop. Now some strains are capable of giving 100% increase in the yield of mulberry leaves. Sericulture research stations and grainages have evolved techniques for handling of young leaves easily with respect to temperature, humidity, quality, quantity and frequency of feeding, spacing, aeration and protection against diseases. A number of techniques have developed which has resulted in the improvement of the maintenance of silkworms.

Although India occupies second position after China in silk production yet the production in India is one fourth of the total production in China. The increasing demand of silk cloth in India and its decreasing production in Japan has placed China as the biggest market of silk in the world. The ever growing interest shown by Japan in the manufacture of electronic goods has left Japan much behind in silk production. Central Silk Board was established in 1949 in India and since then, through development and research plans, silk industry got a great encouragement. But in 1989, with the cooperation of 'World Bank', 'National Silk Project' has doubled in silk production in seven years and in the next five years the production may be still doubled from the present quantity. 85% of the silk cloth manufactured in India is utilized in the country itself. India imports raw silk for its industry from China. Out of the total silk cloth woven here, 65% is woven by handloom, 30% by powerloom and only 5% in mills by modern machine. In India the export quality of silk can only be produced

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by using threads manufactured by modern machines only. At present 3.5 lacs hactare of land is under mulberry cultivation in India. In Karnataka, Andhra Pradesh and Tamil Nadu the interest of the farmers in silk production is continuously increasing day by day. In the country to day silkworm rearing programme is providing whole time and part time employment to 75 lacs of people.

Distribution of silk industry in India

Of the 6.5 lac villages in India sericulture is practised in about 75,000 villages. The production of mulberry silk is confined to the five traditional states like Andhra Pradesh, Karnataka, Tamil Nadu, West Bengal and Jammu and Kashmir. Now it has also been initiated in other twelve states like, Kerala, Maharashtra, Bihar, Jharkhand, Madhya Pradesh, Chattis Garh, Orissa, Gujarat, Rajasthan, Punjab, Haryana, Uttar Pradesh, Uttaranchal, Assam and Himachal Pradesh and gaining success in some other states. The traditional states produce about 99% of the total mulberry raw silk in the country. The major production of tasar raw silk is achieved from Bihar, Jharkhand, Orissa, Madhya Pradesh, Chattis Garh, Andhra Pradesh and West Bengal, while Maharashtra and Uttar Pradesh are producing tasar raw silk on a small scale. The eri raw silk production is being achieved from major eri silk producing states like Assam, Bihar, Jharkhand, Meghalaya and Manipur while it is also produced in Arunanchal, Mizoram, Tripura, Nagaland and Orissa at small scale. Manipur, Nagaland, Mizoram and Arunachal Pradesh are the oak tasar silk producing states. The production of muga silk is mostly confined to the states of Assam but now-a-days this silk is also produced in Mizoram, Meghalaya and Nagaland.

National sericulture project (NSP)

For the rapid development of mulberry sericulture industry in India, a five year programme. 'National Sericulture Project' of Rs. 555 crore was launched in 1989 by the World Bank and the Swiss Development Corporation under the supervision of Central Silk Board. This project was implemented by the department of sericulture in five traditional mulberry silk producing states like, Andhra Pradesh, Karnataka, Tamil Nadu, West Bengal and Jammu and Kashmir. Twelve pilot projects in the 12 states like, Assam, Bihar, Jharkhand, Gujarat, Kerala, Haryana, Himachal Pradesh, Madhya Pradesh, Chattis Garh, Uttar Pradesh, Uttaranchal, Punjab, Maharashtra, Rajasthan and Orissa were implemented by the Central Silk Board to create additional facilities for the silkworm seed production, training, maintenance of germplasm and extention programmes as well as research and Development facilities.

The broad objective of NSP was the introduction of mulberry sericulture in non-mulberry silk states, and expansion of this industry in mulberry silk producing states. The other important objectives of this project were generating employment opportunities for an additional one million people, increasing raw

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silk production, improving quality of silk produced, strengthening the infrastructure for research, extension, seed production, silk processing and development of market support for raw silk and cocoons. In addition to the above objectives the financial support to rearers, reelers and twisters, increased participation of private sectors, involvement of Non-Governmental Organisations and improved participation of women were also the priorities of NSP.

The specification of National Sericulture Project in Traditional and Pilot states was of different nature on the policy as well as application level. In traditional states the main thrust was towards consolidating the status of progress already achieved by strengthening the existing infrastructure and by providing additional facilities for further expansion. The development of water management technique, evolvement of rainfed technology for mulberry, promotion of smokeless chulhas in reeling units, establishment of grainage, basic seed farms, quality control measures, women welfare and sound Research and Development facilities were the main features of NSP. The Central Silk Board has strengthened the already existing research facilities at various centres like Central Sericulture Research and Training Institute (CSR and TI) Berhampore, Central Sericultural Research and Training Institute (CSR and TI) Mysore, Central Silk Technological Research Institute (CSTRI) Bangalore and a number of Regional Sericulture Research Station (RSRS). Central Silk Board has also established three new research institutes like Seribiotechnology Laboratory (SBL), Silkworm Seed Technological Laboratory (SSTL) and Silkworm and Mulberry Germplasm Station (SMGS) during the tenure of NSP in traditional states.

Before the launching of the NSP in 1989 mulberry sericulture was already growing in small pockets of some non-traditional NSP states like Uttar Pradesh, Uttaranchal, Bihar, Jharkhand, Assam, Orissa and the North- East but no integrated developmental effort were taking place in absence of infrastructural facilities. The pilot projects of CSB under NSP in pilot states provided comprehensive packages right from basic seed production to the yarn production. The CSB has invested Rs. 660 million in non traditional states from 1989 to 1994. The pilot activities were restricted to one district (in some cases more) in each non-traditional state to ensure the achievement of the target. The district taken under pilot project were Akola and Buldana (Maharashtra); Ambala (Haryana), Bastar (Chattisgarh); Dehradun (Uttaranchal) and Saharanpur (Uttar Pradesh); Hoshiarpur (Punjab), Jorhat and Sibsagar (Assam); Koraput (Orissa), Palakkad and Idukki (Kerala); Purnea, Kishanganj and Araria (Bihar); Solan (Himachal Pradesh); Surat and Valsad (Gujarat) and Udaipur and Banswara (Rajasthan).

Sericulture industry and women welfare

It is a reality that spite of all efforts the status of women in the industrial sector is not significant because there are so many constraints for a women to participate freely in the industrial activities. Sericulture is such an agro-based cottage industry in which there is involvement of interdependent rural, semi-urban and urban

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based activities in which the estimated participation of women is about 60 per cent. Thus, in contrast to other agro-based profession the role of women in sericulture industry is dominating which will be helpful for improving the status of women in family enterprises. In the light of women welfare through sericulture industry the Central Silk Board has established a special component of 'Assistance to Women and NGO's' into the National Sericulture Project. For the women welfare sericulture should lead to formulate positive additions to rural women's awareness, participation in decision making and proportional control over resources and income. For achieving improved status and recognition of their value and importance to household, community and society as a whole, group formation should be encouraged among the women involved in sericulture industry.

Central Silk Board (CSB)

Central Silk Board, a statutory organisation under the administrative control of the Ministry of Textiles, Government of India, was constituted in 1949 under an act of the Parliament. After its constitution, Central Silk Board has taken overall responsibility for the intensive development of growing sericulture industry in India. The Board is constituted by 36 members including the Chairman, Vice-Chairman, Member Secretary, representative of both the Houses of Parliament, Central and State Government's nominees, Rearers, Reelers, the Trade and Industry. The head quarter of CSB is in Bangalore.

Functions of Central Silk Board. (1) Proper development of sericulture industry in the country through promoting necessary measures.

(2) To promote and encourage scientific, technological and economic research for further advancement of sericulture industry.

(3) To develop healthy silkworm seed and ensure their proper distribution.

(4) To devise advanced means for the improvement of mulberry cultivation, silkworm rearing, reeling of silk and spinning.

(5) To search and establish the means of standardisation and quality control of silk and silk products.

(6) To stabilise the prices of silk cocoon and raw silk, and rationalise the marketing.

(7) To collect the statistics regarding sericulture industry.

(8) To prepare and furnish the relevant reports on sericulture to the Central Government.

(9) To give proposal and advise to the Central Government for the intensive development of sericulture industry in the country.

Co-ordination of Central Silk Board with states. Being a state subject in the concurrent list, the schemes for the proper development of sericulture industry are formulated and implemented by State Governments. For performing this work, additional money is allocated to the State Governments on the basis of the annual plans approved by the planning Commission. Besides coordinating the sericulture developmental activities in states and advising the Central

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Government in policy making programmes, the CSB is also directly concerned with the sericulture research activities, sericulture Post Graduate Training programmes, basic seed production, distribution of raw silk, inspection of silk goods and standardisation and quality control.

The Central Silk Board has established 5 'Regional Offices' and 7 'Regional Development Offices' in different parts of the country. The Regional offices are Bangalore (Karnataka), Mumbai (Maharashtra), Kolkata (West Bangal), New Delhi (Delhi) and Srinagar (Jammu and Kashmir). The Regional Development offices are Bhubaneswar (Orissa), Guwahati (Assam), Hyderabad (Andhra Pradesh), Lucknow (Uttar Pradesh), Chennai (Tamil Nadu), Maheshmati (West Bengal) and Patna (Bihar). Special attention for promoting sericultural programmes in North-eastern region has been paid by CSB and an office of the Director (NE) is functioning at Dispur in Assam.

Silk development and research

Though the sericulture is one of the ancient industries in India yet it remained inadequate from technological know how and productivity. The establishment of Central Silk Board in 1949 has been proved to be the backbone for developing sericulture industry in India which is providing the much needed research and developmental support to this growing industry. Within the span of five decades the achievement of CSB is encouraging particularly in the field of research and training programmes. To meet this requirement 'Central Sericultural Research and Training Institute was established in Mysore in 1962. Further, the status of Central Sericultural Research Station, Berhampore, established in 1943, was upgraded into a research institute. In 1972 the Regional Tasar Research Station on Temperate Oak Tasar came into existence. The state research stations were taken over by the CSB and two Regional Research Stations were established at Titabar and Majra. The establishment of International Centre for Training and Research in Tropical Sericulture (ICT RETS) in Mysore initiated international cooperation in sericulture development. For conducting research on silk reeling, spinning, weaving and processing of silk the first institute of its kind in the world, Central Silk Technological Research Institute,' was set up in Bangalore in 1983. There is a wide network of extension centres carrying extensive work for the transfer of sericulture technology from lab to land through out the country. Now a days a number of Research Institutes and Regional Research stations are actively engaged in sericulture research activities. The list of these institutes and stations is as under :

Silk--Research Institutes

(1) Central Sericultural Research and Training Institute (CSR and TI) Mysore (Karnataka).
(2) Central Sericultural Research and Training Institute (CSR and TI) Berhampore (West Bengal).

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(3) Central Tasar Research and Training Institute (CTR and TI) Ranchi (Jharkhand).
(4) Central Silk Technological Research Institute (CSTRI) Bangalore (Karnataka).

Regional Silk-Research Stations

A number of Research Centres have been established in different parts of the country for carrying out research in mulberry, oak tasar, muga and eri silk :

Mulberry Silk-Research Station

(1) Bangalore (Karnataka)
(2) Chamaraj Nagar (Karnataka)
(3) Salem (Tamil Nadu)
(4) Coonoor (Tamil Nadu)
(5) Kalimpong (West Bengal)
(6) Dhule (Maharashtra)
(7) Pampore (Kashmir)
(8) Anantpur (Andhra Pradesh)
(9) Jorhat (Assam)
(10) Ranchi (Jharkhand)
(11) Koraput (Orissa)
(12) Mothabari (West Bengal)
(13) Majra (Uttaranchal)

Oak Tasar Silk Research Station

(1) Batote (Jammu and Kashmir)
(2) Bhimtal (Uttar Pradesh)
(3) Imphal (Manipur)

Muga Silk Research Station

(1) Boko (Assam)

Eri Silk Research Station

(1) Mendipathar (Meghalaya).

IMPORTANT QUESTIONS

» ***Long answer type questions***

1. Give an account of the species of silkworm and also mention the life history of *Bombyx mori*.
2. Give an account of the rearing of mulberry silkworm.
3. Describe the status of sericulture industry in India.
4. Write an eassay on the diseases of silkworm.

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» ***Short answer type questions***

1. Give an account of the supply of seed to rearers for commercial rearing.
2. Illustrate post cocoon processing in sericulture industry.
3. Write short account of flacherie or maggot disease of silkworm.
4. Write short account of Pebrine or Polyhydrosis in silkworm.
5. Mention about Central Silk Board and its function.
6. Commence about National Sericulture Project.

» ***Very short answer type questions***

1. Illustrate the spinning of cocoon by silkworm.
2. Define stifling in sericulture industry.
3. What is raw silk ?
4. What is silk ?
5. Commence on the economic importance of silk.

» ***Objective type questions***

1. The common name of *Attacus ricinii* is :
   (a) Tasar silkworm (b) Muga silkworm (c) Eri silkworm (d) Giant silkworm
2. The common name of *Antheraea paphia* is :
   (a) Muga silkworm (b) Eri silkworm (c) Oak silkworm (d) Tasar silkworm
3. Which of the following silk is produced only in India ?
   (a) Muga silk (b) Eri silk (c) Tasar silk (d) Oak silk
4. The term uni Voltine/Bivoltine is related with :
   (a) Apiculture industry (b) Sericulture Industry
   (c) Lac industry (d) Fish culture industry
5. Single female of *Bombyx mori* may lays about :
   (a) 400 eggs (b) 200 eggs (c) 100 eggs (d) 50 eggs
6. The weight of newly laid 200 eggs of *Bombyx mori* comes to about :
   (a) 1 gm (b) 2 gm (c) 3 gm (d) 4 gm
7. How many moultings ocur in larvae to attain the final instar stage in *Bombyx mori* ?
   (a) Three (b) Four (c) Five (d) Six
8. The length of silk thread secreted by single caterpillar of *Bombyx mori* is about :
   (a) 1000 metre (b) 2000 metre (c) 3000 metre (d) 4000 metre
9. One pound of mulberry silk can be obtained from :
   (a) 1000 cocoon (b) 1500 cocoon (c) 2000 cocoon (d) 2500 cocoon
10. In *Bombyx mori,* the weight of single cocoon may be about :
    (a) 1 gm (b) 2 gm (c) 3 gm (d) 4 gm
11. In **Bombyx mori,** the weight of single cocoon shell may be about :
    (a) 0·5 gm (b) 1·0 gm (c) 1·5 gm (d) 2·0 gm
12. The maximum number of cocoons cut by single Nagahara machine is about :
    (a) 2,000-5,000 (b) 5,000-10,000 (c) 10,000-15,000 (d) 20,000-25,000
13. The maximum number of eggs laid by one female of *Bombyx mori* is about :
    (a) 200 (b) 300 (c) 450 (d) 600
14. Stifling is related with :
    (a) Sericulture (b) Apiculture (c) Lac culture (d) Fish culture

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15. Silk is :
(a) Animal fat (b) Carbohydrate (c) Animal protein (d) Phospholipid

16. Which of the following statement is correct ?
(a) Only fibroin is found in silk. (b) Only sericin is found in silk.
(c) Fibroin and sericin is found in silk.
(d) Silk is secreted through mouth during spinning in *Bombyx mori.*

17. The elasticity found in silk fibre is about :
(a) 5% (b) 10% (c) 20% (d) 30%

18. Pebrin is caused by :
(a) *Tricholyga sorbillans* (b) *Bacillus megatherium*
(c) *Spicaria prasina* (d) *Nosema bombycis*

19. Head quarter of Central Silk Board is :
(a) New Delhi (b) Bangalore (c) Chennai (d) Kolkata

20. Central Silk Board was established in :
(a) 1847 (b) 1949 (c) 1955 (d) 1960

Answers

1. (c)	2. (d)	3. (a)	4. (b)	5. (a)	6. (a)	7. (b)	8. (a)	9. (d)	10. (b)
11. (a)	12. (c)	13. (c)	14. (a)	15. (c)	16. (c)	17. (c)	18. (d)	19. (b)	20. (b)

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9

Edible Fresh Water Fishes

From pre-historic period fishes have been used as protein-rich diet for human beings. The popularity of fishes has been mentioned in our religious books like Ramayan and Mahabharat also. In West Bengal, Bihar, Jharkhand, and Orissa, the fish industry is about 1,500 years old. In Bengal every family traditionally has at least one pond for fishes. It is a blind belief that if fish, particularly *Labeo rohita* is offered in the Shradh ceremony (ceremony performed after death of persons) the dead person will certainly go to the Heaven. There is another view also that human race originated near the water reservoirs and the fishes might have attracted the human-beings. Fresh water fishes provide valuable source of food supply to the inhabitants of the countries located in tropical regions. In America, the fishes of Great Lakes are of considerable economic importance. Flesh of fish is a highly perishable commodity constiuted by 60-80% water and 13-20% protein and greater or lesser amount of fat. The flesh also contains phosphorus and vitamins.

It is notable that the fishes kept in simple pond start growing and breeding there. The importance of fishes may be examined from the following points of view :

(i) Is the fish suitable for fish culture ? (ii) Can it grow faster ? (iii) Can it attain good length and weight ? (iv) Can it provide nutritive and digestible food ? (v) Is it palatable ?

There are a number of freshwater fishes which are of much economic importance. Some common edible fresh water fishes are listed here.

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A. Major Carps

1. *Catla catla* (Ham.) 'Catla'

Class ..... Teleostomi
Order ..... Cypriniformes
Family ..... Cyprinidae
Genus ..... *Catla*
Species ..... *catla*

This fish is distributed throughout India. It attains maximum length of about 180 cm but is suitable for food when it is not more than 61 cm. Body is deep, stout with broad snout and mouth is large, provided with prominent lower lip and large gill apparatus. The colour is grayish on the dorsal side while silvery on the lateral side. Fins are dark and sometimes black also (Fig. 1).

Catla is one of the fastest growing fishes and largest carp which migrates towards rivers in plain regions in the breeding season *i.e.*, from June to August. After 16 to 18 hours of fertilization, larvae are hatched which are 4.4 to 5.3 mm in length. The young ones measure up to 15 to 20 cm in length and feed exclusively on water fleas. This can grow 7.5 to 10 cm per month and 2 pounds per year in weight. Catla is very strong fish and can jump over the fishing net when captured inside the net.

Fin Formula :

$D_{18-19\,(3/15-16)}$; P_9 ; V_9 ; $A_{8\,(3/5)}$; C_{19} Ll_{43} ; $Ltr_{7\frac{1}{2}/6\frac{1}{7}}$ B. One pair.

D-Dorsal fin. C-Lateral row of unperformed scales.
P-Pectoral fin. Ll-Lateral line of perforated scales.
V-Ventral fin. Ltr- Lateral transverse line.
A-Anal fin. B-Barbels. C-Caudal fin.

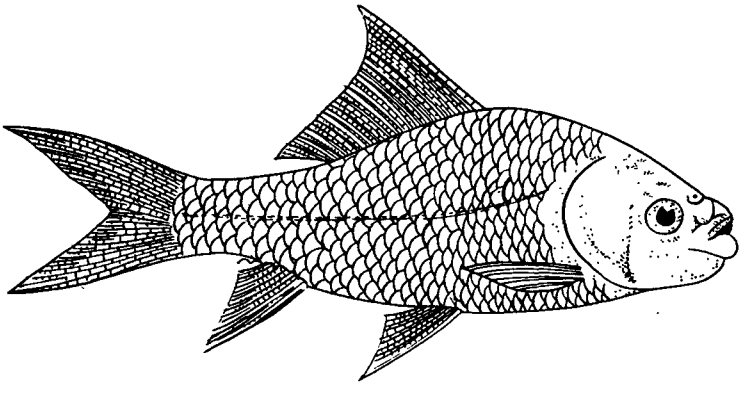

Fig. 1. *Catla catla.*

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2. *Labeo rohita* (Ham.) Rohu

Class ..... Teleostomi
Order ..... Cypriniformes
Family ..... Cyprinidae
Genus ..... *Labeo*
Species ..... *rohita*

This is famous and very valuable carp distributed in the plains of India except in the southern part. It attains a length of more than 90 cms. The body is elongated and bluish or brownish gray on the dorsal side. Snout projects bluntly with abruptly undershot mouth. The barbels are feebly developed, lips are thick with inner fold and the fins are gray, red or blackish (Fig. 2). It is pond and bottom feeder both and most suitable for pond culture. They can make easy dive in the water. The younger fries may feed on zooplankton, fleas etc. but adults are found to be vegetarian and feed upon the bottom sand, mud, vegetable leaves of aquatic plants, algae etc. It breeds in flooded river during monsoon period. Its fecundity is reported to be greater than that of Catla. Female lays about 2 million eggs at a time. Young ones may attain a length up to 45 cms and a weight of about 675 gm in one year. Fries may be transported over long distances with little mortality. It is distributed in Pakistan and Burma also.

Fin Formula :

$$D_{16\,(3/13)} ; P_{17} ; V_9 ; A_{7\,(2/5)} ; C_{19} ; Ll_{40-41} ; Ltr_{6\frac{1}{2}-7\frac{19}{2}} ; B-1 \text{ pair.}$$

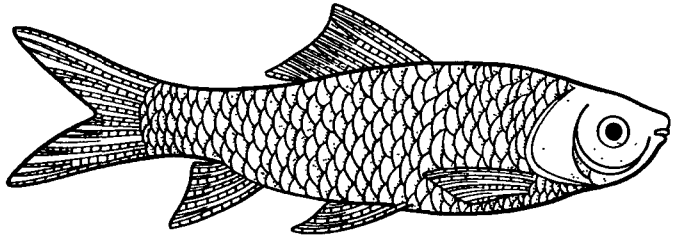

Fig. 2. *Labeo rohita.*

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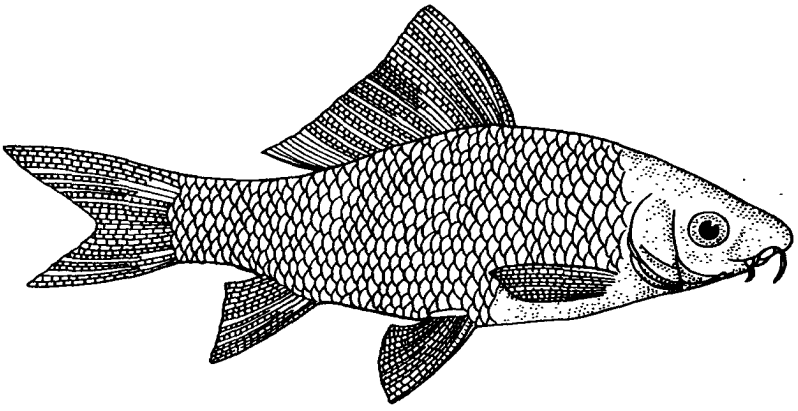

Fig. 3. *Labeo calbasu.*

3. *Labeo calbasu* (Ham.) Calbasu

Class ..... Teleostomi
Order ..... Cypriniformes
Family ..... Cyprinidae
Genus ..... *Labeo*
Species ..... *calbasu*

It is an excellent food fish distributed in the rivers of Punjab, West Bengal, Orissa and part of South India. They are found in large number and are also available in the ponds alongwith catla and rohu. Body is deep, stout with rather long conical head. The presence of elongated barbels and special pigmentation in the cone is characteristic feature of this fish. Maximum length recorded for this fish is 91 cms but commonly in a well maintained pond they can grow up 25 to 30 cms in length per year and attain a length of 42 cm (Fig. 3). The main food of this fish is snail, worms, bottom algae etc. It breeds during monsoon period like catla and rohu. This fish is also found in Burma and Pakistan.

Fin Formula :

$D_{17\,(3/14)}$; P_{19} ; V_9 ; $A_{7\,(2/5)}$; C_{19} ; Ll_{41} ; $Ltr_{(7\frac{1}{2}-8)}$; B. 2 pairs.

4. *Labeo gonius* (Ham.) Cursa

Class ..... Teleostomi
Order ..... Cypriniformes
Family ..... Cyprinidae
Genus ..... *Labeo*
Species ..... *gonius*

This is found in the fresh water of North India, Assam and Orissa along the east coast up to Krishna. It is regarded to be a food carp because of its better

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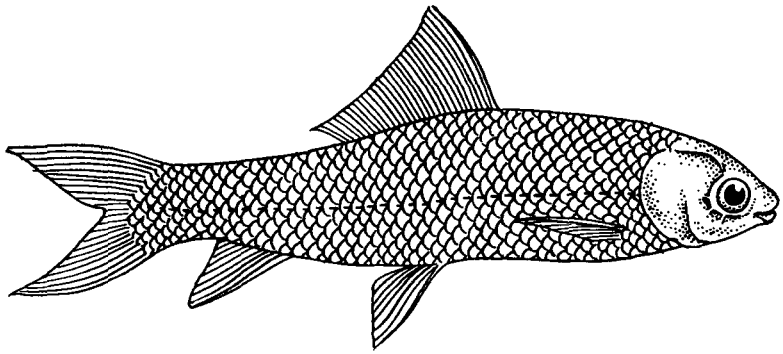

Fig. 4. *Labeo gonius*.

taste. The dorsal side of the body is grayish in colour while the ventral side has lighter colour. Scales are smaller provided with dark margins and the lips are pronounced and thicker (Fig. 4). The feeding habit is the same as of Rohu and the food consists of vegetable matter, organic debris, planktonic algae etc. The breeding season of this fish is monsoon period.

Fin Formula :

$D_{16\,(3/13)}$; P_{17} ; V_9 ; $A_{7\,(2/5)}$; C_{19} ; Li_{74} ; $Ltr_{16/17}$; B. 2 pairs.

5. *Cirrhinus mrigala* (Ham.). Mrigala

Class ..... Teleostomi
Order ..... Cypriniformes
Family ..... Cyprinidae
Genus ..... *Cirrhinus*
Species ..... *mrigala*

This is mainly found in fresh water or Northern India, Punjab, West Bengal and Orissa. This carp resembles very much with *Labeo rohita* except that it has wider mouth and thinner lips. Body is dark gray on the dorsal side while orange coloured on the ventral side. The maximum length attained by this carp is about 90 to 100 cm and the growth of about 20 cm is recorded in 8 months. This growth data is based on an experiment conducted on 6,000 fingerlings (Fig. 5). The young ones have similar feeding habits as Catla and Rohu but fingerlings and adults feed on the huge amount of decaying organisms. Major food consists of sand, mud, algae and decaying vegetations. The males attain maturity after

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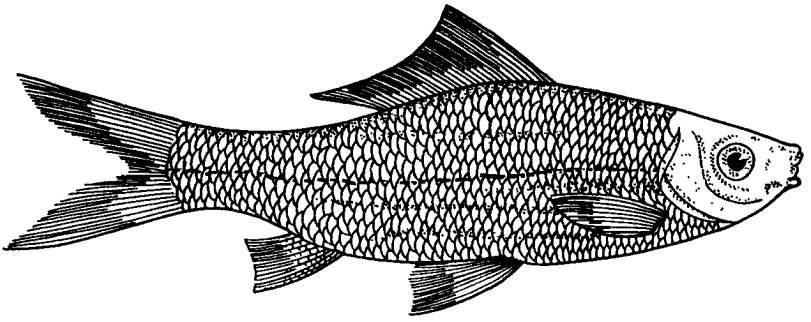

Fig. 5. *Cirrhinus mrigala.*

one year while the females mature before compilation of one year age. Breeding takes place in flooded rivers during July to September.

Fin formula :

$D_{16\,(3/13)}$; P_{18} ; V_9 ; $A_{8\,(2/6)}$; C_{15} ; Ll_{42-44} ; $Ltr\ {}^{6\frac{1}{2}}/_{6\frac{1}{2}}$ B. 1 pair.

6. *Cirrhinus reba* (Ham.) *Reba*

Class ..... Teleostomi
Order ..... Cypriniformes
Family ..... Cyprinidae
Genus ..... *Cirrhinus*
Species ..... *reba*

It is distributed throughout India and is quickly identified by hexagonal scales, dark pigmentation and small tapering head. The male is small than the female and may attain maximum length of 30 cms (Fig. 6). The young ones feed on

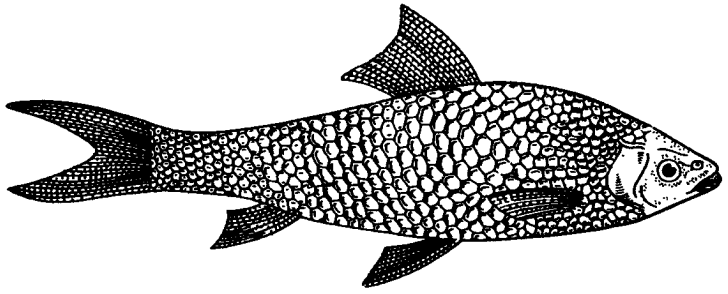

Fig. 6. *Cirrhinus reba.*

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zooplanktons and grow faster than fries of Catla. The adult Reba mainly (60%) feeds on planktonic algae but sand, debris, mud and vegetation etc., also constitute the food of this fish.

Breeding occurs in flooded marginal shallow waters in June to September. The larvae emerge after 14 to 15 hours of fertilization and may take 14 to 15 weeks to attain adult stage. Fries are collected for stocking in ponds and even in the seasonal waters due to its quick growth.

Fin Formula :

$D_{11\,(2/9)}$; P_{16} ; V_9 ; $A_{8\,(2/6)}$; C_{19} ; Ll_{36-37} ; $Ltr_{7/5}$; B 1 pair.

B. Cat Fishes

The cat fishes are provided with very small eyes and well developed barbels by which they make a good vision and find their way. This is why they are called as 'Cat fishes.' They are of good nutritive value and utilize less quantity of oxygen so have more haemoglobin in the bood.

1. *Wallago attu* (Schn.) Parhin

Class ..... Teleostomi
Order ..... Cypriniformes
Family ..... Siluridae
Genus ..... *Wallago*
Species ..... *attu*

These fishes are distributed in lakes and rivers all over India and are commonly known as fresh water sharks. This is one of the largest fresh water cat fishes and attains a maximum length of about 183 cm but is usually 61 to 91 cm long (Fig. 7). This species is good for eating and also a good game fish. *Wallago* is

Fig. 7. *Wallago attu.*

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predatory in nature so causes extra destruction to young carps in stocking ponds. They are provided with large mouth and sharp teeth helpful for predatory action. They feed on human and other caracases also. Breeding takes place in rainy season. They are found in fresh water in India, Pakistan, Burma, Jawa, Sumatra and Indonesia.

Fin formula :

D_5 ; $P_{1/14}$; V_{10} ; $A_{86\,(4/82)}$; C_{17} ; B. 2 pairs

2. *Mystus seenghala* (Sykes) Tengra

Class ..... Teleostomi
Order ..... Cypriniformes
Family ..... Bagridae
Genus ..... *Mystus*
Species ..... *seenghala*

This fish is found in riverine system like Ganges and Jamuna and also inhabits small reservoirs. Body is brownish on the dorsal surface and silvery on lateral sides. The fish is predatory on small carps, other fishes and prawns. When matured, it attains a length of about 46 cm. Tengra can attain maximum length of 117 cm and weight of 11 kg (Fig. 8). They are also observed to be feeding on some insects, larvae, crustaceans, aquatic weeds etc. It breeds in the river and ponds and the breeding season is April to July. The breeding of this fish is peculiar *i.e.*, they score around and lay eggs in excavated portions and the eggs are guarded by them.

Fin formula :

$D_{1/7/0}$; $P_{1/9}$; V_6 ; $A_{11-12\,(3/8-9)}$; C_{19-21} ; B4 pairs

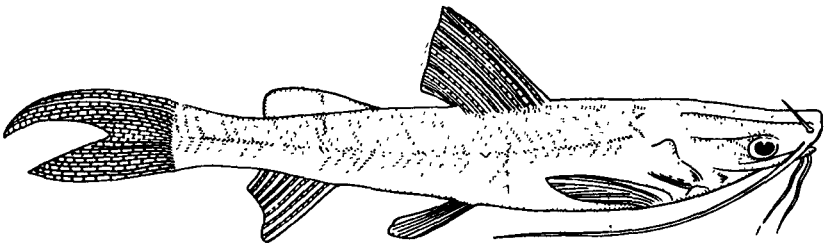

Fig. 8. *Mystus seenghala.*

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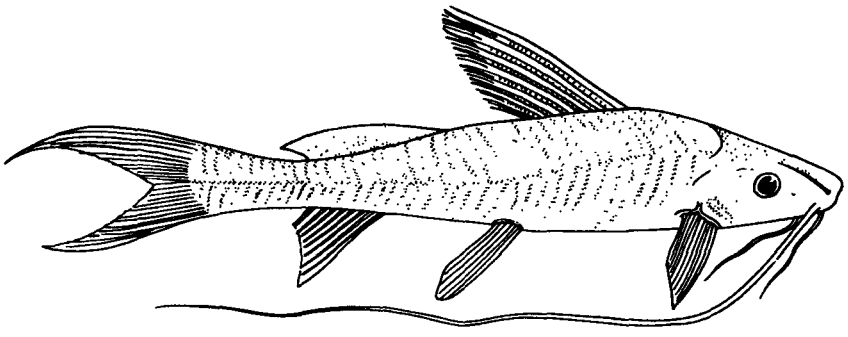

Fig. 9. *Mystus aor.*

3. *Mystus aor* (Ham.) Dariai tengar

Class ..... Teleostomi
Order ..... Cypriniformes
Family ..... Bagridae
Genus ..... *Mystus*
Species ..... *aor*

This fish is widely distributed and eaten locally. The body is bluish-gray dorsally and white on the ventral side. It attains a maximum length up to 91 cm. The ventral surface in the male gets inflammed and is thrown into vascular folds during the breeding season. Villiform process secretes a white proteinous fluid which nourishes the young. The female partner never takes part in the parental care of young ones (Fig. 9).

Fin formula :

$D_{1/7/0}$; $P_{1/10}$; V_6 ; $A_{13\,(3/10)}$; C_{17} ; B4 pairs

4. *Mystus cavasius* (Ham.) Sutahawa tengara

Class ..... Teleostomi
Order ..... Cypriniformes
Family ..... Bagridae
Genus ..... *Mystus*
Species ..... *cavasius*

This is very common fish in fresh waters throughout India (Fig.10). This is lead coloured on the dorsal and yellow on the ventral surface. This attains maximum length up to 46 cm. This fish is widely used and is an esteemed food for human beings.

Fin formula :

$D_{1/7/9}$; $P_{1/9}$; V_6 ; $A_{11\,(3-4/7-8)}$; C_{16} ; B 4 pairs

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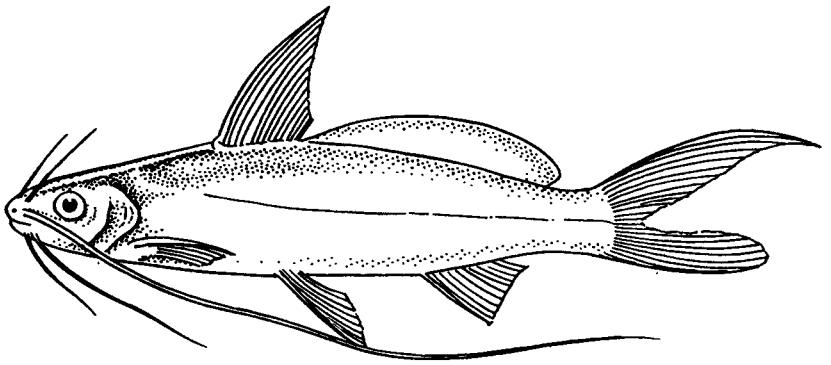

Fig. 10. *Mystus cavasius.*

5. *Pangasius pangasius* (Ham.) Payas

Class ..... Teleostomi
Order ..... Cypriniformes
Family ..... Schibeidae
Genus ..... *Pangasius*
Species ..... *pangasius*

This fish is widely distributed in big rivers and found generally near Bay of Bengal. The body is elongated and compressed and the head is covered with soft skin. It attains a maximum length of 122 cms (Fig. 11). Pangsa feeds partly upon young fishes *i.e.*, mostly on carps but the chief food of this fish is mollusc. Breeding season of this fish is monsoon. They are distributed throughout India, particularly in Rohini and Rapti rivers.

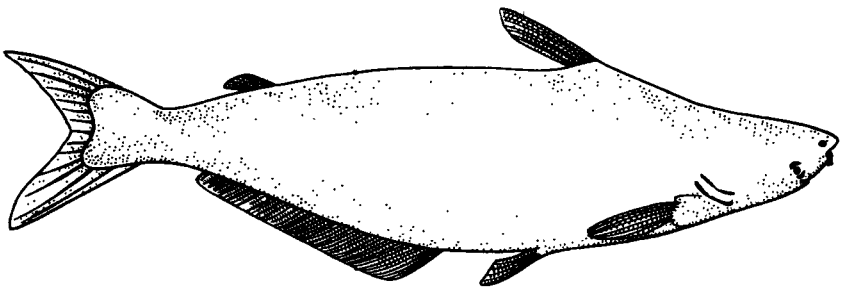

Fig. 11. *Pangasius pangasius.*

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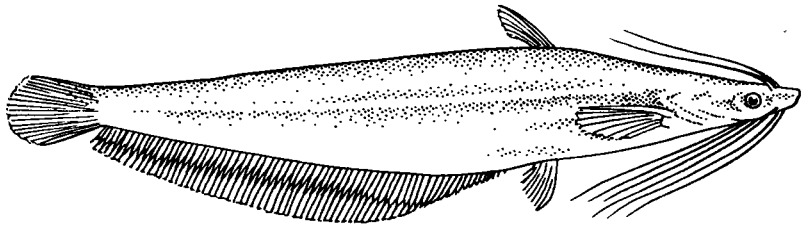

Fig. 12. *Heteropneustes fossilis.*

6. *Heteropneustes fossilis* (Bl.) Singhi

Class ..... Toleostomi
Order ..... Cypriniformes
Family ..... Heteropneustidae
Genus ..... *Heteropneustes*
Species ..... *fossilis*

This is a common cat fish, possessing accessory respiratory organs so also considered in 'live fishes.' They are found in fresh waters throughout India. The head is flattened wide and usually 30 cm long. The pectoral spines of this fish are poisonous (Fig. 12). They are predatory in nature but not piscivorous. The main food of this fish consists of insects, worms, algae, fish-remains and mud. The breeding season of this fish is from April to June.

Fin formula :

D_6 ; $P_{1/7}$; $_{1/2}$; V_6 ; A_{62-66} ; C_{19} ; B_4 pairs

7. *Clarias batrachus* (Linn.) Mangur

Class ..... Teleostomi
Order ..... Cypriniformes
Family ..... Clariidae
Genus ..... *Clarias*
Species ..... *batrachus*

This fish is found in fresh waters of plains throughout India. This is usually found in the mud but can survive independently on aquatic respiration. The body is elongated with laterally compressed head. The body colour is either uniformly reddish-brown or greyish black. It may attain a maximum length of 45 cm (Fig. 13). The chief food of this fish is prawn, aquatic insects, larvae, sand and algal filaments. Breeding season is from April to June. It is considered to be delicious fish so it is in great demand and fetches more price than carps.

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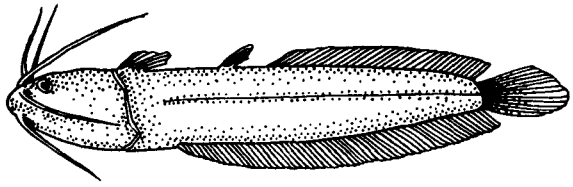

Fig. 13. *Clarias batrachus.*

It is also found in Sri Lanka, Malaya, Burma and other countries. Now-a-days it is widely used as experimental fish for biological studies on pituitary hormones.

Fin formula :

D_{65-70} ; $P_{1/8}$; V_6 ; A_{47} ; C_{17} ; B4 pairs

C. Live Fishes

1. *Channa punctatus* (Bl.) Gurrie

Class ..... Teleostomi
Order ..... Ophiocephaliformes
Family ..... Ophiocephalidae
Genus ..... *Channa*
Species ..... *punctatus*

The fish is found throughout the plains of India and Pakistan. They prefer to live in stagnant water. The colour of fish varies according to surrounding water. It may attain a length of 31 cm in plains but on hills it is only 11 cm (Fig. 14). The major food of this fish is aquatic insects, micro-organisms, small fishes, molluscs and shrimps. They are prolific breeder and the development is much rapid.

Fin Formula :

D_{29-30} ; P_{16-17} ; V_6 ; A_{20-22} ; C_{12} ; Ll_{35-37} ; $Ltr_{4-5/7}$

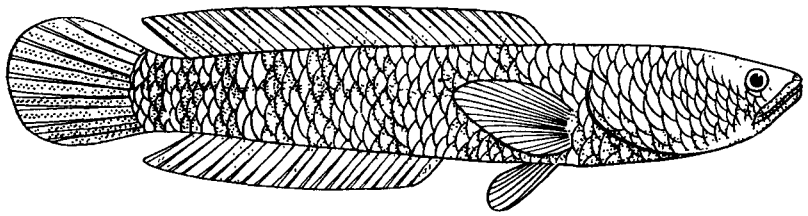

Fig. 14. *Channa punctatus.*

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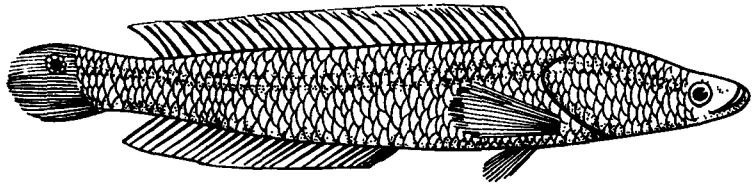

Fig. 15. *Channa marulius.*

2. *Channa marulius* (Ham.) Saul

Class ..... Telestomi
Order ..... Ophiocephaliformes
Family ..... Ophiocephalidae
Genus ..... *Channa*
Species ..... *marulius*

This fish is distributed in fresh waters of India, Pakistan, Sri Lanka and China. This fish prefers deep clean water with sandy or rocky bottom specially at the junctions of streams. This may be cultured in irrigation wells also in South India. They may attain a length up to 122 cm but are usually of 46 cm (Fig. 15). They prefer to feed on carps, kitchen refuse, frogs and dead animals. The fry can be safely transported by road with only a few changes of water. This is an esteemed food for human-beings. The breeding season is from April to June.

Fin formula :

D_{46} ; P_{18} ; V_6 ; A_{32} ; Ll_{65-66} ; $Ltr_{6/11}$

3. *Channa striatus* (Bl.) Sowra

Class ..... Teleostomi
Order ..... Ophiocephaliformes
Family ..... Ophiocephalidae
Genus ..... *Channa*
Species ..... *striatus*

This is found in the fresh waters of Uttar Pradesh, Punjab and South India. The body of this fish is darkbrown or black dorsally and yellowish or yellow from the ventral side (Fig. 16). They are main bulk of pond fishes. They always prefer stagnant, muddy waters and feed on worms, tadpoles, other fishes, insects, frogs and even on small snakes. After two years of age, females get matured and start breeding throughout the year in ponds but peak breeding is noticed in monsoon period. The highly developed fish may attain a length of about 90 cm. This fish is very economical and is more palatable even than Rohu and Catla both. Due to these reasons they are costly and in demand in markets.

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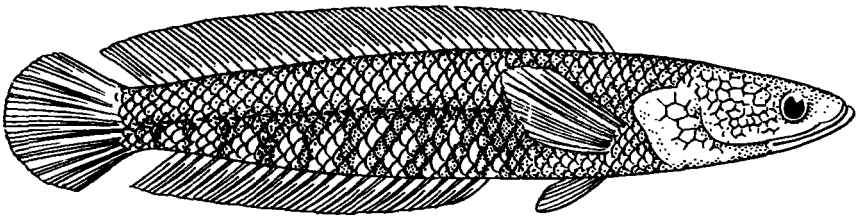

Fig. 16. *Channa striatus.*

Fin formula :

D_{41-43} ; P_{16-18} ; V_6 ; A_{24-25} ; C_{10} ; Ll_{58-60} ; $Ltr_{7/10}$

4. *Anabas testudineus* (Bl.) Anabas

Class ..... Teleostomi
Order ..... Perciformes
Family ..... Anabantidae
Genus ..... *Anabas*
Species ..... *testudineus*

This fish is found in estuaries and fresh waters of India and are costly and highly nutritive. The body of this fish is stout, almost cigar shaped, slightly compressed, with a wide head, and green or greenish brown in colour. They may attain a length of 26 cm (Fig. 17). This fish is carnivorous in nature and has been reported to leave the water in search of earthworms etc. for food. This fish can survive out of water in moist air for six days. The young ones are voracious feeders. It has a pleasing flavour and is very popular as food.

Fin formula :

$D_{17\,(9-10)}$; P_{15} $V_{1/5}$; A_{10-11} ; C_{17} ; LI_{29} ; $Ltr_{4/7}$

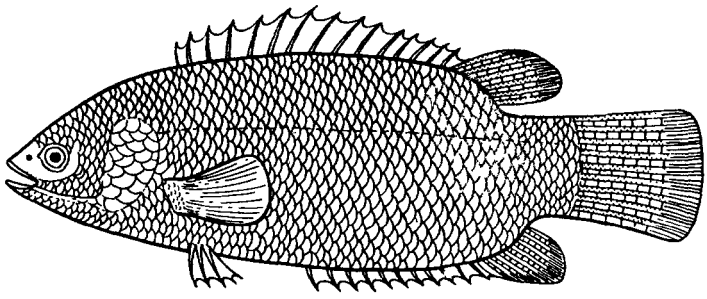

Fig. 17. *Anabas testudineus.*

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D. Other Fishes

1. *Notopterus chitala* (Ham.) Chital

Class ..... Teleostomi
Order ..... Clupeiformes
Family ..... Notopteridae
Genus ..... *Notopterus*
Species ..... *chitala*

This is feather back fish and is called as 'Moi'. This fish is recognised by deeply concave upper profile of head while dorsal profile is convex. The abdominal profile is straight. The body colour of the fish is coppery brown or grayish along narrow back, with 15 silvery transverse bars meeting across dorsal ridge. The snout is prominent (Fig. 18). The fish is mainly found in the rivers Ganges, Brahmaputra and Mahanadi. They may attain a maximum length of 122 cm but commonly are 26 cm in length. The flesh of this fish is also very much tasty. They lay their eggs which get attached to submerged objects.

Fin formula :

$D_{8\,(1/8)}$; P_{16} ; V_6 ; $A_{110-118}$; C_{18} ; $Ll_{160-180}$

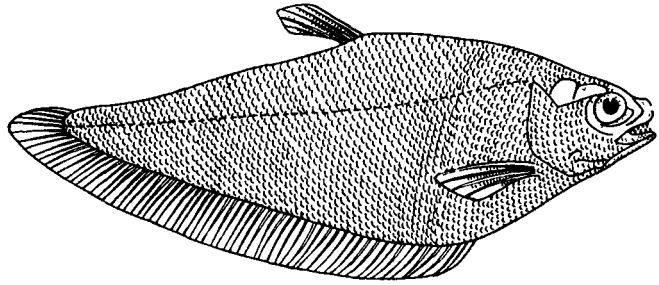

Fig. 18. *Notopterus chitala.*

2. *Mugil corsula* (Ham.) Mullet

Class ..... Teleostomi
Order ..... Mugilformes
Family ..... Mugilidae
Genus ..... *Mugil*
Species ..... *corsula*

This is commonly known as fresh water gray mullet. Buldging eyes are developed on the dorsal side. It swims on the surface in shallow waters keeping the eyes above the surface. The eye sight is very sharp (Fig. 19). They prefer to feed on mud, algae and sand but young ones are voracious feeders and feed on planktonic crustacean eggs etc. They can make good long jump and die rapidly.

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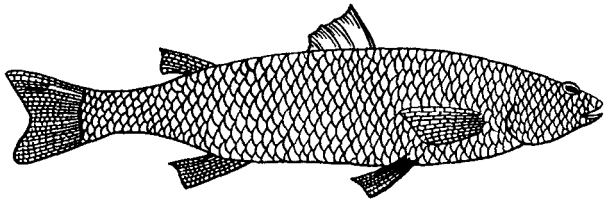

Fig. 19. *Mugil corsula.*

They are reported to be of common occurrence in Uttar Pradesh, Bihar, Bengal and Burma. It can attain a maximum length of 46 cm but are usually of 31 cm. The flesh of this fish is known to be an excellent food.

Fin formula :

$D_{4\,(1/8)}$; P_5 ; $V_{1/5}$; $A_{3/8-9}$; C_{15} ; L_{52} ; Ltr_{15}.

3. *Mastocembelus armatus* (Lac.) Baam

Class ..... Teleostomi
Order ..... Mastocembeliformes
Family ..... Mastocembelidae
Genus ..... *Mastocembelus*
Species ..... *armatus*

This fish is found in fresh and brackish waters in the plains and hills of India. Dorsally they are brown coloured while pale coloured from ventral surface. They can attain a maximum length of 61 cm. The flesh of this fish is very tasty for human food (Fig. 20).

Fin formula :

$D_{37-39/78-82}$; P_{23-25} ; $A_{3/75-78}$

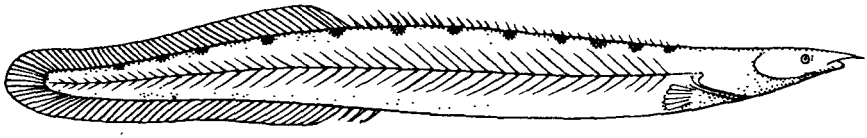

Fig. 20. *Mastocembelus armatus.*

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IMPORTANT QUESTIONS

» ***Long answer type questions***

1. Give short account of edible fresh water fishes in India.
2. Give detailed account of major carps of economic importance.
3. Mention about "cat fishes" and "live fishes" of economic importance.

» ***Short answer type questions***

1. Commence upon three species of *Labeo* useful as food for human consumption.
2. Commence upon two species of *Cirrhinus* useful as food for human consumption.
3. Describe in brief about different species of *Channa* useful as food for human beings.

» ***Very short answer type questions***

1. What are the main points to examine the suitability of culturable fish ?
2. What are the cat fishes ?

» ***Objective type questions***

1. *Catla catla* belongs to family :
   (a) Cyprinidae (b) Bagridae (c) Siluridae (d) Ophiocephalidae
2. Which of the following is Major carp ?
   (a) *Mystus seenghala* (b) *Catla catla*
   (c) *Wallago attu* (d) *Pangasius pangasius*
3. Which of the following is cat fish ?
   (a) *Labeo rohita* (b) *Cirrhinus reba*
   (c) *Channa punctatus* (d) *Wallago attu*
4. Which of the following is Live Fish ?
   (a) *Channa punctatus* (b) *Catla catla*
   (c) *Labeo rohita* (d) *Pangasius pangarius*
5. The common name of *Notopterus chitala* is :
   (a) Mullet (b) Sowra (c) Soul (d) Moi
6. Which of the following is not of the same group as rest three ?
   (a) *Channa punctatus* (b) *Anabas testudineus*
   (c) *Channa marulius* (d) *Labeo rohita*

Answers

1. (a) 2. (b) 3. (d) 4. (a) 5. (d) 6. (d)

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10

Fish Culture

In Country like India the intake of meat and milk is low, so fish has special importance as a supplement to ill-balanced cereal diets. Today protein deficiency is the world's most serious human malnutritional problem, and perhaps 30 to 40% of the world population is suffering from protein deficiency. It is estimated that about 10 million tons of fish is required annually to meet the present day demand of fish protein in the country against an annual production of only 3.5 million tons.

In India, inland water with potentialities of fish culture is approximately 7.5 million hectares or 2.34% of the total area of the country. Many of the water reservoirs remain either unused or not properly used for fish culture for want of proper scientific know-how. In recent years researches conducted by the Central Inland Fisheries Research Institute have revolutionised fish culture in India and a net production of 85,000 kg/hectare/year has already been achieved.

Evolution of Fish Culture

From ancient times man has utilized the ponds and kept fishes for their interest. Afterwards they started to use the fishes for food. It was a problem before them as how to increase the fishes in number and maintain them in ponds. Previously nothing was known about the environmental and physiological conditions of fishes hence the process of fish culture was unsuccessful. Thus the workers in their anxiety to know more about the fishes started to study the morphology, physiology, histology, habit and habitat of the fishes, and concluded that :

(1) Fishes are growing themselves.
(2) Fishes are breeding themselves.

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These findings proved to be keynote and encouraged them to think about the fish culture at commercial level. In India, first of all the fish culture was started in West Bengal. Now-a-days fish culture is expanding under the pressure of growing population in China, Indonesia, Vietnam, Africa, Cambodia. U.S.A. and also in India. The cultivation of a number of economically useful fish species, artificial fertilization, induced breeding etc. has opened a new era in the fish culture programme.

Aim of Fish Culture

(1) The main aim of fish culture is to obtain maximum yield of fish.
(2) To obtain palatable and highly nutritive fish flesh.
(3) By products of fishing industry.

Qualities of Culturable Fishes

The main attraction of fish culture is to obtain more fish. So, before starting this complicated programme it is essential to have a comprehensive idea about the fish itself. The culturable fishes,

(1) should have ability to feed on natural food.
(2) should have ability to feed on artificial diet.
(3) should consume small quantity of food for development.
(4) should be herbivorous in nature.
(5) should be able to tolerate a sudden change in climatic conditions and nature of water in ponds.
(6) should be fast growing and can attain good length and weight both.
(7) should live in ponds with other fishes without any disturbance.
(8) should be able to resist against diseases.
(9) should be prolific breeder.
(10) should be palatable and much nutritive.

Types of Cultivable Fishes

The cultivable fishes are of 3 types :

(1) Indigenous or native fresh water fishes *viz.*, major carps.
(2) Salt water fishes acclimatized for fresh water *viz.*, Chanos, Mullets.
(3) Exotic fishes, imported from other countries *viz.*, Mirror carp, Chinese carp, Crucian carp and Common carps.

Types of Culture in India

It is practically difficult to find all the characteristics of a culturable fish in any one of the fishes but some fishes are found most suitable for fish culture. Among these, 'Major Carps' have proved to be best culturable fish in India having following qualities.

(1) Carps feed on zoo-and phyto-planktons, decaying weeds, debris and other aquatic plants.

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(2) Carps can survive under somewhat higher temperatures and also in turbid water.
(3) Carps can tolerate oxygen variation in water.
(4) Carps have fast growth rate and can attain good size and weight.
(5) Carps can be transported from one place to other easily.
(6) The flesh of carps is mostly palatable and much nutritive.

External Factors Affecting Fish Culture

Now-a-days, profitable fish culture has become purely technical and scientific because a number of environmental factors affect the fish culture programme. A number of factors *viz.*, temperature, light, rain, water, flood, water current, turbidity of water, diseases, toxic pollutants, pH, hardness and salinity of water, dissolved oxygen etc. play a vital role in fish culture. The temperature and light intensity both have profound effect because fish can not breed above or below the critical temperature which may be variable according to the species of fish.

Management of Fish Culture Programme

Fish culture is a complicated process, so for an ideal fish culture one should have an idea about the different stages of fish culture *i.e.*, topographic situation, quality of water, source of water, and other physical, chemical and biological factors. Ponds are the sites where fish develops and grows. The management of ponds has its own importance and has to be tackled from the point of view of breeding, hatching, nursing, rearing and stocking ponds. The nature of ponds may slightly vary with the species on the fish. Even different stages of the same fish are cultured in the ponds having quite different properties. Keeping in view the various stages of fishes, the following different types of ponds have been recommended to manage them.

Breeding Pond

First step in the fish culture is the breeding of fishes, therefore, for proper breeding special types of ponds are prepared called as breeding ponds. These ponds are prepared near the rivers or other natural water resources.

Types of breeding

According to the mode of breeding there are two categories :
(1) Natural breeding (Bundh breeding)
(2) Induced breeding.

[I] Natural breeding (Bundh breeding)

The natural bundhs are special types of ponds where natural riverine conditions or any natural water resource conditions are managed for the breeding of culturable fishes. These specially designed bundhs are constructed in large

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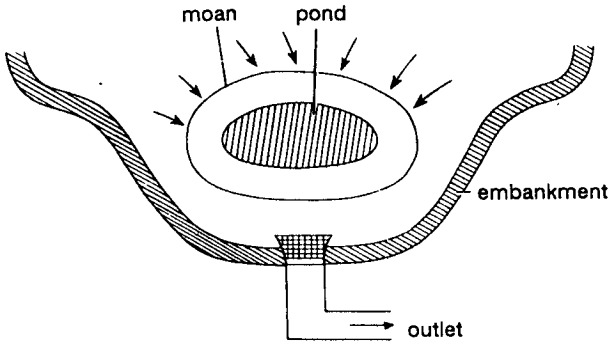

Fig. 1. Wet bundh.

low-lying area having facility to accommodate large quantity of rain water. These bundhs are having an outlet for the exit of excess rain water. The shallow area of such bundhs is always used as spawning ground. These bundhs are of three types :

(1) Wet bundh. (2) Dry bundh. (3) Modern bundh.

1. Wet bundh. The ponds specially constructed for fish breeding having water throughout the year are known as wet bundhs or perennial bundhs (Fig. 1).

An inlet is formed at the higher level of bundh for the entrance of the water while an outlet is prepared in low-lying area for the exit of the water from the bundh. The flow of water from outlet is controlled with the help of bamboo fencing.

2. Dry bundh. This type of ponds is purely seasonal with shallow water areas. This is constructed by keeping soil walls from three sides and open area from one side. In monsoon period rain water flows towards this bundh and fills the pond. But after monsoon water this bundh dries up after a month or two (Fig. 2).

3. Modern bundh. This is known as 'Pucca bundh'. It is a masony construction and a sluice gate at the lower-most level of the bundh is the

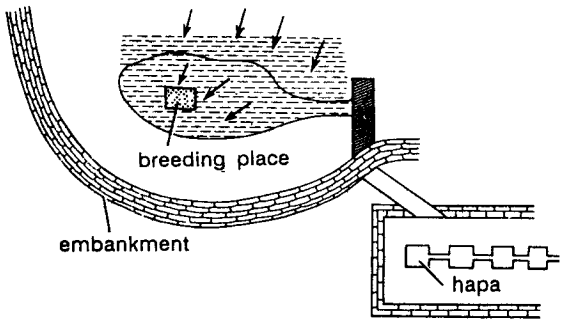

Fig. 2. Dry bundh.

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characteristic feature. The total exit of water from the bundh is possible by this gate so that after each spawning, bundh is cleared of water.

According to the breeding nature of different fishes, suitable bundhs are used for spawning.

[II] Induced breeding

The fish seed is commonly collected from breeding grounds but this has certain drawbacks because a mixture of eggs of various types of fishes is obtained in which some eggs may be of predatory fishes. Keeping this in mind some advanced techniques have been devised for the super quality of fish seed by artificial method of fertilization.

Artificial fertilization. In this method of fertilization ova from the females and the sperms from the males are taken out by artificial mechanical process and the eggs are got fertilized by the sperms. This is of two types :

(1) Dry method (2) Wet method

1. Dry method. Eggs and sperms of fishes (which are just taken out) are mixed thoroughly and left in this condition for about 30 minutes. Now water is added in this mixture after the fertilization of eggs.

2. Wet method. Eggs are kept in water and milt of the male is spread directly into this water. This method is commonly used in sticky eggs.

For artificial fertilization, mature female fish having eggs is taken in hand and dried by towel. The belly of this fish should be upward. Stripping should be started with the thumb of the right hand from the anterior to the posterior direction for the ejection of the eggs due to force. In this way eggs are collected separately. Further, a male fish is caught and its belly is kept downward. The milt of the fish is stripped with the help of the thumb and index finger and collected separately. Now the eggs are subjected to fertilization as mentioned above.

Types of induced breeding. In accordance with the breeding habit, two types of fishes are found *i.e.*, fishes commonly breeding in ponds and fishes not commonly breeding in ponds. Therefore, induced breeding is managed in both types of fishes by different methods as described below.

1. Method of inducing in pond breeding fishes. Although pond breeding fishes are well adapted for breeding in the maintained ponds yet for effective and successful breeding some inducement is given to the pond breeding fishes also. First of all they are segregated sex-wise to prevent wild spawning. Further, they are allowed to breed under the influence of any one of the following spawning stimulants :

(i) by the introduction of specific selected brood fishes in breeding ponds. (ii) by replacement of old water by fresh rain water. (iii) by providing suitable site for the attachment of the laid eggs. (iv) by providing particular temperature and light intensity.

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2. Method of inducing in difficult spawning fishes. The fishes like Chinese carp, Cat fishes, Mullets, Milk fish etc. do not commonly breed in ponds, therefore, some breeding stimuli are needed for proper breeding which are given below :

(a) Induced bundh breeding. Spawning in bundhs occurs after continuous heavy showers when rain water covers the bundh. The breeding of carp is very much interesting. The male and the female indulge in sex play. The male starts chasing the female with vigorous splashing of water. The female is then held by the male and ova are released, at the same time male ejects the milt over the eggs. After spawning the breeders remain guilt for sometime and then swim away. The bundh breeding of 'hardly spawning' is induced by the following factors :

(1) Spawning is stimulated by the following monsoon.
(2) Water current also induces spawning.
(3) Temperature between 24 to 32°C is found best inducer for spawning of fishes.
(4) Cloudy season followed by thunderstorm and rain also stimulates spawning of fishes.

(b) Induced breeding by hypophysation (Hormone). The gonadotropin hormone (F.S.H. and LH) secreted by pituitary gland influences the maturation of gonads and spawning in the fishes. In India, Khan (1938) successfully induced *Cirrhinus mrigala* to spawn by injecting mammalian pituitary hormone.

Method of hypophysation. First of all pituitary is taken out, then preserved in absolute alcohol inside the sealed tube in a dessicator at room temperature or in acetone for about 36 hours and stored in sealed phails in refrigerator. The pituitary glands should be taken out form fully mature, healthy and freshly killed fishes. The donor fish of the same species are most preferred for this purpose.

For the preparation of extract, the weighed glands are homogenized in distilled water of 0.3% saline or glycerine and centifuged for 15 minutes at 20,000 rpm. The supernatant thus obtained is injected intramuscularly on the back or on the base of the caudal fin. In some cases intraperritoneal injection is also recommended at the base of the pectoral fin.

Dose for hypophysation. For the first time 2 to 3 mg of pituitary extracts/kg body weight of fish is injected. After 6 hours of first injection, slightly higher dose of 5 to 8 mg/kg body weight of female and 2 to 3 mg/kg body weight of male are injected. Now both male and female are released into a 'cloth hapa' which is fixed with bamboo poles in the breeding pond. The breeding hapa is a rectangular box formed of mosquito net cloth and closed from all sides.

After 24 hours of injection the male and the female start to swim, become excited and restless and always try to jump out of the hapa. The male and female chase each-other and push each-other with their snouts and spawnings occurs as result of which eggs are fertilized. Now the fertilized eggs are removed from spawning place and kept into hatching hapas.

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Synthetic hormone. With the advancement of fish culture programme the synthetic hormones have been introduced in the field for breeding of fishes. The human chorionic gonadotropin (HCG) and some cortic steroids particularly 'Deoxycorticosteron' are most successfully used for induced spawning of cultivable fishes. A mixture of chorionic gonadotrophic and mammalian pituitary extract as 'Synaphorin' is used in combination with the fish pituitary extract.

Fish Seed

The fish seed is collected from the breeding ponds. A large number of fish collection stations have been established at Ganga, Yamuna and Brahamputra etc. The fish seeds are collected from the breeding grounds of Ganga, Yamuna, Gomati, Betwa, Ghaghra and others. The best suited places for the collection of fish seeds are on the curve area of these rivers. The spawn collecting net is commonly called as 'Benchi Jal' (Shooting net). The shooting net is a funnel shaped structure consisting of closed mesh or cheap coarse cloth (Fig. 3). The whole net is 10 to 20′ 'in length and both the ends *i.e.*, anterior and posterior are open. At the posterior end of the net a tailed-structure is attached which is a rectangular piece (2′ × 1′ × 1′) called as 'Gamcha'. All stages of fish can be collected in this gamcha from where they are scooped and transferred to the 'Hatching pits.'

B. Hatching Pit

The fertilized eggs are kept into hatching pits for hatching. At the time of construction of hatching pits one should see that the hatching pit :

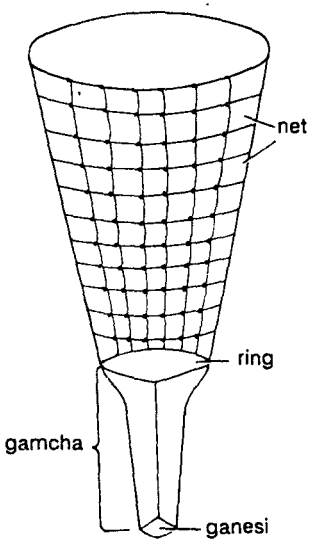

Fig. 3. Benchi jal.

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(1) should be nearer to the breeding grounds.
(2) should be smaller in size.
(3) should contain such a quantity of water which must dry within a month or two.
(4) should be more in number.

Types of hatching pits

Hatching pits are of two types :

1. Hatcharies. These are small sized ponds (Fig. 4) in which fertilized eggs are transferred. After 2 to 15 hours the fertilized eggs are hatched. Some draw backs make the hatcharies unfit for advanced fish culture programme. These drawbacks are as under :

(i) sudden rise and fall in temperature, (ii) entrance of predators in ponds, (iii) drying of water from ponds may cause mortality of eggs.

To overcome all these drawbacks specially designed hatcharies and hatching hapas are constructed.

2. Hatching hapas. Hapas (Fig. 5) are rectangular trough shaped tanks made up of cloth supported by bamboo poles fixed in the river. In these hapas fish eggs are aerated by continuous flow of current. The size of hapa is about $3' \times 1.5' \times 1'$ and is made up of mosquito net cloth which is fixed into outer larger hapa made up of coarse cloth. Two types of hapas are designed :

(a) Fixed type hapa. If possible to fix the perpendicular poles (arms of hapa) only then the fixed type of hapa is used for hatchings of eggs otherwise floating type of hapas should be used.

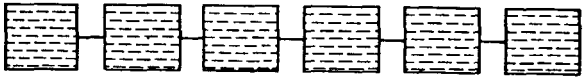

Fig. 4. Hatcharies.

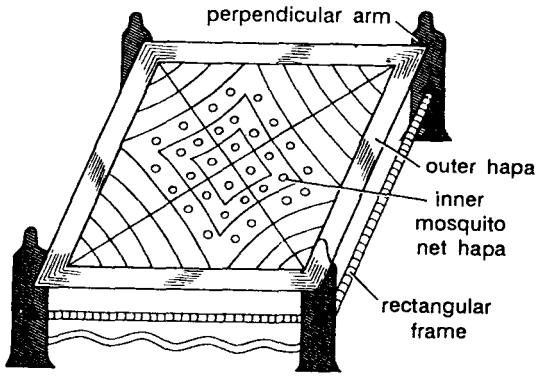

Fig. 5. Hatching hapa.

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(b) Floating type hapa. In hard bottom areas where it is not possible to use fixed hapas, floating hapas are built. These hapas are arranged in large number in series attached with the bamboo and floated on water surface. To avoid overcrowding of eggs, only one layer of eggs is spread in each hapa. Hatching of eggs takes place in the outer hapas leaving the egg membrane in the inner one. The hatchings are kept for 36 to 48 hours in hapas and then transferred to the nurseries.

Transport of Fish Fry to Nursery Ponds

The fish fries are collected and transported to nurseries. In West Bengal these are transported in earthen 'Hundies' which cause heavy mortality due to the following factors.

(1) Decreased dissolved oxygen concentration in water.
(2) Increased carbondioxide concentration in water.
(3) Toxicity of wastes like excreted ammonia.
(4) Hyperactivity and its strain.
(5) Physical injury to fries during transport.

To overcome the above mentioned injuries, fries are subjected to conditioning before transportation by keeping them into fixed volume of water for definite period and then transported in open or closed vessels. Temperature of the water of the vessels can be kept lower by tieing a wet cloth around the vessel. Dead fries should be removed to avoid the pollution and infections. Now-a-days fries are transported in sealed metal containers with oxygen. In India alkethen bags of different sizes are used for the transportation of fish fries from hatching hapas to nursery-ponds.

Nursery Pond

The newly hatched fries transported from hatching hapa to nursery ponds (Fig. 6) are very tender so one should be very careful in maintaining them there. Nursery ponds should always be near the hatching hapas. The nursery ponds are small set of shallow (3′ to 5′ in depth) water reservoir. But now-a-days generally more deep (5′ to 8′) ponds are prepared having an area of about 1/2 acre. The ideal and recommended nursery ponds are 50 to 60′ × 30 to 40′ × 4 to 5′. The nursery ponds should be prepared before the hatching of fries. The exit and entrance of water should also be under control.

In nursery ponds natural resources of food are less and when large number of fries are released they certainly suffer due to lack of food. First of all predatory and weed fishes should be removed form pond. The chemical fertilizers *viz.*, ammonium sulphate, sodium nitrate and superphosphate should be used along with cowdung. The amount of chemical fertilizers should be less in quantity. 5,000 to 70,000 kg cowdung/hectare is recommended in accordance with the nature and fertility of the pond soil. Due to these manures numerous zooplanktons

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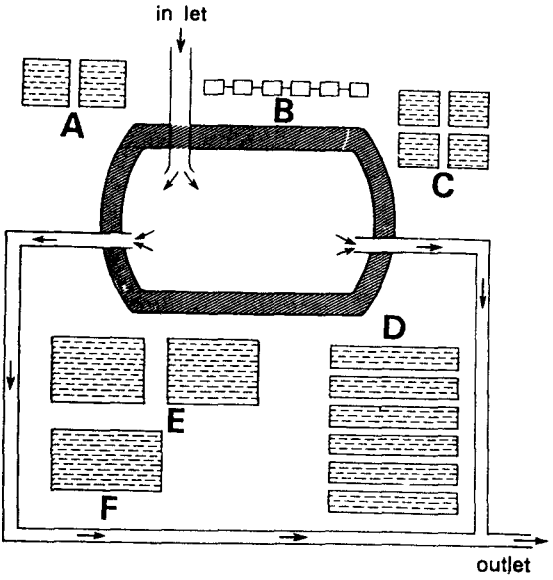

Fig. 6. A Fish farm. (a) Breeding ponds; (b) Hatching pits; (c) Nursery ponds; (d) Rearing ponds; (e) Stocking ponds; (f) Marketing ponds.

are developed within 10 to 20 days and phytoplanktons are also grown up within 10 to 15 days. On these phyto-and zooplanktons they can feed easily and comfortably.

Mortality in nursery pond

The heavy mortality of fish fries has been recorded in nursery ponds. The following factors are responsible for such mortality :

(1) Sudden change in the quality of water form hatching hapa to nursery ponds.
(2) Lack of suitable food in pond.
(3) Presence of predatory fishes and predatory aquatic insects in the pond.
(4) Overgrowth of plankton.
(5) Decreased oxygen concentration in water.
(6) Cannibalism.

Precautions for nursery ponds

(1) In the nursery ponds water should be under good control and circulating.
(2) Pond should be nearer to the hatching ponds.
(3) Ponds should be predator free.
(4) To avoid the overcrowding, fries should be kept in limited number.
(5) Supply of food material should be proper.

When fries are more developed in the nursery ponds and attain a length of 10 to 15 cm they should be transferred into the rearing ponds.

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Rearing Ponds

For good health and growth of fingerlings the exercise is essential for them inside the rearing ponds (Fig. 6). So these fingerlings are reared in longer and narrower ponds to provide them long distance for swimming. The water of this pond may be seasonal or perennial. The rearing ponds should be free from toxicant and predators. The depth of the pond should be about six feet containing nutritive food material in accordance with the population of fingerlings. As fingerlings attain a length of about 20 cm they should be transferred to the other type of ponds called as stocking ponds.

Transport of fingerlings

The fingerlings are transported form rearing ponds to stocking ponds in a container of 1,000 litre capacity. This container is internally lined with foam to avoid physical injury. The proper arrangement for aeration of the tank is essential during transport. To make the fingerlings inactive various sedative (sodium amylate and barbifurate) are used. This is only for less consumption of dissolved oxygen during transport. Sometimes some diseases, parasites and predators are also transported alongwith fingerlings.

To avoid these the fingerlings should be washed carefully before packing and the use of antibiotics, methyl blue, copper sulphate, potassium permanganate, formalin and common salt are recommended. Taking all these precautions, the fingerlings are transferred to the stocking ponds.

Stocking Ponds

The stocking ponds (Fig. 7) should be cleaned of weeds and predatory fishes. Sufficient food is essential for good growth of fishes in these ponds hence proper manuring should be done to increase the production of zooplankton because large number of fishes may not be able to feed properly due to lack of food material. As for the proper organic manuring cowdung is the best and should be used at the rate of 20,000 to 25,000 kg/hectare/year. The inorganic chemical fertilizers are also used *viz.*, super-phosphate, ammonium nitrate and ammonium sulphate at the rate of 1,000 to 1,500 kg/hectare/year.

The powdered rice, paddy, oil cakes, coconut, mustard, groundnut, etc. are commonly used as artificial food for the fishes. The artificial food used for the fishes should be easily digestible in natural form and economically suitable. The best time for feeding the fishes is in the morning hours. The quality of food should not be changed suddenly. The amount of fertilizers used is totally dependent on the fertility of the soil, number of fishes and types of fishes being kept in the stocking ponds. When fishes attain maximum length and weight they should be harvested.

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Harvesting

Harvesting is done to capture the fishes from the water. The well grown fishes are taken out for marketing and smaller ones are again released into stocking ponds for their growth. In highly organised and well planned fish farming the fishes below a particular size are not generally captured.

Methods of Fishing

For proper and scientific management of fishing from different resources, the idea of fishing gear and net in accordance with the size and habitat of fish is essential. The oldest art of fishing in the form of stones and spears has been converted into complex traps, nets and lines. In our country, though a large number of fishing methods are in use but all are not of common use throughout the country. Some common methods of fishing are described here :

1. Stranding. It is widely used in shallow water resources in which some of the shallow area of the pond is separated from the main body by throwing up a low earthen bundh when almost all the water is thrown out from this area, fishes are gathered and caught out. This method is economical but can only be used in shallow swamps and burrow pits.

2. Angling. This is also very common in practice for fishing of large and predatory fishes. Along the banks of rivers of ponds fishing rods are left dug into the soil and the owner of rod visits to unhook the occasional catch or renew the bait consisting of earthworms. Sometimes very long lines containing 100 to 250 hooks attached to it, are also used for fishing. This method can be used both in shallow and deep waters.

3. Traps. This may also be used in shallow and deep waters both. Traps are made of basket work of varying materials. They vary in shape, size and mode of operation. The cage trap is of fixed type whereas scoop and cover traps are movable at the time of operation. Cover traps are under common practice throughout the country and specially used in muddy bottom. The basket is plugged into the water where fish is supposed to be present and then the fish is searched by hand from an opening of the top of the trap. Fishes like *Clarias, Heteropneustes, Anabas, Eel* etc. are trapped commonly. Sometimes in deeper water two persons are needed for the operation of the traps.

4. Scooping. The rim of rectangular, triangular or round bamboo frame is used and the net of same size and shape is loosely hung with this frame. The rounded net is generally used for transfer of fresh catch from the drag net.

5. Dip or lift net. The basic principle of lift net fishing is to keep the net in water for about 5 to 10 minutes, and then pull it out rapidly. In this method the fishes which are over the net at that time may be caught. Some baits are also put on the net or suspended over it. On this principle varying nets of different shapes and sizes are used in different regions. All these nets are fixed

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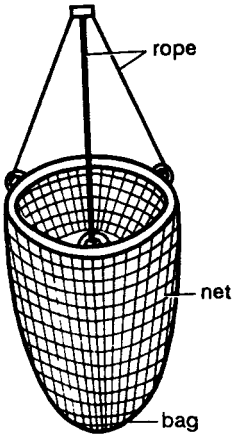

Fig. 7. Dip net.

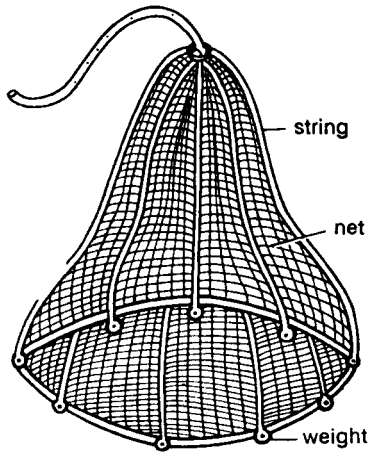

Fig. 8. Cast net.

to frame for catching large and small sized fishes. Four types of net *viz.*, Helajal, Kharra Jal, Bhesal Jal and Khoursla Jal are commonly used (Fig. 7).

6. Cast net (Ghagaria jal). This is a circular umbrella-shaped net made up of cotton twine. The number of meshes on the mouth is 50 and at the periphery around 1,000. The size of the mesh is 2.5 cm and at the periphery circular pockets are formed by folding the net inwards to about 6.5 meshes in depth. Each pocket contains two iron sinkers. On its apex a thin rope of 3 mm diameter is woven through 50 meshes and it is tightened to close the mouth. The free end of the rope is tied to the fore finger of the left net. At the time of fishing the net is swung over head and dropped to the distance reachable by attached rope. Cast net is operated from the boat. After sometime it is slowly dragged in water with the rope. The fishes enter in the net pockets and thus are caught and collected (Fig. 8).

7. Purse net. Purse nets are generally used to capture the migratory fishes like *Hilsa* in the month of October to January and large sized carps and cat fishes are fished in May to July. In river Ganges purse net fishing is recorded. Two types of purse nets are operated in our country *i.e.*, Kharki Jal and Shangla Jal. The wide mouth has two flexible bamboo rods hinged at the two angles and forming upper and lower lips. The net is suspended in deep water and attached from the boat. At the time of operation the mouth is kept open but as fish enters into the net, mouth is closed due to pressure on the bamboo poles (Fig. 9).

8. Gill net. Gill nets are wall-like with a mesh opening of varying size with type of fish to be fished. The net is set on the transverse direction of the migrating fish. The net is made up of common hemp fibers but now-a-days nets are prepared from synthetic impermeable fibers due to which it is not possible

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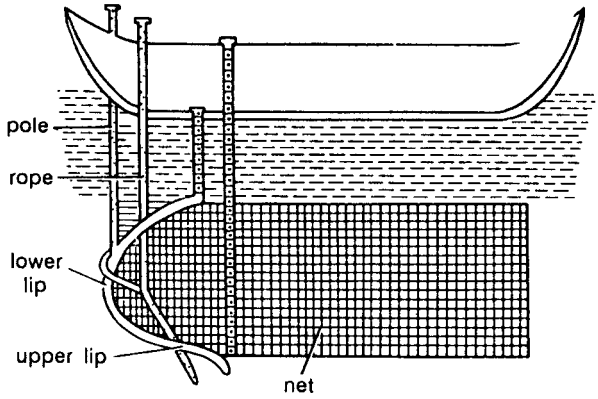

Fig. 9. Purse net.

for the fishes to see the nets. So, as fishes try to swim through a net wall the meshes from a noose round its head and they are caught. Three types of gill nets are commonly used *viz.*, Set net (stationary nets), Floating gill net and Drift net. The net is set in the morning hours and caught fishes are collected in evening. The fishes caught by this net are Seenghala, Pangasius, Major carps, Silonia, etc. This net is fit for fishing in fast current (Fig. 10).

9. Drag net. This net is commonly used for fishing in lakes and rivers. It is provided with a main rope which carries floats and a foot rope bearing sinkers. The shape and size of the net is varying according to the water source where fishing is to be performed. Some drag nets are provided with peripheral pockets (Fig. 11).

Mainly two types of drag nets are constructed :

(1) The first one is consisting of a bag with two wings.

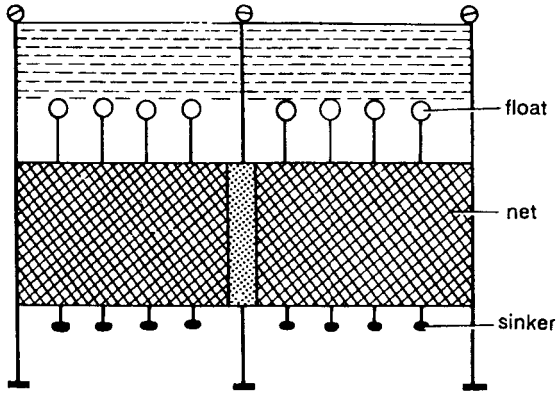

Fig. 10. Gill net.

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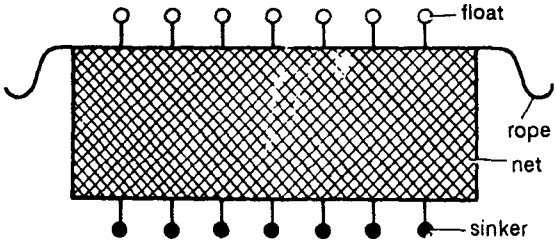

Fig. 11. Drag net.

(2) The second is a wall like formed of a very long net of which the upper margin is supported by a strong rope and having a number of wooden floats. It extends from bank to bank and needs 25 to 30 fishermen to drag it.

It is hoped that expert and advanced technology would be able to design some net in future which may make fishing efficient and easy.

Electric Fishing

Although it is not of common use but sometimes it is used with precautions for fishing. It is reported that fishes are attracted towards electric field on electrode. The current is produced by generator or from batteries. The electric current is of about 15 amperes. The voltage may vary according to the depth, distance and conductivity of water. Large fishes are more sensitive than smaller ones. The voltage is between 150 to 250 volts. Direct current, alternating or interrupted current can be used. If the voltage and intensity is well regulated the fish soon recover from the shock in the electric field.

Preservation and Processing of Fish

If not preserved, fishes get spoiled due to decomposition. Fish flesh comprises of protein, fat, minerals, vitamins, amino acids, iodine, phosphorus and large quantity of water. Fishes are also provided with a number of bacteria which after the death, start to attack various constituents. In this light the preservation of fishes is an essential process. The following methods of preservation of fishes are generally practised in India and abroad.

1. Refrigeration. The basic idea behind refrigeration is to preserve the fish at 0°C which prevents the spoilage for short period. For this purpose alternate layers of fish and ice are kept in closed vessels to maintain the temperature at 0°C. In case of large fishes ice pieces are kept in abdominal cavity of gutted fishes.

2. Deep-freezing. Before this freezing, fishes are washed properly and kept at a temperature of $-18^{\circ}C$ for longer period. Only the fresh fish in good condition are deep-frozen. Before keeping the fish in this process the heads of large fishes are removed. They are also gutted and washed. By this method fishes can be kept for longer period without spoilage.

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3. Freeze drying. This is long process and expensive so only good quality of fishes are put to this type of preservation. The first step is the freezing of the fish, which is then allowed to dry by sublimation. In this process ice is changed into water vapour without melting. The colour and nutritive substances are completely preserved by this technique. Further, the fish is frozen to –20°C by keeping them in freezing chamber. After freezing, fishes kept in trays are sent to the cabin containing horizontal heating plates for drying in vacuum. Now fishes are well dried due to hot plates and packed in air-conditioned chamber.

4. Sun drying. Small sized fishes are dried in sun light specially in tropical countries like India, China, Japan and others, where sun rays are very powerful (scorching) to dry the fishes easily. The fishes are kept for dehydration on a mat or anything for 3 to 5 days and during this period turning over the fishes is continued. Larger fishes are cut into pieces for easy drying. But this method is not perfect for longer preservation.

5. Sun curing. An advanced method over simple sun drying is developed in which body of the fish is opened from the ventral side and the viscera and the gills are removed. Then the fish is washed and salted in ratio of 1 : 3 to 1 : 8 (salt : fish) which is related with the size of fish.

6. Mona curing. This is basically similar to sun curing with the difference that no incision is made in the body of the fish to remove the intestine and the gills. In this method the intestine and the gills are removed directly from the mouth. Further, eviscerated fishes are cleaned, salted and dried as earlier.

7. Wet curing. It is just like sun curing with the only difference in the packing of salted fish as such. This method is employed only for fatty fishes.

8. Salting. The partial dehydration of the fishes by osmosis with sodium chloride is termed as salting. If intense, this will kill the microbes and stop diastasis. The heads of the fishes are removed, gutted and washed then salted as soon as possible. Salting can be carried out as follows :

(1) Dry (alternate layer of fish and salt).
(2) In brine (light, 16% salt : strong, 25% salt).
(3) In brine after the fishes have been dipped in salt.
(4) Cold by spreading salt and crushed ice on the fish.

For the light and cold salting, the processes, should be performed in cold room (2 to 3°C) but for strong salting this process can be performed at the normal room temperature.

9. Smoking. The preservation by the action of wood smoke is known as smoking of the fish. This permits the preparation of delicate specialities. The temperature of the smoke and its rate of circulation should be controlled. The smoking may be of hot or cold type. For cold smoking fishes are dried, salted, exposed to a smokeless fire (38°C) and then processed for real smoking at 28°C. The hot smoking is performed on fresh fishes in which fish is subjected at

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130°C on strong fire which is followed by smoking at 40°C. The industrial smoking is done in galleries with a smoking installation and a system for the proper circulation of smokes. This method was used to preserve the fishes in World War II but it is not recommended in the present day fish industries.

10. Canning. The canning of fish is a long, complicated and advanced process in which head and viscera are first removed, eviscerated fishes are treated with brine, washed, dried and cooked in olive oil to remove the excess of water for 2 to 4 minutes only. Now cooked fishes are packed in olive oil in tins and sealed and then dispatched out for markets. This is very costly process so it is not in common use. This process of preservation is widely used in America, France, Japan and Spain.

Fish Culture and Water Pollution

Water pollution is a serious event is many countries of the world where, alongwith the industrialization programmes, population pressure increase also takes place much faster than the treatment facilities. Effluents of fertilizer factories, pulp mills, textile, paper mills, distilleries, nuclear reactors, thermal plants and use of pesticides, herbicides, etc. change the quality of water resources with regard to their chemical, physical and biological parameters. The fishes are directly influenced due to these toxic chemicals which cause mortality and several diseases as a result the growth is ceased. The breeding capacity of fishes are also hampered due to these toxicants. Pollution affects the fish culture programme directly and indirectly both as given :

(1) Change in physical, chemical and ecological nature of water resources.
(2) Decreased percentage of dissolved oxygen in water affects the respiratory function of gills.
(3) Cause reduction in phyto and zooplanktons.
(4) Destroy the spawning grounds and other nourishing materials.
(5) Fish flesh is loaded with pollutants.
(6) Flesh becomes unpalatable.
(7) Sewage and silt cause quick destruction of ponds.

Therefore, water resources should be kept free from these toxic pollutants which would be of great help for fish industry and human-beings also.

Composite Fish Farming

It is found that if few selected species of fishes are stocked together in proper proportion in a pond, total production of fishes is increased many times. This mixed fish farming is termed as composite fish farming or 'Polyculture'. The main idea behind this type of farming is given as :

(1) All available nitches are fully utilised.
(2) Competable species do not harm each other.
(3) No competition among different species is found.
(4) Fishes may have beneficial effect on each other.

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Food material supplied in this type of farming is in accordance with the feeding habit of the different species. In India mixed fish culture is an old practice in which *Catla catla, Labeo rohita* and *Cirrhina mrigala* are surface feeder, column feeder and bottom feeder respectively and are used for composite fish farming.

Naw-a-days in India polyculture is progressing well in larger ponds on commercial scale. In W. Bengal at Anjana fish Farm, 4,000 kg/hectare/year production of fish has been recorded. In Central Fisheries Research Institute investigations are going on for best combination of fishes for polyculture in Indian water resources. It is hoped that successful steps of polyculture would certainly increase the fish production rate in our country.

Exotic Fishes

The fishes imported into a country for fish culture are called as 'Exotic fishes' and such fish culture is known as 'Exotic fish culture'. A large number of exotic food fishes have been imported and a few of them have achieved good success for fish culture industry in India.

(1) The Gourami (*Osphronemus goramy*) is native of Indonesia and has been introduced in Kolkata. In 1809 same fish was introduced in the ponds of Chennai and Nilgiris from Mauritius.
(2) The Tench (*Tinca tinca*) was imported from England and introduced into the Ootacamund lake. It is quite successful fish for fish culture.
(3) The Crucian carp (*Carassius carassius*) is a golden carp, native of central Europe. It was introduced in 1870 in Ooatacamund lake and further transferred in ponds of Nilgiris.
(4) The common carp (*Cyprinus carpio*) is native of China and was introduced in Shri Lanka from Prussia in 1914.

There are three varieties of this carp *viz.,* Mirror carp (var. *specularies*), Scale carp (var. *communis*) and Leather carp (var. *nudus*). The mirror carp is most common. Before three decades the mirror carps were introduced into plains of Nainital district, Ram Nagar, Kichha as well as Mirzapur district and some other places in U.P. where it has adapted well and are surviving. Other exotic fishes *viz., Tilapia mussambica* from Bangkok, *Puntius javanicus* from Indonesia and *Hypopthalmichthys molitrix* from Japan have also been imported and are among good food fishes.

The introduction of exotic fishes in fish culture does not appear to harm the indigenous fauna of fishes but some workers have warned that introduction of exotic fishes is not very safe as they may upset the balance of natural fauna. Strict quarantine restrictions should be exercised during import of fishes.

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Fish Marketing

The history of fish taming and its use by man is as old as the history of man himself. Fishing is an old practice of mankind all over the world. Though fishery is very important sector in a nation's economy yet the people connected with its production are neglected and are socio-economically backward, therefore, they are facing many problems. Proper development of fish industry requires efficient use of available resources, machines, capital, skill, management and well developed marketing system. The marketing system in different countries like India, Singapore, Philippines, Sri Lanka. Malayasia, Indonesia, Japan, Hong Kong etc. are different according to the availability, consumption and demand of fish.

Market is an area for potential exchange where supply, demand and negotiation are important factors between sellers and buyers. The status of market may vary from local to International, retail to wholesale and short term to long term. For the proper management of an industry, it is essential to develop an efficient marketing system. At certain places in the earlier days, the term '**Fish marketing**' was known to be buying and selling of fish but after the world war II, the simple concept of marketing has been changed completely in accordance with the business management of fishing industry. Now-a-days, the fishing industry in many countries is highly technical and advanced to meet the existing demand of fish in the world market. With the rapid increase in the production and processing of fish, the concept of fish marketing has been changed completely in accordance with the supply and demand. The marketing patterns are typically settled by wholesalers, retailers and middle man in the markets. Now-a-days, the processing and packing of frozen fish has been reached to very high standard and still improving day by day. The frame and form of fish marketing differs all over the world depending on the steps of collection, processing and dispersion of fish. The supply of fish is dependent on many natural factors, therefore, its supply is very much uncertain. In such situation the marketing structure has a vital and very important role. Generally two types of fish markets are found viz., dry fish market and fresh fish market. Just after catching the fish, its sorting out starts and is arranged in different grades in accordance with the quality and type of fish and sellers in the market.

Main fish marketing system includes the export of frozen and dried fish and simultaneously includes the fresh and dried fish for domestic purpose. The channel of fresh fish marketing includes commission agents, assemblers, agents of assemblers, wholesalers, retailers etc. These are four patterns of fish marketing in retailing business viz. door to door retailing, retailing on road side, retailing in organised market and retailing through cold rooms.

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Marketing Intermediaries

Likewise agriculture sector, there are intermediaries between the fishermen and the consumers which leads to low income of producer fishermen and higher price burden for consumers. Thus, the intermediaries are found to own an important position in marketing system. The producer gets a maximum of 15% price spent at consumer level.

Channels in Marketing System

Wholesalers and middlemen are principal factors in deciding the marketing pattern. The wholesaler first manages to procure exportable fish, dry edible fish, fresh fish and dry fish meal for marketing. The market elements of Mumbai directs the marine fish market and besides the local traders are the functionaries of Mumbai merchants. Usually fishermen sell the fresh fish to the suppliers of fresh fish. From these local suppliers, the fresh fish merchants buy the fresh fish for the consumption of people. An other channel of selling the fresh fish by fishermen is to sell the fresh fish directly in local market by themselves. Thus, the local consumers buy fish directly from either fishermen or the retailers. Likewise agriculture, there is long chain of middlemen between fishermen and real consumer of fish. In this long chain, the fresh fish are processed by wholesalers or procurement agents and sell to different consuming centres.

Hand crafts and trucks are commonly used for carrying the fish from landing centres to the market and are further sent to other cities either by trains or by trucks.

Some Analysis of Fish Marketing System

On the basis of informations obtained from different levels certain analysis have been made as following :

(1) Common fishermen don't own cold storage and processing facilities. As fish is a perishable commodity, fishermen are bound to sell the fish at any price immediately after capturing.

(2) Fishermen generally sell their fish at unfavourable place, time and the terms. When fish is catched in a season there is a fish-glut in the marke then the price offered for fish is quite low.

(3) The presence of long chains of middlemen reduces the share of the consumers price received by the fishermen.

(4) The wholesale price gets vary considerably from place to place as the fishermen have no information about the trend of National or International market price.

(5) There is not a uniform method of payment, for selling fish, to the fishermen. Sometimes there is problem of delay payment too. Besides, some time there is facility of advance payment by the fish merchant to the fishermen

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and therefore the fishermen are bound to sell their fish to the same fish merchant.

(6) It is often reported that most of the fishermen even don't try to obtain high price of their fish.

(7) Some fishermen believe that fish merchant exploit them regarding the weight, price, quality etc. of fish.

Thus, it can easily be concluded that fish market is not widely developed properly. There is no efficient marketing system and the fishermen are bound to sell their fish immediately after capturing them because there is no cold storage and processing facilities with them. The fish merchants, traders and agents cheat the fishermen regarding price because fishermen has no knowledge of the market price. It is, therefore, advised that efficient development of cooperative marketing system is essential for the sustainable development of fish industries in India as well as in different parts of the world.

IMPORTANT QUESTIONS

» ***Long answer type questions***

1. Give an account of the management of fish culture programme.
2. Give detailed account of induced breeding in fishes.
3. Give an account of some common methods of fishing in well planned fish farming.
4. Give an account of preservation, processing and marketing of fish.

» ***Short answer type questions***

1. Define breeding in fishes by hypohysation.
2. What is bundh breeding in fishes ?
3. Define composite fish farming.

» ***Very short answer type questions***

1. Explain floating type of hatching hapa in fish culture.
2. What is electric fishing.
3. Define canning for the preservation of fish.
4. How deep freezing is performed for the preservation of fish ?
5. How freeze drying is helpful for the preservation of fish ?

» ***Objective type questions***

1. Which of the following statement is wrong ?
   (a) The culturable fish should be herbivorous in nature.
   (b) The culturable should be fast growing
   (c) The culturable fish should be able to resist against diseases.
   (d) The culturable fish should not be prolific breeder.
2. Which of the following is exotic fish ?
   (a) Anabas (b) Singhi (c) Mirror carp (d) Payas

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3. Which of the following statement is wrong ?
   (a) Major carps have fast growth rate.
   (b) Major carps can survive some what under higher temperature.
   (c) Major carps can not tolerate oxygen variation in water
   (d) Major carps can be transported from one place to other easily.
4. Which of the following gland is involved in the induced breeding by hypohysation ?
   (a) Thymus (b) Adrenal (c) Pituitary (d) Hypothalmus
5. Which of the following statement is wrong ?
   (a) Hatching pit should be nearer to the breeding ground.
   (b) Hatching pit should be larger in size.
   (c) Hatching pit must dry with in a month or two.
   (d) Hatching pit should be more in number
6. Which of the following statement is correct ?
   (a) *Catla catla* is surface feeder (b) *Labeo rohita* is surface feeder
   (c) *Cirrhinus mrigala* is column feeder (d) *Anabas testudineus* is vegetarian
7. The generic name of Golden carp is :
   (a) *Tinica tinica* (b) *Cyprinus carpio*
   (c) *Putinus javanicus* (d) *Carassius carassius*
8. Which of the following statement is against the principle of Polyculture ?
   (a) All available nitches are fully utilised.
   (b) Competable species harm each other.
   (c) No competition among different species is found.
   (d) Fishes may have benefitial effects on each other.

Answers

1. (d)	2. (c)	3. (c)	4. (c)	5. (b)	6. (a)	7. (d)	8. (b)

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11

Economic Importance of Fish

It is an old version that there is more gold in water than on the land. Three-fourth of the earth surface is covered by sea. Other water reservoires like rivers, canals, lakes, irrigation tanks, pools, ponds etc. are in abundance on the earth. Fishing is of great importance to human beings and in addition to providing good food, most of the fishing industries yield a number of by-products of commercial importance viz., body oil, liver oil, fertilizers, fancy articles etc.

Food

Since the time immemorial fishes have been used as good protein diet of man, therefore, fishes are very popular throughout the world. In Japan and Hawai Islands, raw fishes are eaten. The flesh of fish is a highly perishable commodity and consists of 60 to 82% H_2O and 13 to 20% protein and greater or less amount of fat. The flesh of fish is also rich in phosphorus and vitamins. Shark and rays are also used as human food in many countries but it is restricted to poor classes only. The Japanese prepare a dish from flesh of shark which is known as shark fish paste.

By products of Fishing Industry

Fish Oil

Fish oil is extracted from fatty tissues of the fishes. It is a mixture of triglycerides containing cholesterols, other alcohols, pigments, vitamins, glycerids, ethers and fatty alcohols. Fish oil is grouped into body oil and liver oil.

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[I] Body oil

Body oil is extracted from the whole fish body and further sub-grouped into following, as :

1. Dry oil. It is obtained from Sardine, Salmon, Herring, Markerel, Anchovy and white fish.

2. Semi drying oil. It can be obtained from carps and sparts containing very low iodine percentage.

Body oil is generally used for industrial purposes, like lubricants, cosmetics, paints etc.

[II] Liver oil

It is extracted from the liver of fishes and is of great medicinal value since ancient times. It is the main source of vitamin A but in some species of fishes liver oil contains vitamin C, D and E also. In nature 3 types of fish livers are found :

(1) Liver containing higher percentage (60 to 75%) of oil contents and low percentage of vitamin A e.g., Cod liver. Its commercial name is Cod liver oil.

(2) Liver containing lower percentage (4 to 28%) of oil contents and higher percentage of vitamin A, e.g., *Tuna* and *Halibuts* liver.

(3) Liver containing higher percentage (25 to 75%) of oil contents and higher percentage of vitamin A,. e.g., Hammer headed fish and Sharks.

The concentration of vitamin 'A' in the liver oil varies according to the food given, age of the fish, sex and growth of fishes. In different fishes the ratio of vitamin A/kg body weight of fish varies in the liver oil. Existence of vitamin A is very much influenced by protein and oil contents both present in the liver of the fish. Liver oil of certain fishes like Tuna, Halibut, Cod etc. are rich in vitamin D content. Vitamin E (a-ocopherol) present in fish liver oil checks the oxidation of vitamin A, so functions as preservative of vitamin A.

Extraction of body oil

Body oil is mainly extracted from Sardine, Herring and Salmon. Process of oil extraction may be of two types : (1) Wet process, (2) Dry process.

1. Wet process. The oil rich fishes are crushed directly and cooked in steam in a continuous vertical cylindrical cooker. After cooking, it is pressed and oil with sticky water (Press liquor of fish soluble) mixture is drawn into settling tanks or passed through centrifugals to separate the oil. The residual cake is dried, powdered and marketed as fish meal.

2. Dry process. Fishes with low oil content are crushed, ground and cooked under continuous stirring in a cylinder externally heated by steam and the oil is then passed outside. Oil, thus obtained is refined by alkali treatment, and decoloured and then processed for hydrogenation.

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Use. Minor industrial application of fish oil include manufacture of candles, lubricants, cutting oils, cosmetics, pharmaceuticals, linolium, rubber substitutes, water proof compositions, printing ink, core oils etc.

Extraction of liver oil

The liver of fishes is taken out and either preserved in common salt or frozen. The extraction of oil is related to the oil content of the liver and the vitamin A potency. For medicinal purposes, only healthy livers are taken while for technical grade oil diseased livers may be used. For the oil extraction four processes are involved in different types of liver.

1. Liver with high oil content. The liver is cut into very small pieces and cooked in a cooking tank at 85 to 90°C by simple steaming. After sometime of cooking, liver cells are broken and oil floats over the condensed water and is collected from there.

2. Liver with low oil content and high vitamin A. Here also the liver is cut into small pieces, ground, mixed with dilute caustic soda (1 to 20% w/w) or sodium carbonate (2 to 5%) and then cooked with steam at 82 to 88°C with constant stirring for one hour. The stirred extract is centrifuged and thus the oil extract is obtained. But for the separation of vitamin A it is treated with sardine oil after the process of digestion.

3. Enzyme alkali digestion process. The liver is cut into small pieces and mixed with equal volume of water. HCl is added to the mixture to maintain the pH at 1.2 to 1.5 Pepsin (0.5%) is added and maintained at 43 to 49°C for complete digestion. Then sodium carbonate is added to raise the pH upto 9.0 and temperature is raised up to 80°C for about one hour. After one hour floating oil is filtered.

4. Solvent extraction method. This process is also employed for the separation of oil from the liver containing more quantity of oil. The oil obtained by this method is usually darker in colour, highly viscous and in well refined form. The oil extracted by any of the methods is kept for 1 hour and the clear oil is separated. The oil of medicinal grade is refined by filtering, centrifuging, etc. and is called as 'Congealing oil'. The non congealing oil is prepared by cooling the oil slowly at 0 to 10°C and filtered in the cold room.

In India fish liver oil industry was set up in Chennai and Travancore during World War Second when import of cod liver oil from foreign countries had become difficult. Liver oil produced in Kerala. Karnataka and Tamil Nadu is refined and marketed by the Government Oil Factory Kozikode (Kerala). It has been estimated that India produces about 425 quintals of fish oil annually.

Fish Meal

The fish meal is prepared from the wastes of fish oil or canning industry or from the whole fish of non-oil-type. Wastes of cod industry are known as

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'White fish Meal'. Different methods of its preparation are adopted with regard to the materials used for fish meal. The chemical composition of fish meal shows wide variations in their constituents containing protein 55 to 70%, minerals 10 to 20% and moisture 6 to 12%. The protein content of this meal is highly digestible, nutritive and of biological importance. The fish meal also contains calcium (5.36%), Phospholipids (3.42%) and iodine. Sometimes A, D and K are also found to be present in the fish meal. Fish meal is also used as major food of domestic animals like pigs, poultry, cattle etc. For younger animals it has proved to be a good nutritive diet because it contains easily digestive proteins, calcium and phosphorus.

Fish Protein

Fish protein is extracted from fish wastes by removing the fat with dilute caustic soda solution, neutralized, dried and obtained as white powder containing 80 to 90% of soluble protein free from any fish odour or taste. It is used in preparation of ice cream, pharmaceuticals, paints, varnishes, textile, paper and cosmetics.

Fish Flour

It is highly nutritive food for human beings, and prepared commercially by solvent extraction process. It is easily digested by the infants of 3 to 4 months also and is eaten in the form of biscuits, bread, cakes, sweets and soup. It has particular odour so it has to be treated chemically to remove the bad smell.

Fish Roes

It is widely used as valuable food containing thymine, ichthulin, creatine, taurine, tyrosin, glycocoll, xanthine, hypoxanthine, etc. It is a good source of vitamin B and contains vitamin C, D and E also. The higher percentage of lectithin (59%), and cholesterol (14%) are also found in fish roes. Fish roes is widely used due to its higher digestibility and biological value both.

Fish Selage

It contains high percentage of unaffected vitamins free from fishy odour. It is semi-solid material prepared from fresh pieces of fish treated with sulphuric acid, formic acid or mixture of sulphuric acid and molasses.

Fish Solubles

It is residual liquor obtained from the fish oil plant and is widely used as food for animals because of higher protein percentage, vitamin B complex and some amino acids. The condensed fish solubles are not easily handled and stored hence generally used in powdered form after dehydration.

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Fish Fertilizer

The wastes obtained during the preparation of fish meal is widely used as manure for coffee, tea and tobacco plantation. Three types of manures are prepared.

1. Dry fish manure. It is obtained from destroyed fishes which are not edible. For this purpose whole fish is dried in sun light and used as manure containing nitrogen 5 to 7%, phosphorus 4 to 6% and calcium 4 to 6%.

2. Pit fish. It is obtained by burning the fish waste into the pits prepared in the soil and left for 35 to 60 days and allowed to dry in sun light after fermentation. It contains nitrogen 3 to 5%, phosphorus 2 to 6%, and calcium 1 to 5%.

3. Fish guana. The refuse of cooked fish body obtained after proper pressing during the extraction of oil is fish guana. It contains 8 to 10% nitrogen, phosphoric acid and disintegrates easily in the soil.

Fish Fins

The fins of large sized sharks are used for the preparation of soups and further washed into sea water, dusted with wood ashes and lime and finally sun dried to get the cured shining product.

Fish Skin

The skin of some fishes like sharks and rays is used for covering card cases, jewel boxes, scabbards and for several other ornamental purposes. After special tanning *i.e.*, after removal of dermal denticles, strong and highly durable leathers are prepared. The natives of certain Islands of south sea use dried and spiny skins of the globe-fishes or porcupine-fishes for war helmet. In Japan, it is a common practice to make lanterns by fish skins. The shark leather is used in manufacture of shoes, hand bags, wallets and tobacco pouches. The skins of cod, salmon, halibut and other large fishes are also tanned and converted into leather.

Silver Scale

The scales of Black fish (*Albunus*) which is found in Europe, North Pyrenees and Alps were used in the manufacture of artificial pearls, specially in France. A pigment obtained by scraping the scales and is coated inside the hollow glass beads then these are filled with wax.

Fish Glue

Fish glue is obtained from Cod, Haddock, Pollak and Hake. Glue is prepared from skins, trimmings and bones. During the course of preparation, the material is washed, ground and charged into steam jacketed cookers. The charge is

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covered with water and small amount of acetic acid and cooked for 6 to 10 hours. The liquor is separated from residue and concentrated.

Chum

The residue obtained during extraction of glue after proper drying is used as poultry feed or fertilizer. Dried chum contains 53% proteins, 1.5% fat, 0.8% crude fiber, 27% calcium and magnesium phosphate and 5.7% other materials.

Isin Glass

Isin glass is a high grade collagen produced from the air bladder or swim bladder of certain fishes *viz.*, cat fishes and carps. The air bladder and swim bladder is firstly washed to remove the blood and other extra matter and then outer layer is scrapped off. The scrapped bladder is airbried and used for the preparation of purse, honey comb, book and ribbon. The isin glass prepared in Russia is of best quality in the world.

Sterols

Cholesterol is main sterol found in the unsaponifiable fraction of fish oils. It is detected from the fish meal. It is basic raw materials for the preparation of vitamin D_2.

Squalene

It is also a constituent of the unsaponifiable fraction of fish oil. It is especially detected in certain Shark liver oils. Squalene is widely used as a mordant in the dyeing of synthetic fibers.

Lecithine

Lecithine is found to be present in fish liver oil of shark and dogfish. It is widely used as wetting in the chocolate industry.

Pharmacopoeia

Certain by-product of fish industry are used in Ayurvedic and Unani system of medicine. Sharks are used in the cure of duodenal ulcers. Certain by-products are used in night-blindness, skin diseases, colds, cough, bronchitis, asthama and tuberculosis.

IMPORTANT QUESTIONS

» ***Long answer type questions***

1. Give an account of the economic importance of fish.
2. Give detailed account of fish oil as by-products of fishing industry.

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» ***Short answer type questions***

1. Give an account of the extraction of liver oil from fish.
2. What is body oil of fish ? Describe the process of extraction of body oil.

» ***Very short answer type questions***

1. Define 'fish meal' as by-product of fishing industry.
2. What is 'fish rose' as by-product of fishing industry.
3 What is 'isinglass' as by-product of fishing industry ?

» ***Objective type questions***

1. Which of the following fish is not suitable for the extraction of body oil ?
   (a) Sardine (b) Herring (c) Salmon (d) Cod
2. Which of the following fish is not suitable for the extraction of liver oil ?
   (a) Cod (b) Tuna (c) Halibut (d) Sardine
3. Wastes of cod industry is termed as :
   (a) Fish rose (b) Fish protein (c) White fish meal (d) Fish flour
4. 'Fish fins' are used for the preparation of :
   (a) Soups (b) Honey comb (c) Purse (d) Cakes

Answers

1. (d) 2. (d) 3. (c) 4. (a)

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12

Fish Diseases

One of the most serious problems of fish culture industry is the mortality of fish due to environmental stress and various types of diseases. The death of fish due to environmental stress is more or less rapid for fish of all sizes which may be of different species. In intensive farming, fishes may be subjected to many diseases but certain diseases cause considerable loss such as infectious dropsy of carp and the viral haemorrhagic septicaemia in trout. The diseases which occur on fish farms are mostly due to poor pond management. The ponds which are heavily stocked, may provide a favourable situation for the rapid spread of infection among the fish. The occurrence and magnitude of infections are closely related to the sanitary conditions prevalent in the water as also the general health of fishes themselves. In a wild state, fish are dispersed, therefore, the risks of contamination are least. The diseases of fish may be categorised according to the organs affected, type of parasites and non-parasitic diseases.

1. Bacterial Diseases

In India, common bacterial diseases of freshwater cultivated fishes are infectious abdominal dropsy of carps, fin and tail rot, eye disease and ulcer disease.

Infectious abdominal dropsy of carp

This is a serious epidemic disease in carp culture which is caused by the bacterium *Aeromonas* (*Pseudomonas*) *punctata*. The physical condition of fish and environmental states are basically responsible for the occurrance of this disease causing several physiological problems in carps.

Symptoms. The symptoms of this disease appear when the water start to be warm in the spring and the fishes start dying, which diminishes gradually

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during the summer. On the basis of exterior characteristics two types of dropsy viz., intestinal and ulcerative, are recognized which may be often quite separate. In intestinal form of dropsy, the swelling of the belly of infected fish is caused due to the accumulation of a yellow or pink coloured liquid in the body cavity. In the beginning of infection, the fish start jumping showing restlessness. In ulcerative type of dropsy the blooded areas appear on the body surface in which muscles are seriously affected. Sometimes the fins of infected fish are partially damaged.

Treatment. The treatment of the infectious abdominal dropsy of carp is possible by applying various preventive and curative measures.

1. Preventive measures. Everything which might weaken the fish should be avoided as bad wintering, lack of natural food, long duration of storage, unnecessary handling of fish etc. The infected and dead fish must be removed carefully and then destroyed. The emptied ponds should be left dry throughout the winter and disinfected with quiklime. The ponds prepared with fertilizers and rich in natural food should be used for stocking in the spring. The fish of different origins should not be mixed. One should try to select carp which may resist dropsy.

2. Curative measures. The use of antibiotics is useful in fish farming in carps which are reared for eating but for restocking carps, there is always a danger of relapse after the change of environment. The antibiotics may be given mixed with food, in a bath or through injection. The antibiotics chloramphenicol is used against *Aeromonas punctata*, a bacterium generally found in abundance among infected fish. If the infection is due to other similar bacteria or resistant strains of *Aeromonas punctata*, latest antibiotics should be adminstered. For the ulcerative form of infectious abdominal dropsy, the antibiotics is mixed with the food in such a way that fish weighing 100 gms may absorb definite quantity of antibiotics per day.

Fin and tail rot

This disease affect both adults and youngs. The infection during its early stage appears as a white line on the margin of the fin, spreading towards the appendages which eventually putrefies and disintegrates. The disease is contageous and may cause considerable damage. The treatment of this disease may be performed by different concentrations of copper sulphate solution viz., bath for 1-2 minutes in 1 : 2,000 solution, one minute dip in 1 : 3,000 solution and 1 : 20,000 solution for 10-15 minutes treatment of infected portions.

Eye disease

This disease is caused by a variant of the bacterium *Aeromonas liquefaciens* affecting medium sized and large sized catla. The sites of infection are eyes, optic nerves and brain of the fish. The pathogenic bacterium *Staphylococcus aureus* has been reported to cause catract like symptoms in the eyes of *Chamra*

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marulius. The disease may be avoided by disinfecting the fish environment with $KMnO_4$ (dose 0.1 ppm) followed by liming (300 ppm).

Furunculosis of salmonids

This bacterial disease is caused by *Aeromonas salmonicida* attacking brown trout and brook trout. The transmission of this parasite takes place either through digestive tract or through small wounds on the skin. The parasite multiplies in the blood, kidney, liver and spleen. Two years old salmonids are severely attacked by this parasite.

Symptoms. The bloody boils of various sizes under the skin are found in certain cases of infections. Often, the centre of infection is hidden in the muscular fibres. The disease in fish develops slowly. In some cases it becomes difficult to identify the disease. Most of the internal organs are infected by bacteria causing severe mortality in fish. But for final diagnosis a bacteriological examination is essential.

Treatment. The infected ponds should be isolated and dead fish should be removed carefully and destroyed. After emptying, the ponds should be disinfected with quicklime or calcium cyanamide. Sudden change in the fish environment should be avoided. This disease may be treated by mixing sulphonamides, nitrofurans and antibiotics with the food as soon as the disease is noticed.

2. Viral Disease

Viral haemorrhagic septicaemia of trout (VHS)

This viral disease of fish is found frequently on intensive trout farms especially in rainbow trout. This disease is also known as infectious anaemia, egtved disease and Danis Virus.

Symptoms. The environmental conditions and feeding status seemed to play important role in appearance of the disease and its development. In earlier stages, it is difficult to discover the disease but suddenly the disease may become chronic causing high mortality of fish particularly when the environment is altered or the diseased fish are handled. The disease in its chronic form checks the normal growth of fish. Any unfavourable condition like cold season, in summer if sudden fall in temperature or less quantity of dissolved oxygen in the surrounding water is sufficient to kill the diseased fish rapidly. In most of the viral diseases at one time one organ and at another time another organ is attacked, though most often the kidney and the liver are affected. But the other diseases with same symptoms may be present at the same time. The most characteristic symptoms is that the diseased fish move very little, rest on the surface of water close to banks and disordered movement with abnormal position in the water. Some fishes attain dark colour, eye swellen, become anaemic and gills turn pale which become pale grey immediately after death. The belly swells and the body cavity is filled with a foul smelling yellowish liquid. The other

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symptoms are protruded anus, haemorrhaged swim bladders and muscles, grey brown liver, posteriorly swellen kidney, reddish intestine, frayed fins and sores on the skin.

Treatment. In fact, there is no effective treatment of this disease. As preventive measure, it may be possible to obtain certain degree of immunity by putting young fish in contact with the diseased fish. The selection of resistant strains of fish is also advisable. The ponds should be with cleaned bottom with sufficient water supply. The high stocking densities and over feeding should be avoided. The food should be rich in vitamins A, B complex and E containing sufficient protein. In chronic cases of disease feeding should be temporarily stopped.

Infectious pancreatic necrosis of trout (IPN)

This viral disease brings sudden and widespread death to young trout at the start of artificial feeding.

Symptoms. The infected fish with IPN revolve on its longitudinal axis and swim around rapidly in a disordered fashion. Further, fish become immobilized either near the banks or on the bottom of the pond. After some time the eyes of fish protrude and their colour become dark. The spleen and liver become pale and the gall bladder shows severe necrosis.

Treatment. In fact, there is no treatment of this highly infectious disease. The feeding of fish on povidone iodine has been suggested to be beneficial.

3. Fungal Diseases

The fungal infection of fish is caused by water mould (*Saprolegnia*) and filamentous fungus (*Branchiomyces*).

Saprolegniosis

Saprolegnia parasitica infects injured, weakened, diseased or dead fish. The fungus also develops in dead eggs in incubation trays or jars and by contact can contaminate healthy eggs. The fungi are present in all freshwater and live as saprophytes on remains of food and body of dead fish. The fry, fingerlings and adults of live major carps which get mechanically injured or bruised during transportation over long distances or even by rough handling, are liable to fungal attack unless properly disinfected.

Symptoms. The infected fish is characterised by wooly, grey-white or lightly brown blotches on the skin, fins, eyes, mouth or gills. The infected eggs are completely covered by the fungus. The infected fish becomes weak and lethargic and gradually dies after ulceration or exfoliation of the skin followed by haemorrhage, exposure of jaw bones, blindness, congestion at the base of pectoral and anal fins, inflammation of the liver and intestine.

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Treatment. (1) The primary causes like injuries, long storage in cement tanks, diseases, weakness, unhealthy surroundings, bad quality water should be avoided.

(2) The treatment of stored fish may be done by dipping in 3% common salt solution or 1 : 2000 solution of copper sulphate or 1 : 1000 solution of potassium permanganate for 5-10 minutes or one minute dip in 1 : 3000 copper sulphate once daily for 3 to 4 days.

(3) A daily formalin bath for 15 minutes may stop fungal growth on the eggs. The malachite green (copper oxalate) may be used to treat fungi when they appear and develop on incubating eggs. A concentration of 10 mg of malachite green per litre for 15 minutes after alternate day is recommended for treatment.

Gill rot or branchiomycosis

This disease is caused by the filamentous fungus, *Branchiomyces sanguinis*, which obstructs the veins in the gill filaments. It occurs in the hottest time of the year and is associated with excessive organic matter and abundant phytoplankton.

Symptoms. In the beginning, the fish have pale gills showing deep red coloured patches. In the later stage the gills are partially destroyed and turned in yellow brown colour.

Treatment. (1) The dense stocking of fish in warm weather and the water supply with rich organic matter as lightly polluted water in hot days should be avoided. When the weather is very hot, good supply of fresh water should be managed.

(2) Addition of quick lime (50-100 Kg/ha) is advisable.

(3) 5 to 10 minutes bath in 3 to 5% salt solution or in 5 ppm $KMnO_4$ solution is recommended.

(4) Benzalkonium chloride may be used as a 1 hour bath containing 1 to 5 ppm of active ingredients.

4. Protozoan Diseases

The body of fish is attacked by a number of parasitic protozoan. They parasitise the skin, the gill muscles and cartilaginous tissues. Some of the important protozoan diseases are given :

Ichthyophthiriasis

This white spot disease is caused in major carps by protozoan ciliate, *Ichthyophthirius multifilis* which affects different regions of the body externally and causes simple hyperplasia of the epidermal cells around the site of infection causing formation of pustules. The young parasites are very small and move

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about in the water seeing a host. When they attain full size, they leave the host and further, the swarmed young parasites move in search of host.

Symptoms. The presence of small whitish cysts on the skin, gill and fins are the signs of the infection by this parasite. They jump in water and rub themselves against bottom or any submerged object.

Treatment. (1) The affected ponds should be disinfected with salt or quicklime.

(2) If the infection is severe, the pond must be emptied.

(3) The infected fish should be dipped in 1 : 5000 formalin solution hourly for 7 to 10 days or in 2% common salt solution for more than 7 days or in 1 : 50,000 quinine solution for 3-10 days.

Costiasis

This disease is caused by flagellate protozoan, *Costia necatrix*, measuring about 20 thousandths of a millimeter, observed in Indian carps. This disease develops from storage and generally noticed during the stocking in ponds. Parasites attack on skin, fin and gills of fish.

Symptoms. The indications of costiasis are presence of a bluish coating on the skin of the fish and presence of large amount of mucus. The parasite causes irritation and disturbs respiratory function in fish. The fish weaken and lose appetite while small carps swim slowly.

Treatment. (1) After bath, infected fish should be placed in food rich ponds and should not be stocked densely.

(2) Bath of 10 minutes duration in 3% common salt solution or 1 : 2,500 formation solution or 1 : 500 glacial acetic acid solution is recommended against this parasite.

Whirling disease

The causative agent of this disease is *Myxosporadian*, a typical parasite known to produce cysts on different regions of the body and internal tissue organs. The common genera are *Leptotheca*, *Chloromyxum*, *Myxobolus*, *Henneguya*, *Thelohanellus*, *Myxidium* and *Lentospora*. This disease leads to a high mortality rate causing severe economic loss. The spores are found in the mud of pond bottom.

Symptoms. The fingerlings whirl round and round in the same direction several times and fall to the bottom. The weakness, falling of scales, loss of chromatophore and perforation of scales are the sign of this disease.

Treatment. (1) It is not possible to cure the infected fish, therefore, steps must be taken to avoid infection by this parasite.

(2) After infection, only complete and careful disinfection may combat the disease.

(3) Mrigal fingerlings affected with *Myxobolus mrigalae* should be disinfected with candy's fluid or a weak solution of sodium chloride.

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(4) Myxosporidian infections in over-stocked ponds are controlled by thinning the population and using yeast pellets at 1g/Kg of feed.

5. Worm Diseases

The fishes are attacked by a number of worms as external and internal parasites. The structure, habits and mode of damage by worms vary considerably. The fish diseases caused by certain worms are given as under.

Gyrodactylosis

Of various monogenetic trematodes reported as parasites in fishes, *Dactylogyrus* and *Gyrodactylus* cause serious infections. *Gyrodactylus* attacks on the gills and skin of fish, whereas, *Dactylogyrus* infects only the gills of fish. *Dactylogyrus* has been reported to feed on blood in the thin capillaries of the branchial region.

Symptoms. The drooping of scales, secretion of much mucus on candal peduncle and fins, fading of colours and peeling of skin are the signs of infection by this parasite. In case of gill infection the death of fish occurs due to hyper secretion of mucus on the gill surface causing irritation, therefore, fish rub their body against hard surface.

Treatment. (1) The infected fish should be dipped for 5 minutes in 5% common salt or for 5 to 10 minutes 1 : 5,000 formalin solution.

(2) Alternate bath in 1 : 2,000 acetic acid and sodium chloride solution has been proved to be effective in case of major carps.

Diplostomiasis

This disease is caused by *Diplostomum* spp or *Diplostomulum* spp. which is a digenetic trematode. This disease is also termed as black spot disease. It is common in the rearing and stocking ponds of fish.

Symptoms. The symptom of the infection of this parasite is presence of numerous small black nodules or cysts of 1.3 mm diameter all over the body of fish.

Treatment. The infected fish should be isolated and dipped in 3 : 1,00,000 picric acid for a period of one hour to control the disease.

6. Crustacean Diseases

A number of crustacean are ectoparasites of some important fishes which are attached with the body of fish causing mortality in fish. The important parasites are *Argulus*, *Ergasilus* and *Lernaea.*

Argulus

It is commonly known as **carp lice** which are common parasite. It is small flat crustacean, green yellow in colour and upto 8 mm in length in case of *Argulus foliaceus* and 12 mm in case of *Argulus coregoni.* It attaches itself to the body of fish by means of suckers and hooks, but it can also swim freely in water.

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Symptoms. The sting of *Argulus* causes red blotches on the skin. The infected fish becomes nervous and scratch herself to get rid of the argulids.

Treatment. (1) The fish should be bathed with one gram potassium permanganate dissolved in one liter of water for 40 seconds.

(2) Lindane bath are given to carp during transportation. 0.3 gm of lindane per cubic meter of water is put in tank for this bath.

Lernaea

It is also known as **anchor worm** which is external parasite of fish. It attaches itself to the host fish anywhere on the body by the anchor-like appendages present on the head of parasite. Its anterior part buried deep into the skin of host fish while posterior part of the parasite is visible freely in water. During summer, most of the carps are parasitised by *Lernaea.*

Treatment. In case of minor infection, the parasites may be removed mechanically by means of fine foreceps and further fishes are bathed in weak permanganate solution for 2-3 minutes. But when the large number of fish are parasitised, the dip treatment in the 5 ppm solution of $KMnO_4$ is advisable. The sprinkling of Diptrex over the surface of water is advisable in case of *Lernaea cyprinacea* infection.

Ergasilus

It is parasite on the gill of fishes but not reported to be very harmful. Its control measures are almost similar to that of *Lernaea.*

IMPORTANT QUESTIONS

» ***Long answer type questions***

1. Give short account of the diseases in fish.
2. Give an account of the Bacterial and Fungal diseases in fish.
3. Give an account of Protozoan, worm and crustacean born diseases in fish.

» ***Short answer type questions***

1. Give short account of 'infectious abdominal dropsy of carp'.
2. Give short account of "Viral haemorrhagic septicemia" of trout.
3. Give short account of whirling disease in fish.

» ***Very short answer type questions***

1. What are the symptoms of infectious abdominal dropsy of carp ?
2. What are the symptoms of viral haemorrhagic septicemia of trouts ?
3. What are the symptoms of Saprolegniosis of fish ?
4. What is whirling disease of fish ?
5. What is Gyro dactylosis disease of fish ?

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» ***Objective type questions***

1. Which of the following is Bacterial disease of fish ?
   (a) Saprolagniosis (b) Branchiomycosis
   (c) Infectious abdominal dropsy of carp (d) Pancreatic necrosis of trout
2. Which of the following is fungal disease of fish ?
   (a) Branchiomycosis (b) Whirling disease (c) Costiasis (d) Diplostomiasis
3. Which of the following is Protozoan disease of fish ?
   (a) Whirling disease (b) Diplostomiasis (c) Grylodactylosis (d) Branchiomycosis
4. Which of the following is worm born disease of fish ?
   (a) Whirling disease (b) Costiasis (c) Grylodactylosis (d) Gill rot
5. *Aeromonas punctata* is causetive agent of :
   (a) Whirling disease (b) Gill rot
   (c) Infectious abdominal dropsy of carp (d) Eye disease
6. *Saprolegnia parasitica* is causetive agent of :
   (a) Saprolegniosis (b) Gill rot (c) Fin and tail rot (d) Whirling disease
7. Which of the following is not the crustacean parasite of fish ?
   (a) *Dactylogyrus* (b) *Lernaea* (c) *Argulus* (d) *Ergasilus*

Answers

1. (c) 2. (a) 3. (a) 4. (c) 5. (c) 6. (a) 7. (a)

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13

Poultry

Fowls are widely distributed as domesticated animal since times immemorial. In twentieth century poultry keeping has become an important small scale industry due to modern need for palatable and nutritive food which it provides in the form of eggs as well as adult animals. The storage and transport facilities also have helped to a great extent in its becoming popular as a trade. This naturally has attracted the attention of the people at large and the scientists in particulars necessitating new researches on breeding, hatching and rearing of fowls. India is the native place of the wild jungle fowl but little attention has been paid for developing poultry industry in comparison to other countries. In country like India, the increased egg consumption is essential for the proper nutrition of human beings. The researches carried out at the Imperial Veterinary Research Institute, Izatnagar have demonstrated the high biological value of eggs and recommended the consumption of eggs in supplementing the defective human diets. For the successful management of poultry industry one should have detailed idea about the poultry ground, habitat of fowl, breeds, breeding and rearing of chickens. Though there are several Government Poultry Farms in India but the poultry is almost entirely in the hands of poor persons, thus eggs available are of small size.

Habitat of Fowl

1. Soil. For fowls, soil should be sandy, gravelly and abounding in kunkar alongwith good amount of lime. The stony soil is not suitable for fowls because stones cause damage to feet of the fowl. The heavy soil with high percentage of moisture is harmful. The marshy, dirty and drained grounds are fatal to the animals.

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2. Shelter. The poultry should be protected from the cold winds and heavy rains. They should not be allowed to walk in water.

3. Shade. The poultry should be well protected from hot sun and hot wind in summer season, so the site for the poultry ground should be such as to have a number of shrubs and trees. In summer season the west side of the poultry house should be closed in the day time otherwise they will die due to westerly wind. The places where trees are not found, a shed of 10 to 15 square feet should be made with bamboo and straw. The shed should be kept 3 feet above the ground surface with the help of bamboo posts. The ground where such shades are not possible, it may be constructed with metal and raised 2 feet from the ground on stone pillars. The ground beneath the shed should be raised about 3 inches from general surface for good drainage.

Fowl-House

Fowls can be reared in the hills of India without houses but in plains the specially constructed houses are essential for fresh and cool air in the early morning and evening. One adult fowl needs twenty five cubic feet of space. A house of $6 \times 5 \times 5$ feet has sufficient accommodation for six fowls. An open shed or verandah must be attached to this house as run way to the fowls for exercise. It is recommended that for six fowls a run of 40×30 feet is sufficient.

The fowl house may be either of wood or brick or metalled but the house of 'all metal' is best. The outdoor of houses must be towards south. It is advisable to construct a number of small houses rather than a single large one. The roof of poultry houses should be of either corrugated iron sheets, thatch, or wood. For the proper ventilation, the south side of the house should be enclosed with half inch mesh wire netting and other 3 sides have openings ($12'' \times 6''$) and covered with wire-netting. The door of the house should be made up of an angle iron frame covered with mesh $\left(\frac{1}{2}''\right)$ wire netting. The floor of the house should be pucca cemented and covered with coarse sand or dry earth sprayed with kerosene oil or phenyl. The sand layer must be changed after one month. The tick-proof perches of strong wood (3″ in width) should be placed inside the house above 1.5 feet from the ground running parallel at 1.5 feet from the wall. The laying nets made up of 9 inch earthen gumlas (1.5 feet diameter, 9 inch depth), provided with dry ashes, sand or earth, should be kept in the corners of the poultry house for egg laying. A small gumla filled with old lime and mortar and the other gumla filled with coarse shell grits should be placed in the shed to supply the necessary grit and lime essential for the formation of egg shell.

Light is also essential for the well-being of poultry, so these houses should always be constructed where natural light is possible without which fowls will die due to cold. Near the shed door or in the yard, a vessel filled with clean

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and fresh water should also be placed. Care should be taken against sun-warmed water which causes cholera in the fowls.

The house and shed should be cleaned daily and water should be changed twice a day. All wood work must be cleaned and painted with a mixture of tar and kerosene oil. The fowl house must be rat-proof because they destroy the eggs of chickens, and carry diseases into the fowl house. The broken glass should be spread on the floor under the bricks to make a pucca floor because rats can not burrow due to pieces of glass. Other enemy is snake which enters into the fowl-houses through the holes made by rats. Fowls also attack small snakes, kill and eat them but if snakes are cobra, krait or russel's viper the fowls are killed due to snake biting. One way to check the rats and snakes is to fill up the holes of poultry house regularly.

Food and Feeding of Fowls

The quality and balanced quantity of food material are the back-bones of poultry. The oats, peas, grams and beans are good food for fowls. The rice and Indian-corn (makka) are not proper food for the birds. The skimmed-milk, butter-milk and curds, mixed with ground wheat and barley, are of good nutritive value for them. The skimmed-milk is highly nutritive for young chicks and should be given in clean vessels. The boiled potato, mixed with equal part of wheatbran, should be given for the fattening of fowls. Some animal foods like ground fresh bones and meat are also good for the health of fowls. The green food as fresh tender grass, garlic, lettuce, onions are essential part of food and should be given uncooked. The mustard seed, hemp seed and linseed should be given after some interval during cold season, rain and at the time of moulting.

Poultry keeper should have good idea about the amount of food allowed to the fowls at different stages of the life span, type of breeds and area of yards at poultry farms. The best diet recommended by Mr. A.J. Macdonald, ex-Poultry Research Officer, Indian Veterinary Research Institute, Izatnagar, U.P. is given below.

Maize meal	20 parts
Ground oat	20 parts
Wheat bran	40 parts
Earthnut meal	20 parts
Common salt	1 part

A good amount of green food and calcium should also be given with the above food.

Too much grain feeding to fowls is very much harmful to them.

Breeds of Fowls

The whole poultry industry is centred round the fowls so the selection of good breed of birds for particular area is essential. It is well known that the

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original home of the jungle fowl has been the countries of South East Asia *viz.*, India, Burma and Sri Lanka and common species of jungle fowls are *Gallus gallus, G. lafayettii* and *G. Sonneratii.*

The selection of the fowl breed should be based on the object with which fowls are kept. The best layers are Langshan, Rock, Brahma, Australorp, Rhode, Sussex, Chittagong among the layer breeds. The Leghorn, Ancona, Minorca and Campine are the best layers among the smaller breeds. If fowls are bred by the best layers, year after year with proper care, the good quality breeds are established.

The largest and most weightly fowls are Brahma, Australorps, Rock, Orpington, Langshan, Game, Sussex and Cochin. The black Minorcas are very well known as best layer of very large white eggs. It is also notable that all hens of the same breed will not lay eggs of the same size or colour. The fowls famous as the best sitter and mother are Silkies, Wyandottes and Bantams. The common hen is known as the Pati or Desi and is the best mother amongst all the fowls.

The origin and evolution of various breeds and their varieties are due to selective breeding for producing the fowl of different shape, size, colour, comb structure, ear lobe's etc. Domestic fowls may be categorised into two groups like Desi or the indigenous and the exotic or the improved.

Desi Breeds (Indigenous Breed)

The term desi is used to include all indigenous fowls exhibiting great variations in their shape, size and colour which, even if they have local names or pronounced characteristics e.g., Tenis, Naked-neck, Chittagong, Punjab brown, Aseel, Ghagus, Lolab, Titre, Kashmir faverolla, Bursa, Danki, Tellicherry, Kala hasti, Karaknath etc., are pure breed of fowl. The desi hen is, however, the best mother, as a rule, and makes an ideal sitter. She is also known to be very vigilant and a good forager. The pure desi breeds are Assel, Chittagong, and Ghagus.

Aseel. Aseel, means real or true, is the name given to an indigenous breed, because of its endurance, power and fighting qualities. The word Aseel is probably misnomer of the word 'Asli'. The original Aseel is a medium-sized aggressive bird commonly known as the Reza or the Tikra. The remarkable endurance of an Aseel even during the most critical stages of the fight is proverbial, because it fights to the last and prefers going down fighting to withdrawing. Pure specimens of this breed are now rare and are available with some fanciers in parts of Andhra Pradesh, Karnataka and Uttar Pradesh. Several varieties, mostly crosses between Aseel and local fowls are known in other parts *viz.*, Nhurie (white), Hyderabad peela (red), Yakhud (Black and red), Dhummar (blue dust), Teekar (Brown black), Zava (laced), Patteda (single combed) etc.

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Aseel is one of the best table birds as the meat is, delicious and flavoured. Because of its poor growth and low fertility, this breed cannot be bred on commercial scales as table bird.

Chittagong or Malay. It is a native of Malay peninsula and bred in Chittagong (Bangladesh) and is found in some parts of eastern India. The colour of this bird is white with splash of golden markings on the wing. This bird grows faster and is ideal for table purposes as its flesh is excellent.

Ghagus. It is a peculiar Indian breed resembling the Faverolle in appearance but having feathers on the legs. It is a big and hardy breed found in Andhra Pradesh and Karnataka. Ghagus is a good table bird. The hen is a fair layer, good sitter and real mother.

Bustra. It is a minor breed of desi class found in small numbers in Gujarat and Maharashtra particularly around Mumbai. The birds have body conformation typical of layers, and are majestic, alert, deep bodied and light-feathered. The hen of this breed is poor layer.

Improved or Exotic Breeds

The term 'Improved' is applied generally to the exotic and comparatively modern breeds of Chickens imported into this country, where they are bred and acclimatised to the local conditions. The exotic breeds of poultry were introduced in India by early European residents such as missionaries, planters and civil servants. The exotic breeds have become quite popular here. According to the standard classification 'Chickens' are grouped into many classes which are further subdivided into about fifty breeds. Each breeds has several varieties which differ from one another.

American Class

Polymouth Rock. It is one of the most popular breeds of USA as it can attain good size with excellent flesh. It has fair egg laying capability. Six varieties of this breed have been reported of which Barred Polymouth Rock Cocks like those of the Rhode Island-Red, are good for upgrading the ordinary village or desi hens. Other varieties of polymouth Rock breed are the white, Buff, Silver-pencilled, Partridge, Columbian and Blue. The white variety of this breed has been proved to be profitable as it has good capacity for egg and broiler production. The standard weight of this breed is cock-5.5 Kg, hen-4.5 Kg, cockered-5 Kg and pullet-4 Kg.

Wyandotte. It has a rounded body set close to the ground. Like Polymouth Rock, it is good breed for general purposes. It is very well adapted for flesh production and can lay good number of eggs of standard quality. The different varieties of this breed are white, silver-laced, Buff, Partridge, Golden-laced, Silver-pencilled, Columbian and Black. The standard weight of this breed is cock-5 Kg, hen-4 Kg, cockered-4.5 Kg and pullet-3.5 Kg.

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Rhode Island Red. It is one of the most popular breed of fowl in India with good quality of flesh, and the hens are very good layers. This breed is hardiest of all breeds which can survive well in varying climatic conditions. The flocks of this breeds are kept in government poultry farms and by commercial poultry keepers. The chickens grow quickly, are easy to rear and well sited for wet and heavy rainfall regions.

There are two varieties of the Rhode Island Reds : the single comb and the Rose-comb which are otherwise identical. The single comb variety is more popular of the two. The standard weight of this breed is cock-5 Kg, hen-3 Kg, cockered-4 Kg and pullet-2.5 Kg.

New Hampshire. The New Hampshire is a relatively recent Island Red stock. Because of its unusual hardiness, it has gained great popularity in India. Its popularity is also due to its rapid growth, early maturity, fertility, hatchability and good laying capacity. The standard weights are the same as those of the Rhode Island Red.

Asiatic Class

The important members of this class are Brahma, Cochin and Langshan. They are not of any special value for their flesh but these breeds together with those of the Mediterranean class have formed the centre for the progressive development of new breeds and varieties. Fowls of this class mature slowly, are poor foragers and persistent sitters.

Brahma. The earliest Brahma is said to have come from India in the Brahmaputra area, where the fowls of original type, commonly known as 'Grey Chittagongs' are still to be found. This breed is massive in appearance and is one of the largest domesticated chickens. The standard weights of this breed is cock-6.5 Kg, hen-4.5 Kg, cockered-5 Kg and pullet-3.5 Kg.

Cochin. This breed hails originally from the Shanghai district in China and was called as the Shanghai fowl. The breed may be Buff, White, Black or Partridge. Its outstanding characteristics are a massive appearance and well feathered shanks. The feather is long and profuse, which makes the bird appear larger than it really is.

Langshan. This has its origin in the Langshan district of China. As compared with Brahma and Cochin, the Langshan has a shorter but deeper body. It is graceful bird with well proportioned body and with a single comb. The standard weight of this breed is : Cock-5 Kg, hen-4 Kg, cockerel-4.5 Kg and pullet-3 Kg.

English Class

This class comprises of six breeds like, Sussex Oprington, Australorp, Cornis, Dorking and Red cap.

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Sussex. The breeds of this class are provided with prominent breast, and are well developed with excellent fleshing qualities. Fowls of this breed have single comb and horn, coloured beaks, shanks and toes. There are three varieties among the sussex as the light sussex, the Red Sussex, and the Speckled sussex. The Light sussex is the most popular among them, and although originally a meat breed, good laying strains have since been developed which make it a good all-round utility bird. The standard weight of this breed is cock-5 Kg, hen-3.5 Kg, cockered-4 Kg and pullet-3 Kg.

Orpington. It is generally a good table bird, but good egg laying strains have also been developed by selective breeding and management. It has single comb. The bird may be Buff, Black, White or Blue. Of these, the buff variety is the most popular. The black is also important as it has led to the development of an increasingly popular breed-the Australorp of this class. The standard weight is cock-5.5 Kg, hen-4 Kg, cockered-4.5 Kg and pullet-3.5 Kg.

Australorp. This breed was developed in Australia form the black orpington. It is developed as good egg layer and considerable amount of flesh is obtained from this breed which make it a good dual purpose breed. This breed is gaining more and more popularity in India, and like the Rhode Island Red is well suited for small-sized flocks in the 'backyard' type of poultry keeping, especially in the wet and heavy rain fall regions. The standard weight of the bird is : cock-4.5 Kg, hen-3.5 Kg, cockered-4 Kg and pullet-3 Kg.

Cornish. It is originally known as Cornish Indian breed which is said to have been developed in England from the crossing of Indian Aseel and the Malay, and English Game breeds. It is reputed for its close feathering and compact well-flashed body which has a distinctive shape. The standard weight is cock-4 Kg, hen-3 Kg, cockered-3.5 Kg and pullet-2.5 Kg.

Dorking. The dorking, like the Sussex, are characterised by long, broad, deep and low-set bodies. Dorking has a rose-comb and the other two varieties have a single comb. All Dorkings have five toes. The standard weight is cock-5 Kg, hen-3.5 Kg, cockered-4 Kg and pullet-3 Kg.

Red Cap. The name 'Red Cap' is derived from the large rose-comb which is the characteristic of this breed. It is medium-sized bird possessing a fairly long body and a rather prominent breast. The standard-weight is cock-4 Kg, hen-3 Kg, cockered-3.5 Kg and pullet-2.5 Kg.

Mediterranean Class

There are six breeds classified as Mediterranean because of their origin from the Mediterranean region. These breeds are Leghorn, Minorca, Ancona, Spanish, Andalusian and Buttercup. The fowl of this class are small sized, mature early and good foragers of active temperament but they are non sitters. The maintenance of the fowl is economical as their food requirements are comparatively less. They are good layers. *(Z–37/Eco. Zool.)*

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Leghorn. Leghorn is small, active and known for the harmony of its different parts. It has a relatively long back, prominent breast and comparatively long shanks. The common varieties of Leghorn are white, brown, black and buff. Some less common varieties are silver-red, black-tailed Red and the Columbian. The white variety has gained popularity all over the world. Next in order of popularity are brown and black. The white, buff and brown varieties are sub-divided further on the basis of the character of comb *i.e.* whether it is rose or single comb.

White leghorn. It was first introduced into India by foreign missionaries and tea planters about 80 years ago. This variety is not ideal for meat purposes. In India, white leghorn has given good results especially in drier regions, while it does not seem to thrive and produce well on heavy soils and in wet areas. It is most popular as egg producing breed. It matures within 5.5 to 6 months, when pullet start laying.

Brown leghorn. This breed seems to be hardier than the white leghorn and its colours, especially in the chicks, serves as a natural camouflage against predators. This breed is also equally popular because of its excellent productive capacity. It is used for upgrading desi-fowls in areas where birds of white colours are not preferred.

Black leghorn. It is not as good layer as the white or brown varieties and is usually mistaken for black Minorca, but can be easily recognised by their head and body conformation of Leghorn. This variety has no special advantage over the other variety of the breed.

Minorca. It is noticed for its length of body, large comb and long wattles. In fact it is largest of the Mediterranean breeds. There are black, white and buff varieties. The black and white varieties are further sub-divided into the single and rose comb varieties. The most popular is the single comb black Minorca which has an attractive metallic black plumage and an unusually large comb. They are good layers and produce large-size white eggs. The chickens grow fast and are good for table purpose. The standard weight is cock-2 Kg, hen-1.5 Kg, cockered-1.5 Kg and pullet-1 Kg.

Ancona. The Ancona is of the same general type as the Leghorn. The breed has both the single-comb and rose-comb varieties, of which the former is relatively more popular, although the breed as a whole is not so much favoured as the white leghorn. The standard weight of this breed is cock-3 Kg, hen-2 Kg, cockered-2.5 Kg and pullet-1.5 Kg.

Breeding in Fowls

For successful poultry keeping, systematic breeding of fowls must be practised. The following care should be taken and kept in mind :

(1) The largest and best farm fowls should be selected.

(2) The weak, sick and stunt birds should not be taken for breeding.

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(3) Hens should always be best layers.
(4) Two years old hens should be selected to breed with the cocks of one year age.
(5) The male fowl should be of different family from the hen with which mated.
(6) The hen must be mated with a cock superior to her.
(7) For successful breeding nutritive food and intelligent management is essential.

For the breeding purposes the cock, selected, should have good size, bone, flesh, broad chest and colour. He should be active, healthy, energetic, young and of one year in age. The hen chosen for breeding should be equally good having almost the same qualities as the cock. If she is active and young she can lay a good number of large eggs. The number of hens allowed to mate with one cock should be limited and in no case be more than four.

Cross Breeding

For cross breeding purposes a good knowledge of the characteristics of different breeds is essential because all crosses are not good. The first cross of both, the pure hen and pure cock, is the best egg laying but should never be used for further breeding. For cottage industry of the rapid production of eggs and fowls for human consumption, the breeding of cross-breed fowls can be made.

Selection of Best Layer

It is very difficult to select the best layers among the hens. An active intelligent-looking bird, with a bright comb, would always be the better layer than the dull and lazy hen. The thin, sickly, sluggish and poorly feathered hens should always be avoided for breeding. It is said that the greater the capacity the better the layer. The hen in which pelvic bones are fine and wide apart will be good layer. One has to be careful that a very fat hen will not at all be a good layer. Hence the hens should neither be very fat nor too thin.

Eggs and Hatching

The hens normally start egg laying from February and continue till August with some intervals. The hens undergo moulting from July to August so should not be forced for egg laying. Few hens lay form October to January. The best time for egg laying depends upon the climate of a particular region. The rainy season is the best time to raise chickens, because :

(1) there is availability of green food for birds.
(2) plenty of animal-foods are also found available.
(3) the trees and shrubs are in full foliage to provide protection and shed to the fowls.

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(4) the chickens raised in this season grow fast and attain large size which can easily survive in cold season.
(5) the eggs of rainy season are very fertile and hatch out well.

But the chickens should be well protected from frequent showers and heavy rains. The chickens hatched from October to the end of January, develop very well throughout India except the hills. The most favourable period in the plains of India is from January to April.

Selection of Eggs

The selection of eggs is very important so following care should be taken :
(1) The eggs of best hens must be set.
(2) The fresh eggs (3-5 days old in hot weather, and 7-10 days old in cold weather) must be set.
(3) The eggs of too small and too large size must be rejected. The eggs should be of ordinary size and of smooth surface which should only be allowed to hatch.

Treatment of Eggs

After placing the eggs under the hen, one should see every day that they are all right because sometimes eggs get broken in the nest. If any egg is broken the remaining eggs must be removed, washed with water, dried and the ashes and earth of the nest should also be changed. The water used for washing must be at 102°F. The cleaned and dried eggs should be placed under the washed hen in new nest. The infertile and addled eggs must be removed from the nest. The fertility of eggs can be tested by taking a cardboard having a hole of an egg shape. The eggs for testing should be held on the hole against strong light. If the egg is found transparent it is infertile but if small dark body is observed floating in the centre of the egg, it has an embryo. This test should be performed after 14 days of egg setting. Another method for testing eggs is to place the egg after 20th day of setting in a large bowl having warm water (102°F). After one minute the eggs, with live chickens, will start wriggling in water whereas infertile and addled eggs will float on the water surface. On the 20th or 21st day of egg setting the chickens usually come out of the shell. The chickens after emergence do not take food up to 30 to 36 hours, so they must be with mother undisturbed for the minimum period of 24 hours.

Precautions for Hatching

At the time of hatching following care should be taken :
(1) Hen should be set at night in a well ventilated and semidark place.
(2) Seven or eight eggs should be placed under one hen.
(3) Before, setting, hens should be examined that they are free from insects. If they are carrying some insects they should be dusted with suitable insect powder.

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(4) Care should be taken of that the hens come out of the nest daily for food. The maize should be given to hen daily. The fresh water and a dry dust bath should also be given daily.
(5) Hen should be left alone at the time of hatching of the eggs.

Rearing of Chickens

The chickens during their growing stage must be kept under proper management. Different breeds need separate type of nourishment, shelter and exercise. After 36 hours of hatching chickens should be taken out of the old nests with the mother, placed in a clean box or on clean floor under a basket at a dry and warm place. The mother should be given good nutritive food and should be placed with her chickens in the box. After every interval of 2 hours, the food must be given to the chickens in very small quantities. The best food for chickens up to the age of 3 days is stale bread-cumbs moistened with milk and oat meal and broken wheat. Upto the age of 45 days chickens must be fed six times daily. After 45 days to six month's age they must be fed 4 times daily. First feed of the day should be given just after sunrise and last at sunset. Feeding board should alsways be clean. A very small quantity of 'Poultry powder' given in the soft food to chickens is found to be very much beneficial. A little finely-chopped onions and garlic should be given twice a week. After the age of 45 days, half-cooked meat and raw onion with wheat-bran should be given at an interval of one day. The earth-worms and white ants are very nutritive for chickens and they feed on them voraciously. After 3 months of age, oil-cake should be given to the chickens once a day.

The perfectly clean water should always be kept before the chickens. Very small quantity of potassium permanganate should also be added to the drinking water to protect the chickens from sickness and other troubles. The overfeeding of chickens causes greatest danger to their liver and heart.

The standard ratio of chicken food of 100 Kg is given here as under :

Finely cracked wheat	40 Kg
Finely cracked maize	40 Kg
Cracked rice	10 Kg
Bajra	5 Kg
Cracked charcoal	2.5 Kg
Cracked granulated bone	2.5 Kg

When chickens attain the age of six months, they should be fed three times a day on grain, green food and moist mash at morning, noon and at evening respectively.

Diseases of Poultry

The poultry keeper should always be careful against the diseases. The most common disease amongst fowls in RANIKHET DISEASE which is caused

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by a filter-passing virus. The disease affects the fowls of all ages. In this disease bird opens the beak, becomes thirsty, suffers from fever and yellowish white diarrhoea occurs. The crop contains undigested food and the beak is filled with mucus. It is followed by nervous symptoms like twisting of the head, circular walking and wings get paralysed. The birds become very weak and die within 2 to 3 days. Mortality is very high, about 98 to 100%. If a bird recovers it has immunity for life. This disease is transmitted from one fowl to another due to contact with the mucus discharged from the beak. The Indian Veterinary Research Institute Mukteswar (U.P.) has prepared a vaccine which is a boon for poultry industry. The dead birds should be properly disposed off by burying or burning. The chickens should be vaccinated as they attain the age of 40 days.

The other common diseases are loss of feather, feather-eating and egg-eating which can be cured by giving large run and some of the poultry powder or tonic mixture.

Some diseases are serious but not infectious *viz.*, Apoplexy, caused by over feeding; Bumble food due to very large size; Cramps due to exposure in wet or cold: Crop bound, due to over feeding, Diarrhoea, due to over-feeding and dirty water, Dysentery, Liver disease etc.

Some diseases are contagious like Chicken-pox, Cholera, Cold etc. The birds should be destroyed and burnt or buried.

The disease caused by a tick is known as Spirochaetosis (tick fever). The parasites feed on the blood of fowls in night and leave them during day time. For the prevention of this parasite poultry houses should be made up to 'All metal'.

It is advisable for poultry keepers that 'prevention is better than cure' so they must be careful that the fowls should not be attacked by their enemies.

Poultry Products

The main products of poultry farming are eggs and meat in addition to some by-products like manure, feather etc. In India, the primary aim of poultry farming is to obtain egg. The old, surplus and weak stocks are used for the table. The eggs and poultry meat are among the richest sources of protein and vitamins.

Egg

Eggs contribute to the palatability of a variety of dishes and constitute a rich source of easily digestible animal protein. Eggs are regarded as one of the good sources of vitamin A, riboflavin, phosphorus and iron. As per weight for weight data, an egg contains same quantity of animal protein as poultry meat and pork, about two-thirds that of whole milk cheese, and three-quarters that of beef. Eggs are coagulated on cooking. They provide appetizing foods

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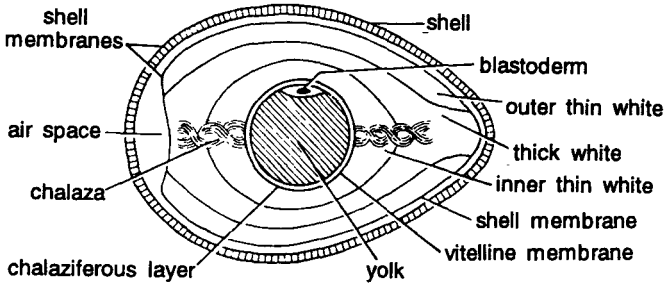

Fig. 1. Structure of egg.

when fried, boiled and poached. They have a leavening (fermenting) action in some foods such as angel food cake and sponge cake, a thickening action in custard, a combining action in noodles and doughnuts. The eggs are used as binding and coating agent during the preparation of soft breads. The formation of large crystals in ice-cream and candy can be reduced or checked by adding the eggs. The egg albumen acts as a clarifying medium for coffee or soups. It is very much useful in many non-food industries due to the adhesive and coagulating nature of egg white. The number of eggs used for other commercial purposes eg. glazing, book binding, medicinal or pharmaceutical preparations, tanning etc. is comparatively very small.

As regard the structure of egg (Fig. 1), it is one of the most wonderful things in nature because of its ability to develop and produce independent life under favourable conditions. The general shape of egg is irregularly ovoid in that one end is broader and some what flatter than the other. This difference in the shape between the two ends is of considerable significance in the development and hatching of embryo. The egg consists of shell and shell membrances 12%, albumen and chalazae 56% and yolk 32%.

Shell. The shell of an egg composed, mainly, of inorganic salts (chiefly calcium carbonate) forms the hard, rigid and porous protective covering for the soft contents within. The pores allow interchange of moisture and gases like oxygen and carbon dioxide between the egg contents and the outside atmosphere. The number of pores per unit area of the broad end is must larger than that found any where else on the surface of the egg. The outer surface of the shell is covered by a thin cuticular structure. Of the two principal layer of shell, the outer is thin, relatively dense and compact, and protects against the entry of bacteria and other unwanted micro-organisms. The inner layer of the shell is granular and besides assisting in maintaining the strength and rigidity of the shell, serves as a source of calcium for the growing embryo. Inside the shell, there are two rough and fibrous membranes, one attached to the shell and the other to the thick white. As the shell contents shrink with cooling and evaporation of moisture, the membranes separate to form the air-cell, usually found at the

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broader end of egg. The outer membrane can only be separated from the shell with greatest difficulty.

Albumen (Egg white). The albumen of the egg consists of four different layers. The outer layer of the thin white is just inside the inner shell membrane and forms about 20% of the total white. This layer is directly in the contact of shell membrane except at both the ends of the egg where the thick white comes in contact with the shell membranes. Inside the outer thin white, the layer of the thick white is found which constitutes about 50% of the total white of an egg. Enclosed within thick white is the inner layer of thin white. The inner most very thin layer of thick white surrounds the vitelline membrane that encloses the yolk. The main difference between the thick and the thin is due to the presence of the 'mucin' in the thick white. The chalazae are the coiled cords of thick white, twisted in opposite direction, arising from the thick white layer at each end and terminating in the chalaziferous layer (inner thick white). The chalazae keep the egg yolk nearly in the centre of the egg and give protection to the egg against rough handling. It also helps the yolk to turn easily within the white. The chalazae significantly are of more value as they ensure uniform temperature for the developing embryo during incubation. The white acts as a shock-absorber, protecting the embryo and yolk from damage, and as a source of food for the growing embryo.

Yolk. Beside the blastodisc, the yolk (yellow portion) is the only part of the egg that has its origin in the ovary. The other parts of egg like shell membranes, albumen and shell are added one after another during the passage of the egg through the oviduct. In a fresh egg the yolk rests slightly above the centre because it is lighter than the albumen of egg. The shape of a fresh egg is usually spherical but if egg is kept for some time, the yolk increases in size by taking water from the white and shows a relatively flattened shape than of the fresh egg. The blastodisc or female germ cell is essentially found in the egg but futher development of the egg starts after fertilization by the sperm. Therefore, for incubation only fertile eggs should be taken because the infertile eggs are incapable of development so, they should be disposed off soon.

Composition of egg. The actual composition of egg is based upon the breed of the bird, their habitat and the ecological conditions of the region where poultry farm is located. Whole liquid egg (excluding shell) consists of 36% yolk and 64% white. Protein is the major constituent of white and rest of the white is formed of small amount of sugars, minerals and fat. The two third of solid yolk is fat and one third is protein. The nature of yolk protein is different to that of white. The other constituents of yolk are lactic acid, creatine, creatinine choline and alcohol.

(a) Carbohydrate. The sugar (glucose) constitutes the major carbohydrate part in the egg. The glucose is more in egg white in comparison to the yolk. An average of glucose content in the hen's egg is as healthy egg-0.45%, egg white-0.47% and egg yolk-0.14%. The egg contains very small amount of

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carbohydrate which yields a reducing sugar on hydrolysis. It is notable that sugar in free form causes heavy deterioration, if present in dry egg products. So, free sugar is eliminated from eggs before drying either by fermentation or by enzymatic oxidation to gluconic acid.

(b) Proteins. Protein constitutes 12% of an egg, of which 64% is from egg white and the rest by yolk. Ovalbumin constitutes about 70% of the total protein in egg white and identified into A_1, A_2 and A_3 proteins. During the storage of eggs this protein is converted into a more stable form 'S-ovalbumin' which is highly resistant to denaturation. Another protein in egg white is canalbumin which is about 17% and reported to be found in two forms like ovomucoid and lysozyme. The egg yolk proteins include vitellenin, livetins, phosvitin, phosphoproteins, lipoproteins, lipovitellin and lipovitellenin. The egg proteins contain all of the essential amino acids required for the development and growth. The egg proteins have been found to be of higher biological value in comparison to the proteins of meat, soya been, milk, wheat, ground nut etc. The protein of egg white is comparatively highly nutritive than that of egg yolk. The egg proteins possess the functional properties of coagulation, foaming and emulsification which are also significant for the consumers of eggs.

Non-protein nitrogenous substances. The non-protein nitrogenous substances like lecithin, free cholin, ovine, and other baser are also identified in the eggs.

(a) Lipids. The ether-soluble lipids amount to 30-35% of the fresh egg yolk (60-70% on dry basis), and the phosphatids 4 to 12%. Component fatty acids of the glyceride and the phosphatid fractions of the egg yolk are palmatic, myristic, stearic, oleic, hexadecenoic, linoleic and unsaturated C_{22} acid. The yolk of hen contains 1.8% of cholesterol.

(b) Vitamins. Eggs are very good source of riboflavin, vitamin A and vitamin D. The different vitamins present in egg are vitamin-A, vitamin-B_{12}, vitamin-D, vitamin-E, vitamin-K, riboflavin, folic acid, niacin, thiamine, pentothenic acid, biotin, choline chloride, pyridoxine and inositol. The losses in vitamin contents during storage of egg is very low.

(c) Enzyme. Some of the enzymes like amylase, diastase, peptidase, phosphatidase, oxidase, various proteolytic enzymes, mono and tributyrases, catalase, tryptic proteinase, lipase, erepsin and salicylase are reported to be present in the egg.

(d) Minerals. Eggs are rich in mineral contents. The minerals like-calcium, iron, phosphorus, sodium, potassium magnesium, sulphur, zinc, chloride, manganese, iodine, copper, fluorine, selenium are reported to be present in the egg. The trace elements present in the egg include lead, chromium, aluminium, molybdenum, strontium, vanadium, titanium and barium.

(e) Pigments. The carotenoid of egg yolk are lutein and zeaxanthin. Ovoflavin, a nitrogenous pigment is also found to be present in the egg. The

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brown pigment of egg shell is Oorodein, which is identical with hematoporphyrin. The blue-green colour of egg shells, named oocyan, is considered to consist, in part, of the bile pigment biliverdin.

Clearing of egg. After laying eggs may become dirty due to so many factors. The dirty eggs should never be washed with ordinary type of cold water. The shell of egg should not be rubbed with the wet cloth or sand paper. For clearing the dirty eggs, sanitizer and detergent (1% sodium hydroxide) solutions are used. Further it should be washed for 5 minutes in warm water (40 to 43°C) containing a detergent. The egg washing equipment has been developed by the central Food Technological Research Institute, Mysore. With this equipment 1000 to 1500 eggs are properly washed within one hour. This can be used advantageously for clearing eggs on a commercial scale.

Preservation and processing of eggs. The production of clean and whole-some eggs has received considerable attention in the developed and developing countries of the world. Eggs are used for household purposes, for confectionery and for other industrial purposes. About 95% of the eggs are used for table and cooking purposes and remaining 5% are used in confectionery. The urban demand of egg is of prime importance from marketing point of view. In India 20% of the eggs produced do not reach the consumers in a good condition and deteriorate during transport from the place of production to the place of consumption. According to the survey made by the Directorate of Marketing, Ministry of Food and Agriculture, Government of India, the deterioration in the quality of eggs is due to the various factors *viz.*, hot weather condition, storage in warm dry places, dirty eggs, fertile eggs, ungraded eggs and defective packing and handling. It is recorded that 5% of entire spoilage of egg is due to the bacterial contamination. The uncared eggs deteriorate quickly. So, eggs should be collected within a few hours after being laid. The preservation of the quality of egg is of great importance in marketing. The problem is however, beset with great practical difficulties, especially under conditions of village production. For the proper care freshly laid eggs are taken to the egg room, maintained at 16°C and 75% RH, and cooled as soon as possible. Even in cool weather, eggs deteriorate when left in the nest in which hens are laying. Eggs should be collected in suitable wire baskets atleast two or three times daily. The following measures are found to be useful in preserving the eggs.

Production of infertile eggs. The fertile eggs deteriorate rapidly than the infertile eggs at suitable higher ranges of temperature so, the production of infertile eggs instead of fertile ones helps in preserving egg quality considerably. Infertile eggs can be obtained by separating the cocks from the hens except during the breeding seasons. It is common impression that the presence of a male bird is necessary for the hens to lay eggs. Hens are capable of laying without the presence of cock bird and the eggs thus obtained are infertile. But this is, however, not always possible under the existing conditions of poultry rearing in rural areas, therefore, defertilization of eggs has to be recommended.

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Defertilization. For the defertilization, eggs are kept in hot water maintained at a temperature range of 135°F to 145°F for about 15 minutes to destroy the germ. The defertilized egg is equally good as infertile egg and can be kept without deterioration for longer period. In villages, an ordinary long, wide mouthed tin vessel is used for maintaining temperature between 135°F to 145°F. Eggs to be defertilized are put in an open basket of wire and dipped into the hot water for 15 minutes after which they are removed and stored in some cool places. In well organised poultry centres, somewhat more elaborated defertilization plants are installed at little cost which consists of water tanks with mechanical stirrers electrical heating arrangements, some wire baskets and egg cooler.

Egg cooling. It is well known that temperature above 68°F is favourable for the development of embryo and consequently makes for rapid deterioration of egg quality. A temperature below 68°F is suitable for maintaining the quality and freshness of the egg. In winter season, cooling devices is not needed when temperature is normally below 68°F but when temperature is higher than 68°F, a cooling device is necessary. The ideal of course, is refrigerated coolers. Some of the cooling systems which can be adopted by poultry farmers are given below.

(a) Cool room. Egg room can be cooled by providing all the outlets with khus tattis kept constantly moist by sprinkling water on the floor. If possible, a ceiling fan will be very much helpful for cooling the room.

(b) Underground cellar. If a cool room is not possible an underground pit should be made which can provide desirable low temperature for the proper cooling of eggs.

(c) Earthen pot. A large earthen pot can be maintained at lower ranges of temperature by keeping it partially buried in a sand heap on which water is sprinkled frequently. In the bottom of pot a layer of dry straw or hay should be kept to avoid the percolating dampness. The pot should be kept in well ventilated place and the mouth of the pot should be covered with thin muslin so that air and moisture can pass freely inside the pot.

(d) Cold storage. The egg quality is fairly well maintained for about nine months in cold storage at 0°C and 85% RH. In India the cold storage of egg is now under practice in well organised poultry farms but in rural areas where refrigeration facility is not common, the cold storage of eggs has been taken upon a large scale.

Freezing eggs. It is one of the best means of conserving the quality of eggs. In this method deterioration is arrested, and the frozen eggs can be held in cold storage for an extended period until needed. In this method, shell eggs are placed in cold storage to preserve the quality. After thorough chilling, eggs are taken to candling room. After the eggs are candled, they are transferred to the breaking tables, where the shell is broken against a blunt knife located above a small tray which is supplied with cups to hold the contents of the egg. Separated

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yolk, and white, or mixed whites and yolks, can be preserved through freezing which checks the growth of bacteria. Frozen whole eggs are used for preparing cakes, pastries, ice-cream etc.

Drying eggs. The drying of eggs is more convenient way of preserving the eggs than even freezing. The drying process reduces eggs to about one-fourth of their original weight, so that about 70 normal-sized eggs make 1 kg of the dried product. The dry egg products like dried whole egg, dried yolk and dried whites, are prepared in farms. In this method the egg pulp is forced under pressure into a drying chamber and sprayed through a nozzle. The incoming air is held at higher ranges of temperature while the exhaust air has a temperature of lower ranges. The spray dried product is usually a fine powder while the pan dried product is made up of flakes or scales which can be ground into powder.

Lime sealing of egg. The lime sealing of eggs prevent the evaporation of moisture and escape of carbon dioxide through shell pores. For lime sealing, shell eggs are dipped for about 18 hours in lime water, containing powdered salt.

Oil coating of egg. The oil coating of shell egg for conserving the quality of egg is an economical and convenient method for common poultry farmers. The oils used for this purpose are carnation oil, a white mineral oil refined from paraffin and coconut oil. The Central Food Technological Research Institue, Mysore has developed a perfect method in which eggs are coated with an oil based on a petroleum product to which some fungistatic and bacteriostatic agents are added. The eggs, kept in wire baskets are dipped for 5 to 10 seconds in a vessel containing the coating oil. Further, baskets having eggs are taken out from the vessel and hung on a hanger for about one hour. During this period fan can be used for proper drying of oil coated eggs. The dried eggs are ready for storage. The coating oil in the vessel can be used for many times with proper filtration and sterilization so that oil may not get dirty. The oil coated eggs can be kept for about 30 days at room temperature (25-27°C) and 80 days at 13°C. Oil coating should be done as soon as possible after the eggs are laid. The oil should be colourless, tasteless and odourless.

Water-glass method. It is a good method for preserving the quality of eggs. For this purpose, commercial water-glass (sodium silicate) is mixed with cooled boiled water in a definite ratio and is kept in an earthen pot and both are mixed thoroughly with an wooden piece. Eggs are dipped in the above solution and covered pots are kept in a cool place.

Products of egg. A number of useful products like albumen flakes, frozen egg yolk and egg powder are prepared from eggs.

1. Albumen flakes. For the preparation of albumen flakes, the thick albumen of egg is broken by the microbial fermentation and glucose is removed. Now this content is acidified and dried in the form of albumen flakes. The albumen flakes are used for the preparation of sensitive mixtures for coating zinc or

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aluminium foils for offset printing. The flakes are also used for the tanning of costly leather.

2. Frozen yolk. The yolk obtained as by product during the processing for albumen flakes are used as such or frozen for use in various purposes. The major products of frozen yolk are plain yolk, sugared yolk, salted yolk and yolk emulsions. Sugared yolk and salted yolk is mixed with 10% sugar and salt respectively which acts as anticoagulant and minimise the chemical changes in yolk during freezing but they affect physical properties of yolk. Another method for the preservation of frozen yolk is by the addition of 6% sodium chloride and 1% of sodium benzoate to it. The frozen yolk after treatment with 0.04% pepsin, can be kept undamaged for about four months.

3. Egg powder. For the preparation of egg powder, eggs are cleaned in running water, dipped into 2% solution of bleaching powder. The cleaned eggs are broken and liquid thus obtained is churned and filtered to separate pieces of shell and chalazae. For the removal of sugar, 0.5% yeast is added and kept at 36°C for 1.5 hours. Now fermented liquid is pasteurized at 60-61°C for about 30 minutes, cooled and 1 N HCl is added to bring the pH to 5.5. This solution is spray dried at an inlet temperature of 160°C and an outlet temperature of 60°C, keeping the automizer at 20,000 r.p.m. Thus the egg powder is obtained which is further kept in vacuum self-drier at 60°C for about 3 hours. In this powder 1.2% sodium carbonate is added and is canned in sealed containers. The egg powder thus obtained consists of moisture 13-15%, protein 45%, lecithin and fat 38-40%.

The dried egg powder can be kept for long period even at higher ranges of temperature. It is very easy to transport the egg powder and the proteins are with the same amino acids as in shell egg. For the preparation of custards, pies etc. the egg powder is commonly used.

Poultry Meat

The use of poultry birds for table is gaining more and more importance in our country which is managed either as a separate enterprise or in conjunction with commercial egg production. The birds for table should be well-fleshed on thighs and breast, fast growing and should have ability for high ratio of gain in live weight to the feed consumed. The weight of mature chicken may vary from 1 Kg to 5 Kg according to the species and feed of birds. The leg represents more of total weight in male chicken in comparison to the females. For the purpose of human consumption, poultry meat should be soft, sound, clean and healthy. It contains less fat than other meats. The tenderness and flavour of meat is influenced by the age and sex of the bird. Chicken upto 85 days of age have a very tender meat and between 85 to 115 days of age have tender meat which can be cooked by roasting. The meat of mature hens is not soft for table purpose.

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Composition of poultry meat

The use of table birds is gaining more and more success as meat is a good source of protein, vitamins B, phosphorus and iron. The losses of these constituents are least during the course of cooking particularly with respect to vitamins B.

Nitrogenous substances. The protein of poultry muscle consists of extracellular protein which includes actinomyosin, globulin X, myogen and myoglobin. In addition, other nitrogenous substances like creatine, carnosine, anserine, adenosine triphosphate, urea, ammonia, uric acid and amino acids are found to be present in crude poultry muscle. The bones are made up of calcium phosphate and collagen. The collagen of skin is changed to gelatin at the time of the poultry cooking which gives a desirable flavour to the soup. The poultry proteins are provided with highly digestible constituents and essential amino acids.

Fat. The distribution of fat constituent varies in accordance with the age, sex, nutrition of the bird and tissue. The abdominal tissue contains about 80% fat, while the breast tissue contains very low (0.3%) fat percentage. The fat may be either neutral fat or phospholipids which contain tetraenoic, pentaenoic and hexaenoic acids. The acidity of the fat is taken as an index of freshness. The increased acidity of fat indicates the deterioration in the poultry meat.

Enzyme. Many enzymes like lipase, catalase, oxidase, peroxidase, reductase, amylase, invertase, glycogenase, maltase, proteinase and antitrypsin are found to be present in the poultry fat and muscles.

Minerals. A large number of minerals like calcium, potassium, sodium, iron, phosphorus, magnesium, chlorine and sulphur are reported to be present in the poultry muscles. Phosphorus and iron are found in good quantity. The trace elements like copper, iodine and manganese are also present in the poultry muscle.

Vitamins. The poultry meat is very good source of riboflavin and nicotinic acid which is directly related with the nutrients given to birds. The other vitamins like vitamin A and vitamin D are present in the liver. The dark muscles of chicken are good source of thiamin and rivoflavin.

Processing the Bird for Meat

The killing of bird for table purpose, dressing and evisceration (to disembowel) come under the poultry processing. Some consumers prefer to purchase living birds while some wish to buy dressed bird as per their requirements.

Dressing. Before killing, birds should be housed and should be given sufficient food and water. Before 3 hours of slaughter, feed should be taken away from the birds but water should be there for all the time. The carotid arteries are cut for complete bleeding because incomplete bleeding results in a dark, unacceptable product. Feathers are removed by immersing the bled bird

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in water at particular temperature for 3-5 minutes which is termed as scalding. Further, feathers are removed by hands or by some simple mechanical measures. The hairs from carcasses are removed by passing them through a hot flame after drying.

Evisceration. Commonly birds for table are purchased in eviscerated or ready-to-cook form so proper care must be paid to save from bacterial infection, rancidification of fat and much moisture losses.

Chilling and freezing. Just after dressing, the carcass should be first kept below 4-5°C and further at 0°C. The process of chilling is performed by slush ice for sudden fall in the body temperature of carcass so that excessive desiccation of the carcass may be checked. Thus, the carcass can be stored in good condition for 20 to 30 days. One should take care that faeces of the bird itself may not come in contact with the carcass to avoid the contamination during this process. During the course of chilling, the free amino acids and basic nitrogen content of meat slightly increases but at the expense of proteins.

If the poultry meat is kept below-9°C temperature, the losses due to microbiological activity ceases as a result the souring and sliming of meat do not affect the quality of meat. Now-a-days, with the advancement of poultry industry in India, large poultry processing system have been established at various centres which have very good capacity for the poultry processing.

Canning. For facilitating the distribution and storage of surplus poultry meat canning is very useful method for maintaining the quality of meat. In canning, the meat is sterilized and protected by a pack container particularly where refrigeration facility is not available.

Meat Products

Canned chicken. The old hens after the age of 20 months become uneconomical for egg laying so they are canned for regular supply of poultry meat. The central Food Technological Research Institute, Mysore has developed methods for canning solid-packed processed chicken in the form of whole chicken, whole boneless chicken, cut-up chicken without bone, cut-up chicken with bones and selected parts such as breast, thigh etc. In the process of canning, chicken broth and chicken jelly are obtained which are used in the preparation of tonics.

Sausages. The small pieces of meat obtained from old hens, roosters and culled birds are mixed with vegetables and after seasoning with spices they are converted to sausages. The product consists of moisture-62-65%, protein-15-17%, fat -15-17% and carbohydrates -3-4%.

Chicken essence. The pieces of meat of healthy young chicken are partially hydrolysed with boiled water and extract is concentrated under vacuum. Further, this concentrated extract is sterilized and fat is removed and diluted to required

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standard. Now suitable preservatives are added and the contents are sealed packed.

Baby food. Some of the baby foods, as a good source of protein, iron and nicotinic acid, are prepared by the meat and broth. The skin and bones are used for the preparation of skin paste or dehydrated product. The baby foods are devoid of any fibre.

By-products of Poultry

Feathers. The feathers of poultry birds are of good commercial purpose. They constitute 4-9% of live weight of bird. They are washed, dried and packed for commercial uses. Feathers are utilized for making pillows and quilts. Due to their light weight, softness and high insulating power the down feathers are of great demand in foreign countries. Since long feathers are under use for making shuttle cocks.

Poultry manure. The poultry manure, obtained from the dropping of poultry birds, constitutes nitrogen 2%, phosphoric acid 1.25% and potash 0.75% so it is highly valuable for the standing crops in the field. Forty birds can give nearly a ton of deep litter per year which is sufficient for fertilizer needs of a hectare of maize or paddy.

By-product feed. A number of poultry by-products like blood-meal, feather-meal, poultry by-product meal and hatchery by-product meal are used as good sources of nutrients for meat producing animals and poultry. These by-products supply protein, essential amino acids, fat, vitamins and good amount of minerals. The feathers obtained from poultry slaugther house are treated under high pressure and feather-meal or hydrolysed feather is formed which contains 80% protein of which 70% is highly digestible. To obtain the poultry by-product meal the dryrendered parts of the carcasses of slaughtered poultry like head, feet, undeveloped eggs, gizzard and intestine are grounded. A mixture of egg shell, infertile and unhatched eggs and culled chicken are cooked, dried and grounded to obtain poultry hatchery by-product meal which contains calcium 18.1%, 413 mg/ 100 g of phosphorus and essential amino acids.

IMPORTANT QUESTIONS

» ***Long answer type questions***

1. Give an account of different breeds of fowls.
2. Give an account of poultry products.
3. Give an account of the breeding in fowls, hatching of eggs and rearing of chickens.
4. What is egg ? Give the composition, preservation and processing of hen's egg.

» ***Short answer type questions***

1. Write short account of indigenous breed of fowl
2. Write short account of the "Americal class" of the fowl breed.
3. What is Asiatic class of fowl breed ?

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4. Mention about the "Mediterranean class" of fowl.
5. Write short account of the diseases of poultry.
6. Write short account of the preservation of hen's eggs.
7. What is processing of bird (hen) for meat.
8. What are the meat products of poultry.
9. Give an account of the by-products of poultry.

» ***Very short answer type questions***

1. Mention about Rhode Island Red' breed of fowl.
2. Write about "White leghorn" breed of fowl.
3. Define selection of "best layer" in fowl.
4. What are the precautions for hatching of hen's egg ?
5. What is Ranikhet disease ?

» ***Objective type questions***

1. Which of the following is not "indigenous" breed of fowl ?
   (a) Aseel (b) Ghagus (c) Chittagong (d) Brahma
2. Which of the following is "Asiatic class" breed of fowl ?
   (a) New Hampshire (b) Plymouth Rock (c) Langson (d) Aseel
3. Which of the following is "exotic" breed of fowl ?
   (a) Bustra (b) Ghagus (c) Aseel (d) New Hampshire
4. Which of the following is "English class" breed of fowl ?
   (a) Minorca (b) Red cap (c) Leghorn (d) Ancona
5. The disease of hen 'Spirochaetosis' is caused by :
   (a) Tick (b) Mite (c) Virus (d) Bacteria
6. Ranikhet disease is caused by :
   (a) Fungus (b) Bacteria (c) Tick (d) Virus
7. Cramps disease of fowl is caused due to :
   (a) Exposure in wet or cold (b) Over feeding
   (c) Very large size (d) Disty water
8. Yolk in hen's egg is :
   (a) 22% (b) 32% (c) 42% (d) 52%
9. The whole liquid egg (excluding shell) consists of :
   (a) 16% yolk (b) 26% yolk (c) 36% yolk (d) 46% yolk
10. The 'Sausages', a hen's meat product, consists of :
    (a) 5-7% protein (b) 15-17% protein
    (c) 22-25% protein (d) 27-30% protein

Answers

1. (d)	2. (c)	3. (d)	4. (b)	5. (a)	6. (d)	7. (a)	8. (b)	9. (c)	10. (b)

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14

Dairy Farming

The dairy industry, covering the production, processing and distribution of milk and milk products is unique in its importance as it is concerned with valuable food stuffs universally consumed by man. Milk is the fresh lacteal secretion of milch animals naturally intended for the nourishment of the offspring, but exploited as an article of food by human-beings. The young ones of other mammals survive only upon their own mother's milk but man uses milk of other mammals as additional source of nutrients for his offspring as well as for himself. Man also uses mammalian milk for a variety of preparations like curd, butter, chees, sweet etc. For the proper and regular supply of milk, man has domesticated a number of mammals. The only mammals which have received attention worth the name are cows, goats and buffalos. The other animals like sheep, cammels, asses and mares are milked in certain confined localities but as producers of milk they are of little importance.

The dairy cattle thrive best in areas where pasturage and other green forage are grown in abundance. Extremely cold climates are not suitable because of the lack of green forage and much expense for protecting the animals from the weather. The modern dairy industry is some what recent in origin. In earlier phase cows were kept to furnish milk for the farm family. The marketing of milk began when customers called at the farm or farmers to distribute their milk directly to users. Within the past 100 years advances along five different lines have caused milk and milk products to become important articles of commerce :

(1) The processing of milk by factory system was started in the middle of 19th century, resulting in greater uniformity of product.

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(2) A number of technological advances like concentrating milk and sealing it in container in sterile conditions, distribution of milk in bottles and other advanced processing of milk began.
(3) The first milk sold in towns and cities came from nearby farms. The knowledge of refrigeration of milk not only aided in keeping milk fresh for a longer period but also made possible the shipping of dairy products to all parts of the world.
(4) In earlier days the method of transporting milk to large cities was to ship it on railways. The motor vehicles and paved roads made possible the supplying of fresh milk to markets hundreds of kilometres distant from farms where the milk is produced.
(5) The adoption of pasteurization and the enforcement of laws requiring proper food value in dairy products greatly benefited the entire dairy industry.

Breeds of Dairy Animals

Cow

The number of well recognised cow breeds in India is about fifty. In addition, a large number of other types which do not confirm to any defenite breed characteristics exist, and are treated as non descripts. The non descripts are very poor producer of milk.

The principal breeds of cows are Haryana, Kankrej, Ongole, Rath, Deoni, Gir and Kangayam. Deoni is found in the locality of North-western and western parts of Hyderabad and are good milkers in the region. Gaolao is common in Wardha and Chindwara districts. Gir is good milker and found in Kathiawar, Rajputana and Baroda regions. Haryana is very good milker found in the vicinity of Rohtak, Hissar, Karnal, Delhi and Uttar Pradesh. Kankrej is common in South east of Rann of Kutch and Ahmedabad region and is fair milker. Ongole is also a good milker and found in Guntur districts. Rath is fairly good milker which is found from Rajasthan to North-western part. Shahiwal and Sindhi are very good milker found in Punjab, Haryana and Uttar Pradesh.

Buffalo

The buffalo is generally regarded as a very good dairy animal in India. The breeds of bufallo are lesser than cow. Murrah is very good milker which is distributed throughout Punjab, Haryana and Uttar Pradesh. Jaffarabadi is a good milker and found in forest regions of Kathiawar. The breeds of Nili and Ravi are common near Ferozepur district of Punjab and are very good milk yielding varieties. The Surti are economical milkers and common in Gujarat.

Goat

The goats are used all over India for supplementing deficiencies in milk production. About 20 per cent of the goat population is used for milk production.

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Though there are many breeds of goats, some are used commonly in different regions of India. The various breeds of goat which are good milkers, are Jamunapari in Ganges-Jamuna riverine tracts. Beetal in Punjab, Bar-bari in Uttar Pradesh but not giving good results in Tarai belt; Outchi in Kathiawar and Kutch, Osmanabad in Hyderabad region, North Gujarat in Kathiawar, Kutch and North Gujarat, Marwari in Jodhpur, Surti near Surat, Sirohi in Sirohi and Palampur and Malabari in North Malabar region.

Breeding

Near about the middle of the 18th century, dairy farmers began the improvement of cattle and other farm livestock. The chief practices followed were the mating of related animals and close culling. The rearing and maintenance of proved and standard breed for distribution upto village level is undertaken in Government farms. The bulls are used for selective breeding in areas of well-defined breeds. Attempts are being made to upgrade non-descripts in several areas by repeated forward crossing. These attempts have given encouraging results but the number of bulls available for breeding purposes are inadequate. The progeny of Shahiwal, Sindhi, Haryana or other well defined bulls, yield atleast twice as much milk as the non-descript dam. The second cross shows a further increase in the production of milk.

Considerable amount of cross-breeding using imported bulls, has been carried out during the last 50 years. In the earlier years, the breeds favoured in India were the Ayreshier. A large number of Friesians were later imported which are reported to have given best results. The Indian Friesian yields on an average 4000 Kg of milk per lactation as compared to 5000 Kg given by Friesian cows. The Friesians are regular calvers, their productivity, however, is dependent on the care and attention given to them. These are maintained in favourable areas and moved to the hills in summer. The yield goes down as the percentage of Friesian blood is increased or decreased. It has been found that an increase in the production of Friesian blood increases the capacity to produce but the constitution of animal is not equal to the strain imposed in producing the milk to capacity. Although cross-breeding with foreign breeds improves the milk production, it is not widely adopted as the animals need expert care and management, not usually given to cattle in India. Experience shows that the cow produced by repeatedly back-crossing the half-bred is superior to the cow started with. For more effective utilization of limited number of breeding bulls now available, artificial insemination has been introduced throughout the country. In the very beginning the artificial insemination was followed at regional research centers in Calcutta, Patna, Montgomery, Bangalore and Izatnagar.

For establishing a good goat farm, a beginning can be made by taking a few good milch-yielding mother breeds with their male and female kids. After making a beginning with small number, in about a couple of years, it would be possible to sort out best milk yielding mothers and those not needed for

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participating in the breeding programme, may be castrated at the age of 3 to 4 months and may be disposed off at the appropriate time.

Feeding Stuffs

The feeding stuff for dairy cattle may be broadly classified into roughages and concentrates. The roughages consist of succulent feeds (natural grazing, cultivated grasses, cultivated fodders and root crops) and dry fodders (hay, straw, chaff). The concentrates consist of carbohydrates-rich materials (oil seed, oil seed cake and meals). In addition to roughages and concentrates, dairy animals also require a certain amount of common salt to keep them in good condition.

Investigations in this area show that a number of materials hitherto considered as wastes, can be utilized as cattle feed eg. mango seed, jaman seed, and mahua flowers (concentrates) and ground nut husk, bajra and coffee husk (roughages). In addition to distillary products (malt sprout, millets and molasses) feeds of animal origin eg. fish meal, blood meal and bone meal may be employed as cattle feed. The table below gives information about the feeding stuff, commonly fed to dairy cattle in India.

Dry roughages	Green fodder	Concentrates
Wheat straw	Maize	Gram
Oat hay	Lucerne	Bran
Rice straw	Berseem	Cotton seed
Maize stalks	Oat	Cotton seed cake
Juwar stalks	Juwar	Mustard cake
Legume straw	Bajra	Linseed cake
Grass hay	Elephant grass	Til cake
Bajra stalks		Ground nut cake
Berseem hay		

Maintenance rations

A well fed dairy cow producing one pound of butter fat per day utilizes about 48 per cent of the food consumed for maintenance. If the ration is cut down to about two thirds, the cow will still need the same quantity of food for maintenance, but the quantity available for milk production is reduced.

The results obtained from maintenance rations trials on cow show that animals fed on green fodder and hays remain fit for a long time with a positive nitrogen balance.

The maintenance requirements of dry cows (wt. 400-500 Kg) and heifers (400 Kg) show that they should be given fodders of oats-20 to 25 Kg, barseem-35 to 40 Kg, maize -30 to 35 Kg, bazra -25 to 30 Kg, elephant grass-30 to 40 Kg and sun flower-25 to 30 Kg, per day. The dry roughages like, oat hay-5 to 6 Kg, berseem hay-6 to 7 Kg and maize-7 to 8 Kg should be given daily. Data

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given regarding the composition of rations for the maintenance of dairy cow are of two category. The ration first is constituted of green maize-30 Kg, wheat bran- 2 Kg, gram-1 Kg and toria cake -1/2 Kg in which the total digestible nutrients is 7 to 8 Kg and digestible protein is 1/2 to 1 Kg. The ration of second category is constituted of barseem-30 Kg wheat straw-3 Kg, bran-1 Kg and maize-3 Kg in which the total of digestible nutrients is 7 to 8 Kg and the digestible protein is 1 Kg.

For the maintenance of buffaloes (Wt. 600 to 700 Kg) the nutritive requirements are approximately 1.5 times of those required by an average cow of 400 Kg. A buffalo is more economic producer of milk than the cow, only if the fodder is cheap. It requires considerably more digestible nutrients per Kg of milk produced than the average cow. Buffalo milk contains a higher percentage of fat and this factor should be taken into account in computing rations for buffaloes. The standard maintenance ration for a buffalo of 700 Kg body weight giving daily 18 Kg. of milk containing 7 per cent fat, is green maize-50 Kg, wheat straw-2.5 Kg, bran-2.5 Kg, gram-0.5 Kg, toria cake-1.5 Kg and dry matter-20 Kg which contains total digestible nutrients 12 Kg and total digestible protein 1.25 Kg.

Goats are extremely valuable milch animals because they can be maintained at little cost. Goat milk contains a greater variety of minerals and is particularly rich in iron, phosphates and potassium salt as compared to milk of other animals. The Indian goats are browsing animals and its natural feed consists of tender leaves of tees and shrubs. It eats almost any type of green materials, including grass preferably sweet grasses and fodder crops. Goat should be allowed to graze for 8 to 9 hours a day and, in addition, milch animals should be given a mixture of concentrates, calculated on the basis of milk production. A mixture which has been found suitable, consists of 2 parts of gram and 1 part of bran, fed twice daily at the time of milking. An average goat requires about 4 to 5 Kg of fodeer a day. Green feeds or dry roughages may be tied in bundles and suspended so that the goat can easily get at them. General composition of concentrate mixtures for goat is crushed barley 1 part, crushed maize 2 parts, linseed or mustard cake 2.25 parts and heavy wheat bran *i.e.* bran produced by hand milling-2 parts. Two per cent of a mineral mixture or salt should be added to the diet of goats.

Feeding of Young Stock

The common practice in India is to allow calves to suckle their mothers throughout the lactation period. In other countries, however, the practice is to feed the calves on colostrum for the first few days and on whole milk, either by suckling or by pail feeding, for three or four weeks; they are given other feeds after this period. The detailed data about the feeding of young cow stock is given below :

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	Dam's Coloustrum	Milk	Separated milk	Concentrates	Fodder	No. of Feeds
1st-3rd day	500 g.	x	x	x	x	3
4-7th day	x	500 g.	x	x	x	3
2nd week	x	625 g.	x	x	x	2
3rd "	x	625 g.	x	x	x	2
4th "	x	500 g.	125 g.	25 g.	25 g.	2
5th "	x	500 g.	125 g.	25 g.	50 g.	2
6th "	x	500 g.	125 g.	25 g.	60 g.	2
7th "	x	375 g.	200 g.	40 g.	60 g.	2
8th "	x	375 g.	200 g.	40 g.	75 g.	2
9th week	x	375 g.	200 g.	40 g.	100 g.	2
10th-12th week	x	250 g.	250 g.	40 g.	100 g.	2
13th-16th week	x	125 g.	250 g.	40 g.	125 g.	2
17th-19th week	x	x	200 g.	40 g.	125 g.	2
20th-23rd week	x	x	125 g.	40 g.	150 g.	2
24th-26th week	x	x	50 g.	40 g.	160 g.	2

The figures under all the heads, except fodder, denote quantity of feed per 10 pound of body weight. The figures under fodder show actual proporation of maintenance ration using the ration fed to a cow weighing 500 Kg as standard.

Diseases

The main diseases of dairy cattle in India are rinderpest, haemorrhagic septicaemia, black fever, anthrax, food and mouth disease, three-day fever, pleuropneumonia, tuberculosis, jone's disease, tic fever, Surra, tetanus, rabies, calf diptheria etc. The vaccines and antisera for cattle diseases are produced at various centres in the country. Many of the above mentioned diseases are under control, if proper treatment is given at proper time. Vatenary doctors have been appointed to look after the cattle in villages but due to lack of proper knowledge and facilities dairy animals in the villages are not being cared properly in general routine and illness.

Milk

Milk is produced by the mammary glands which are specialised skin glands. The actual secretion of milk by the mother is stimulated at birth by a lactogenic hormone (galactogen or prolactin) which comes from pituitary gland located at the bottom of brain, adrenal hormones also are essential for lactation. During gestation, the production of lactogenic hormone from pituitary is inhibited by the presence of another hormone, estrogen which disappears at birth. In some mammals the stimulus of sucking offspring serves, through the nervous system, to stimulate the secretion of lactogen.

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Milk is essentially an emulsion of fat in a continuous phase. The disperse phase consists of fat globules of varying diameters from 0.1 to 10%. The number of globules varies from 2.5×10^9 to 5×10^9 per cm. The globules are surrounded by layers of protein, phospholipids and probably also carotene and cholesterol which prevent them from coalescing together to large globules. The protective film may be broken by churning the milk when the fat globules coalesce to form butter. Milk fat or butter consists of glycerides mainly of butyric, caproic and capric acids which possess characteristic odours. The continuous aqueous phase consists of carbohydrates (almost entirely lactose) and a colloidal suspension of casien stablized by lactalbumin and lactoglobulin. Lactose forms the largest single constituent of cow's milk, next only to water. Cow's milk contains 2.4 to 6.1% lactose.

Milk also contains native enzymes (those present in udder) and enzymes originating from bacterial contamination. Amylase, catalase peroxidase, lipase, phosphatase, galactase, lactase and aldehydase are among the enzymes present in the milk. The activity of most enzymes present in milk is destroyed or greatly reduced by pasteurization. The white appearance of milk in reflected light and its opacity in transmitted light are due to the emulsified fat and the colloidal calcium phosphate and caseinate. The creamy colour is due to the presence of carotene in the disperse phase and of riboflavin in aqueous phase. The flavour of natural milk is pleasant and slightly sweet. Milk containing 3 to 5% fat and rich in lactose percentage possesses a better flavour.

As regard to the nutritive value, milk is a complete food for infants up to 6 months of age, after which it acts as a supplement to other food. Cow milk is easily digestable. Fifty per cent of its caloric value is contributed by fat, 20% by lactose and 21% by protein. Milk is a good source of phosphorus, calcium and vitamins. Milk is rich in vatamin A, excellent source of vitamin B_2 and fair source of vitamin B_1. It is deficient in vitamin C.

Due to its high nutritive value and fluid nature, milk is an ideal medium for growth of bacteria and it is of prime importance that handling and processing of milk should be carried out under strictly hygienic conditions. Milk contains bacterial flora normally associated with the udder and those introduced durmg milking. All contaminations should be effectively removed.

Processing of milk

In advanced countries a major part of the milk is processed and rendered safe before distributing to consumers. Among the methods employed, pasteurization is the most important. This consists of applying heat for the minimum period necessary to destroy microbial contaminations, the temperature being high enough to kill them but not so high as to affect the chemical and physical characteristics or the nutritive value of milk.

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Two methods of pasteurization are in use *i.e.* the holding and flash High Temperature Short Time (H.T.S.T.). In the holding method, the milk is heated from 140 to 150°F, held at that temperature for 30 minutes are rapidly cooled to 50°F. In the HTST method, the milk is heated from 160 to 162°F, held at that temperature for 10 to 20 seconds and cooled immediately to 50°F. Holding pasteurization gives a safe and satisfactory product. Pasteurization does not affect the concentrations of vitamin A and D or riboflavin. About 25% of thiamine and 50% of ascorbic acid are destroyed. Among the other milk processing methods the irradiation by ultra-violet light, developed in Germany during world war IInd, is of interest. Irradiation increases the vitamin D content of the milk.

Homogenizing and freezing processes were developed in America. The homogenizer is a pump which is designed to subject a liquid milk product to higher pressure, then allows the product to pass through a special valve. This process breaks up the fat globules, increases the ability of the protein to hold water of hydration and slightly softens the curd. After homogenization the milk passes on to the heating section of the pasteurizer. The bulk of milk is marketed in India in the raw condition. Pasteurization has not been widely adopted in India owing to the difficulty of collecting milk at a reasonable price from rural areas and of finding a market for pasteurized milk.

The pasteurization plants have been set up in organised dairies through out the country. The holding method is generally, employed for despatch to camp or hill depot having a temperature upto 50°F for local sale. Where refrigeration plants are not easily available, pasteurized milk is cooled to 60-65°F. in cold weather by ordinary water. Some of the dairy farms sell pasteurised milk in sterilized bottles. The bottles are washed in washing machines and passed to filling machines. They also make caps from covering strips and seal them on to the bottles. The filled bottles are kept under cold storage till they are taken out for distribution.

Marketing and distribution

In urban areas 60 to 70 percent of the total milk requirements is produced within the municipal limits, the rest is obtained from adjoining rural areas. Only 6 to 8 per cent of the total milk produced in the country is transported from rural to urban centres for consumption as milk and milk products. Nearly 2/3rd of milk received from outside the municipal limits comes from within 8 to 15 kilometres of the towns, and the remaining 1/3rd from beyond this distance. A part of the milk consumed in large cities, like Calcutta, Mumbai, Chennai, Delhi and others, it is obtained from localities situated at a distance of even 75 kilometres. Some successful efforts have been made to organize the production and marketing of milk on a cooperative basis.

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Prices

The price of milk varies to a great extent from place to place. In rural areas there is practically no good market facilities for fluid milk. The milk left over after meeting the demands of the producers family is converted into butter, ghee or khoa. These products are sold at weekly markets at prices largely determined by the distance of the market from the village. As a rule, cow milk is cheaper than buffalo milk but it may not be true for all the time and for all the places.

Milk Products

A variety of milk products is known in India and some of them figure in interstate trade. Dairy products such as cheese, butter, condensed milk, milk powder, curd etc. make the dairy farming a highly attractive industry.

Dahi (Curd)

It is prepared by souring milk with a lactic acid starter which is usually curd of the previous day. For the preparation of curd, milk is first boiled and cooled from 60 to 70°F. Further, starter is added and is kept untouched. Thus, curd becomes ready for consumption in 10 to 12 hours. Curd contains 0.6 to 1.0 per cent titratable acid expressed as lactic acid. It has a lactic flavour and a compact smooth texture. Its composition varies with the quality of milk used, the types of organisms present in the starter and the time allowed for souring. The organisms present in the curd are mainly streptococci (*Streptococcus thermophillus* type) and *Lactobacillus casei.* Curd is normally consumed at the place of production. Curd contains 84.79% water, 7.7% fat, 3.4% protein, 4.6% lactose, 0.7 to 0.8% lactic acid, 0.7% minerals, 0.12% calcium and 0.95% phosphorus.

Cream

Cream is a fat containing fraction separated from milk by centrifuging the liquid milk. The separator, commonly employed, consists of bowl with a large number of conical discs arranged one above the other with intervenning spaces. Milk enters through an opening in the centre and as the bowl is rotated, 3,000 to 20,000 rpm, the lighter fraction which is cream, is driven towards the centre and the heavier fraction or skimmed milk is drawn towards the periphery and drawn out.

The second method to obtain the cream is gravitational method in which milk is kept in a container at 50°F. After 24 hours cream automatically comes on the surface of the milk which is taken out by spoon. The yield and quality of cream vary according to the quality of milk and to the speed of separator. Skimmed milk is obtained as a by product which contains 0.04 to 0.5% fat and is used in the manufacture of condensed milk, milk powder, butter milk and

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cheese. The yield of cream is about 10% from a buffalo milk, 6% from cow milk and 7.5% from mixed milk. The composition of cream is 56% fat, 1.6% protein, 3% lactose, 0.4% minerals and 39% water.

Butter

Butter is a mixture of milk fat, butter milk and water. Salt and colouring materials are often added. It is good source of vitamin A and fair source of vitamin D. Butter is characterized by spreadability, a characteristic not found in butter substitutes. This probably is due to the glyceride structure of butter fat and to the presence of lower saturated fatty acids.

Desi buter or makhkhan is prepared by churning curd after dilution with water, in earthen or tinned metal pots by a wooden pole to one end of which beaters are attached which is known as "mathani". The butter usually contains 18 to 25% water and varying quantities of curd. The composition of butter is 14% water, 83.5% fat, 1.5% lactose, 0.3% minerals and 0.8% aluminium.

Creamy butter

The production of creamy butter in India is confined to few dairies. For the preparation of creamy buter, cream is aerated and ripened at 75 to 95°F to develop the desired smell and to facilitate churning. The ripening is effected usually by the addition of natural starter such as curd, fermented cream, and butter milk or commercial starters containing pure cultures of lactic acid bacteria. The ripened cream, after dilution with cold water is mixed with a small quantity of dye and then churning is started at temperature 50 to 60°F. Churning is usually carried out in the mornings, when temperature is low otherwise ice is added to maintain the desired temperature. The whole operation takes 30 to 40 minutes. Butter milk is drained off and the butter is washed repeatedly with cold water. It is then salted, up to 2.5%, by adding salt solution either in the churn or after taking out the butter. Excess of moisture is pressed out to give a product with a firm and compact texture.

Ghee

Ghee or clarified butter is obtained from butter by eliminating water. It is next to milk in importance as a dairy product. It can be stored over a long periods and for this reason it is preferred in comparison to butter in most of the tropical countries for comon people. Ghee is produced in India according to the traditional process involving sour curding of milk, recovering butter and heating the butter to remove water. Desi butter is preferred to creamy butter as ghee obtained from the former is melted into ghee at once or after storage upto 10 days. It may be partially dehydrated and later converted into ghee according to the demand of market. The temperature employed for clarifying butter varies from 80 to 125°C. Short exposure to 120°C does not

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interfere with the formation of grain nor does it diminish the carotene and vitamin A contents of the ghee. To ensure proper grain formation, the tins to which ghee is transferred should be kept undisturbed and cooling should be allowed to take place gradully. The appearance of colour and grain structure influences its market value. The ghee of cow is yellow and that of buffalo is whitish. The grain in buffalo ghee are bigger than that of cow ghee. The composition of ghee varies according to the composition of the milk from which it is derived. Ghee is mainly used for cooking, frying and taking directly with the food materials. Ghee is subjected to extensive adulteration in the trade.

Malai. When milk is heated, a layer of fat and coagulated proteins, malai, is formed on the surface. Slow heating helps to increase the thickness of the layer. The volume of malai can be increased by boiling the milk until a voluminous froth is formed and cooling slowly over a dying fire. Malai is either consumed directly, or used in the preparation of sweets. Its composition is moisture 60 to 70%, fat 25 to 30%, proteins 3 to 3.5%, lactose 3.3 to 3.8% and ash 0.4 to 0.5%.

Condensed milk. It is obtained by evaporating milk at 130 to 135°C in a vacuum pan to the required concentration. The concentrate is homogenized to prevent the separation of fat, cooled and fortified if necessary. Stabilizers such as disodium hydrogen phosphate or calcium chloride, are added to prevent coagulation during the sterilization. The condensed product is cooled rapidly from 80-86°F and held at that temperature for 15 to 20 minutes. The cooling is so controlled that the crystals are of small dimensions and remain in suspension in the viscous liquid.

Khoa. It is prepared by the rapid evaporation of water from the milk. It is usually prepared from buffalo milk by heating with brisk stirring in flatbot-tomedshallow steel pots until the volume is reduced to about one-fifth. The product is gathered in a compact mass, cooled, and packed for markets. Alum is sometimes added to the milk during the boiling to give a smooth texture to the product. Khoa is consumed directly or used as an ingredient of sweets. It can be kept for 3 to 4 days without deterioration. The common adulterants of khoa are cereal flours.

Cheese. Cheese is the product made form the curd, obtained from whole or skimmed milk with or without added cream by coagulating the casein, and then further the separated curd is treated by ripening ferments.

Soft cheese, known as 'Paneer' is prepared by using coagulants as the source of coagulating enzyme for clotting milk. Milk is warmed to about 100°F and the crushed coagulants are tied in cloth and dipped in it. The milk curdless in 30 to 40 minutes. The coagulum is placed on a muslin cloth and the whey is drained out. The process of cheese manufacture vary very much but not to such an extent as may be with different characters of the final product.

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Future prospects. The present retail prices of milk in urban areas in India are higher than those in the other countries. This is due, principally, to inadequate supply of milk. With a view to increase the per capita consumption of milk, the Planning Commission has suggested the adoption of measures for raising milk production in suburban areas. Emphasis has been laid on the need for maintaining hygienic conditions during the collection, transportation and distribution of milk and for enforcing measures of quality control.

The setting up of a statutory milk board for each urban area, consisting of representatives of producers, distributors, consumers, municipal corporation, health authorities and the state Governments is a good initiative from Planning Commission. The matters related to the handling, distribution, quality control, imports and price of milk, and milk products come under the jurisdiction of the board. The financial assistance needed will be provided by government, municipalities and cooperative banks. Village schemes have been formulated for improving the breeds of milk cattle and for ensuring adequate fodder supplied for dairy cattle.

IMPORTANT QUESTIONS

» ***Long answer type questions***

1. What is milk ? Give an account the processing and marketing of milk.
2. Give an account of milk products.
3. Enumerate different breeds of dairy animals, their breeding and their maintenance rations.

» ***Short answer type questions***

1. Give an account of the feeding of young stock of dairy animals.
2. What is milk ?
3. What are the milk products ?

» ***Very short answer type questions***

1. What is creamy butter ?
2. What is cheese ?
3. How curd is formed from milk ?
4. How cream is obtained from milk ?

» ***Objective type questions***

1. Which of the following is breed of cow ?
   (a) Ongole (b) Rath (c) Deoni (d) Surti
2. Which of the following is not a breed of Buffalo ?
   (a) Murrah (b) Jafarabadi (c) Surti (d) Rath
3. Which of the following is not a breed of goat ?
   (a) Jamunapari (b) Bar-bari (c) Rath (d) Beetal

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4. Which of the following is not the disease of dairy animal ?
   (a) Foot and mouth disease (b) Jone's disease
   (c) Rinderpest (d) Apoplexy
5. *Lactobacillus casei* is present in :
   (a) Cheese (b) Butter (c) Curd (d) Creamy butter
6. In malai, the percentage of fat is :
   (a) 10-15% (b) 15-20% (c) 25-30% (d) 30-40%
7. In butter, the percentage of fat is :
   (a) 60% (b) 65% (c) 71% (d) 83%

Answers

1. (d) 2. (d) 3. (c) 4. (d) 5. (c) 6. (c) 7. (d)

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15

Rat Menace and Ist Control

The history of rats is as old as human-beings. In 'Bhagwat Puran', an old literature of 10th century A.D., people had been warned to desert their dwellings as soon as dead rats were seen. The existence of crop-pests like birds, rats, monkeys, etc. have been mentioned snce 'Pre-Vadic' period and according to 'Kamandak' the heavy rain-fall, heavy drought, rats, locusts and parrots are serious problem for the crops and thereby economy of nation. Lord Ganesh is always conciliated before any worship in Hundu religion for he has subjugated the evil, *i.e.*, a rat which is his convergence. Near Bikaner, in a temple at 'Deshnokh' 80 kg grain is given daily for the feeding of rats.

Rats have been the cause of severe damage to crops, fruits, trees, vegetables in the field and almost every food grain in houses and godowns. Srivastava (1968) has reported 110 species of rats, from India, damaging the crops. They are very active, cunning and prolific breeders so their population is increasing day-by-day. From a data of FAO and UNO it was calculated that world population of rats is more than 42,500 crores. The rat population in India is reported to be more than 10,000 millions. It is our surmise that if rats are allowed to damage freely it would be difficult for human-beings to live in their dwellings and nothing would be left for feeding of human-beings.

For the control of rats, it is essential to have a clearcut idea about their species, habit and habitat, mode of burrowing, their movements, preference of food and a detailed life history of different kinds of rats.

Species of Rats

According to Srivastava (1968) 110 species are found in India of which 70 species belong to the family Muridae and order-Rodentia. The important ones

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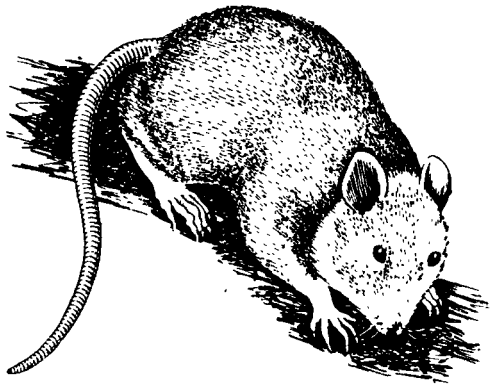

Fig. 1. A common rat, *Rattus rattus*.

belong to 2 sub-families *viz.*, Murinae and Gerbilinae. Three types of rats are reported *i.e.*, filled rats, house rats and rats damaging in houses and field both. Only few important species of rats are given below —

1. *Rattus rattus* Linn. (House rat). It is found dwelling in houses, warehouses, packing houses, seed stores, ships and sea ports. This species is arboreal or climbing in nature and rarely form their burrows for living. Sixteen species are found causing enormous damage to coconuts. They breed throughout the year and the female is provided with 10 to 12 mammae for feeding of young ones. The tail of this rat is longer than the rest of the body. Two races of this rat are observed in India, one with reddish brown dorsal surface and other with black reddish dorsal surface of the body (Fig. 1).

2. *Tetra indica hardwicke* Gray (Indian gerbil). This is found in uncultivated field and is an important carrier of plague. The body colour is light brownish dorsally and darker with pale hairs on ventral side. The hind feet are much longer and well adapted for jumping. It damages grains, succulent stem, leaves, roots, fruits, particularly sorghum and millet crops.

3. *Rattus norvegicus* Berkenhout (Norway rat). This is mainly found in temperate regions and inhabits sea-shore cities. Actually, this is house rat and can live in the field, feeding on crops, also. Fur is softer than that of black rat and the grooved bristles are more slender and smaller in number. The body colour is dark-brown on the dorsal side while white coloured on the ventral side. This rat can also breed throughout the year and the female has 12 mammae. This rat is larger and more robust than black rat. Tail is slightly shorter than the body length.

4. *Mus musculus* Linn (Albino rat). It inhabits the houses but sometimes goes to the gardens and crop fields near villages or towns. The body colour is dark to light brown dorsally and pale brown ventrally. This rat is very much active and can feed upon anything which comes in its way. This can breed

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throughout the year and the female has 12 mammae. Tail is shorter than the body. The most important thing for this rat is that it is used for scientific studies in laboratories for experimental purposes.

5. *Bandicota indica* Bechstein (Large bandicoot rat). *Bandicota indica* commonly inhabits cultivated fields, gardens, lawns and pasture lands. It mostly feeds on grains, succulent stems, roots, grasses, vegetables and fruits. Plenty of hairs are found to be present on the back of this rat. When disturbed it becomes furious, erects its hairs and starts grunting. It breeds throughout the year and the female has 10 mammae. This rat is largest of the field rats found in India and provided with short tail.

6. *Bandicota bengalensis bengalensis* Gray (Indian mole rat). This species commonly inhabits the fields of crops, vegetables and fruits. It is a fierce animal and grunts when in anger. This rat is very good swimmer. The dorsal surface of the rat is covered with thick harsh fur of grayish-brown colour and grayish-white on the ventral surface. Tail is somewhat shorter but sometimes as long as the body. The number of young ones per littre varies from 60 to 15. The burrows are generally shallower and have more than one opening. They stock the food grains inside their burrows for future feeding when food would not be available easily.

7. *Nesokia indica* Gray (Short tailed male rat). These mostly inhabit cultivated lands, lawns and gardens mainly feeding on field crops, vegetables, grass, fruits, etc. The body colour of this rat is brown dorsally and slightly pale on the ventral surface. *Nesokia indica* is found as a race of this species. The tail of this rat is shorter than the body length.

8. *Mus platythrix* Bernett (Brown spiny mouse). This is brown spiny mouse of common size. This rat burrows the side of the tank and so long as it remains inside, it keeps its opening closed with small pebles. The body colour of this rat is dark-brown on dorsal surface while white on the ventral surface. Its tail is very short and it is always shorter than the body length. *Mus platythrix platythrix* (Bernett) occurs as a race of this species. The female has 10 mammae.

9. *Golunda ellioti* Gray (Indian bush rat). It inhabits the bushes or thorny branches or ground. This mostly feeds on vegetables and roots of grasses. Body colour of this rat is yellowish-brown on the dorsal surface and grey-brown on the ventral surface. *Golunda ellioti ellioti* Gray occurs as race of this species. The fur is coarse and not of spiny type. The tail of this rat is shorter than the body length. It is provided with very small feet. This can breed throughout the year and the female has 8 mammae.

10. *Rattus meltada* Gray (Soft fur field rat). This soft fur field rat inhabits cultivated fields and feeds on succulent plants, stems, grains and rhizomes of grasses. The fur is very soft and devoid of spines. The body colour of this rat is dark-brown or pale grey dorsally and greyish-white ventrally. *Rattus meltada meltada* Gray occurs as a race of this species. The colour of the tail is darker

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dorsally and pale from the ventral surface. This can breed throughout the year and the female is provided with 8 mammae.

11. *Millardia meltada* Gray (Grass rat). This is found in wet lands as well as in dry lands and feeds on field crops, vegetables and fruits. This rat burrows in the field and bundhs. The tail is little shorter in length than the body. They may breed two times in a year and the female can produce 1 to 4 littres during breeding season. They keep 1 to 4 openings of the burrow and always have a few grasses in front of the opening of their burrows. They can breed throughout the year.

12. *Mus booduga* Gray (Common Indian field mouse). This is reported to inhabit in dry as well as wet lands and feeds on the grains of paddy. The colour is brownish on the dorsal surface and whitish or grey on the ventral surface. The tail is almost equal to the body length. The burrows formed by this rat are smaller, devoid of branching and provided with single bed chamber. They feed on sugarcane, maize and paddy. The female produces 6 to 13 young ones per littre.

Habit and Habitat

Rats are well adapted to adjust themselves everywhere because they are provided with highly developed sense of smell, taste, hearing and touch. Thus, they keep themselves away from any type of danger. They always go on their runways and remain careful and alert for any new object which they come across. They identify their routes with the help of dark greasy marks left in their way. In the night the rats usually come out of their burrows and actively keep themselves busy in feeding and in storage of food. At the time of this activity rats never get disturbed by any sound but as soon as some one reaches there they become alert. The home range of the males is greater than the female and varies from 50 to 100 feet from their burrows.

Formation of Burrow

Before the formation of burrows the rats survey the field, position of crop and humidity in the soil. The house rats dig their burrows in well sheltered places nearer to the store houses of grains, whereas, field rats form their burrows in the middle area of densely growing crops. They make a number of openings (2 to 42) and chambers *viz.*, breeding chamber and storage chambers in field burrows with a depth of 0.3 to 1.5 metre and diameter 0.03 to 0.685 metre. The length of the burrows is up to 40 metres with variations in the shape, size and depth pattern according to the nature of rat species. The amount of food grains collected from a single burrow of *Bandicota* species was 0.035 to 5.94 Kg, highest of all other species. Thus, the main aim of the burrow formation is protection, favourable micro-climate, storage of food and breeding facilities. It is interesting that the temperature of burrows is lower in summer

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and higher in winter. After observing a large number of burrows it was found that six types of burrowing pattern exists :

(1) Blind short with single opening.
(2) Blind long with single opening.
(3) Blind ramified with single opening.
(4) U-type.
(5) Ramified.
(6) Intercommunicable.

The burrow's fauna and flora consist of earthworm, crickets, earwigs, beetles, ants, pseudoscorpion, millipede, mites etc.

Movements of Rats

Just after harvesting of crops, in unfavourable climatic conditions, due to shortage of food material in a particular area and other factors cause the migration of rats from one store to other or from one field to other. Generally in the months of July-August when fresh food materials are aubndant in the field, rats (grass rat) come out of their burrows in search of suitable food grains in the night and damage paddy crops. The average distance travelled by grass rat was found to be 75.61 metres in 20 minutes. The maximum distance recorded at the time of migration is 551.0 metres in the field.

It has also been observed that rats are very good swimmers. The distance covered by swimming in five minutes has been recorded to be 16 to 19 metres in case of mole rat. The field rats having soft furs get exhausted quickly as compared to mole rats. The antelope rats are very poor swimmers but they were found climbing on trees and walls and can make horizontal jump of 8 feet.

Food and Nature of Demand

Commonly it is found that rats feed on all types of food materials *viz.*, grains, fruits, vegetables, meat, fish, fish products, dairy products, etc., but they prefer fresh and clean food and some have taste pattern very much similar to that of human-beings. The order of food preference of the common rat is soaked wheat > soaked crushed barley > soaked lentils > soaked crushed maize > soaked millets > soaked rice. It has been observed from various data that the average consumption of grains by a rat is between 10 to 15 gm and maximum grain consumption recorded is up to 30 gm per rat. It has also been noted that a pair of *Rattus meltada,* when given separately wheat, maize and grain for one week, consume 34.5, 39.3 and 38.7 gms respectively. But single rat feeds between 25.1 to 36.8 gm when given different food materials as mentioned above.

From a number of data it was generalised that rats eat about 10% of their body weight daily. They have sense to select balanced diet also. It is wonder that males can eat more amount of grains than the females in association with either themselves or with females.

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The nature of damage by the rat is variable from species to species and crop to crop. The first attack of rats is on cereals to dicot seeds and grains. In wheat crop the maximum damage was recorded at the ripening stage. The loss calculated per hectare in the yield is about 52 Kg in the field in Punjab. Due to the alternative cropping scheme, the damage by rats per crop can be reduced easily. The damage of sugarcane crop due to rats in the field is much least in early stages but in later stages *i.e.*, from October, sugarcanes are attacked much by rats. In coconut fruits one or two holes are made by the rats near the stack and they damage the carpal of the coconut.

From the data available it is estimated that rat destroys 11.5% wheat, 5.8% barley and 0.9% gram in the field. They destroy 4.6% to 5.4% paddy, 4.1% to 25.8% ground nut, 1.4% maize, 2.2% sugarcane and 5% coconut.

It is interesting to note that the rats feed actively in 5 to 10 metres radius around their burrow. The amount of damage caused by rats is very much proportionate to the population of rats and their species in that locality.

The burrows made by rats weaken the foundation of buildings, cause seepage in channels, damage railway tracks in yards etc. They cause fire by damaging electric wires. The damage to the food material and other materials due to rats in U.K., France and U.S.A. has been estimated to be 15 million pounds, 15 million franks and 300 million dollars respectivley.

Diseases Spread by Rats

Apart from damaging grains, fruits, vegetables, etc. rats spread a number of diseases among human-beings and their pets of common use. Thirty-two diseases of man and other animals are known to be transmitted by rats. They are reported to carry 18 different kinds of lice, fleas, ticks and mites. Different types of viruses, bacteria, fungi, protozoa, nematodes, arthropods cause several diseases like bubonic plague, typhus fever, infectious jaundice, rat bite fever and food poisoning also. *Rattus rattus, Bandicota bengalensis* and *Tetra indica* are carriers of bubonic plague. A large number of ectoparasites are inhabiting the rats *viz.*, Gleas (*Xenopsylla cheopis. X. astia, Cteno cephalides felis*), Mites (*Dermanyssus muries, Laelaps echidninus*), Ticks (*R. sanguines, R. tricuspies*) and Louse (*Polyplax spinulosus*).

Life History

For the effective control measure an idea about the life history of rats is essential. After maturation, rats start living in separate burrows. In case of *Bandicota bengalensis bengalensis* the peak period for breeding is in two seasons *i.e.* March to May and August to October. After the age of 3 to 6 months they start breeding and gestation period lasts from 21 to 25 days. The female of this rat comes in heat after every 4 to 5 days for about 2 to 3 days and breeds commonly twice in a year coinciding with the maturity of

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the crops. The female produces 8 to 10 young ones in a litter but maximum number of young ones recorded is twenty two. Young ones produced are hairless, reddish and with closed eyes. After two weeks of birth, their eyes open and they begin to feed on grains after 3 weeks. The sex ratio is generally found to be 50 : 50. The life span of an adult female is longer than the male.

In case of *Millardia meltada meltada* the sex ratio of male and female is 5 : 9. The breeding season of grass rats in South India is November and January to April and the number of young ones per litter varies from 2 to 12. Thus, it is inferred that life history of rats may vary from species to species.

Ecological Status

The ecological study gives a clear picture about the interactions of rats with the nature. Cats, snakes, mongoose, owls and some other birds use the rats as their food. Thus rats are also at important place in the ecological niche. Our aim should, therefore, not be to eradicate the rats completely but to reduce the rat population. However, very little is known about the ecology of the rats so the investigation on the ecology of the rats is needed for getting clear picture about them.

Rat Control

Rat control is an important and complicated programme in which a number of control devices have been developed as result of practical experiences and scientific researches but none has succeeded in the control of rat population. The integrated control programme comprising of a number of control measures, has been highly recommended for the control of field and godown rats.

Methods of Rat Control

[I] Ultrasonic waves

Hanery Simon (1967) has recommended that ultrasonic waves are very much powerful killers of rats without any damage to human-beings. The wide use of ultrasonic waves in the field is under investigation specially with reference to its effect and high cost of this method for field use.

[II] Traps

This is an old method to catch the rats by various mechanical devices which are used in modified from in different localities and with the species of rat to be controlled. This method takes much time and man power so, practically very difficult to apply in larger field area. Sometimes this method is practised in houses to catch the house rats. The useful and common traps are bamboo bow and arrow trap and pot trap.

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1. Bamboo bow and arrow trap. It is local made and very common in southern India. It comprises of triangular bamboo sticks fixed on bunds, tracks and burrows. As rats get in to take the food, the bamboo sticks snap automatically, trap and kill the rats.

2. Pot trap. It is a round earthen pot of 20 cm diameter and 17 cm height containing a lid and wood pegs of 30 cm. The lid is adjusted in such a way on the ground that the pot falls on the lid when disturbed. The bait is placed on the lid and also inside the pot. The bait when disturbed, falls on the lid and rat is trapped.

[III] Biological control

The natural enemies like cats, terrier, snakes, mongoose and a number of birds are predators of rats in the houses and the field. Cats are very common in houses and also go to the neighbouring fields in search of their prey. They catch the rats very actively. It is also found that in some offices cats are kept as pet specially for rats. Of all the predators snakes are traditionally regarded as the most effective predator of field rats and also of house rats. Some birds like kite, owl and hawk are active predators of rats in the field.

It is surprising that rats are eaten by human-beings also. In the 'Crush rats Campaign' organised in Indonesia (1964), Mr. D.N. Aidit was commander of that campaign. He suggested that the rats be consumed by human-beings.

[IV] Cultural control

Fitzwater and Prakash (1966) have suggested that change in the sowing and harvesting period of crops and the pattern of storage of grains may be quite helpful for rat control.

[V] Chemical control

The chemical means of rat control have proved to be most effective against 'Rat War'. Chemicals of various nature and origin are applied with different modes of action affecting the rat population. They are generally being used in the form of fumigants, attractants, repellents, chemosterilants and rodenticides.

1. Fumigants. The most effective fumigants for rats are : (i) calcium cyanide, (ii) carbon monoxide, (iii) carbon dioxide.

(a) Calcium cyanide. It is a very effective fumigant which on contact with air or moisture, releases 'Hydrocyanin gas' (HCN) diffusing in air. This HCN gas should be blown in rat burrows by rat fumigating machines. In rainy and freezing weather it should not be operated. Ten to twenty grammes of fumigant should be pumped in each live burrow for which about 6 to 10 pumps are

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sufficient. At the time of operation one should avoid to breathe in the fumes because it causes serious hazards for human-beings also. So by now the application of this fumigant has practically been stopped.

(b) Carbon monoxide. It is not quick in action so requires more time (5 min.) to kill the rats in their burrows. It is operated in rat burrows with the help of exhaust of gasolin motor.

(c) Carbon di-oxide. It is used in fumigating refrigerated warehouses, where low temperature is to be maintained to prevent the food spoilage. It is applied in the burrows in the form of dry ice.

(d) Others. Methyl bromide, Ethylene di-bromide and aluminium phosphide are used as fumigants to control the rats in the field or in the well ventilated houses but these should never be used in the bed room.

2. Attractant and repellent. Very little work has been done on the attractants and repellents with regard to rat control. The attractants for rats are saffron, kewra, khas lemon, etc. With the help of these attractants one can first attract the rats either in houses or in the field and kill them mechanically or can given them poison baits easily.

A number of compounds namely, Lauro-nitritie, Actidione, Cycloheximide, Triphenyltin and Malathion have been reported to have worked as repellent. With these repellents one can keep the rats away from the field or house only for some time. So, repellents are totally temporary measure of rat control to keep the danger away till permanent cure.

3. Chemosterilants. The oral feeding of Furadantin and colchicine have been found to cause sterility in male and female of *Bandicota bengalensis bengalensis* respectively. Srivastava (1968) had suggested that both chemosterilants should be mixed (0.25 gm furadantin and 0.001 gm colchicine) in 10 gm of wheat flour because single bait will be eaten by male or female individual only. Chatterjee (1968) has reported that Cadmium Chloride produces sterility in the male and female rats. A new bait 'Glyzophorol' containing butandial-bismethane sulphonic acid ester has been formulated for the sterilization of rats. The chemosterilants affect in different ways, *i.e.*, it may prevent the development of gonads in immature rats, offspring may not attain sexual maturity, pregnant females may produce sterile young ones, sperms of adult males may be unable to move etc. The bait should be palatable so that the rats may easily feed on it. The contact powder (dust) should be mixed with some sticky materials for adhering the dust which affect the gonads.

The other chemosterilants are also being used for rat control. *viz.*, Olidon, Enovid, Tepa, Uracil, Morzid, Norlutin, Aphamide and Nilevar.

4. Rodenticides. The chemicals used as poison for the control of rats are commonly termed as rodenticide as rat also is a rodent. A large number of

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rodenticides are available in the market under different brands and proprietory names.

The rodenticides are grouped into acute and chronic poisons. The common acute poisons are Arsenic trioxide, Barium carbonate, Zinc phosphide, Norbromide, Antu, Red squill, Thallium sulphate and sodium fluoroacetate. Fitzwater and Prakash (1973) have mentioned that chronic rodenticides are derivatives of caumarin (e.g. Warfarin, Dethmore, Caumarin, Ratafin and Racumin) and all are anti coagulents. The LC_{50} and Ld_{50} of different rodenticides vary from species to species and they are used in poison baits. So one should have good idea about poison baiting for effective rat control.

Poison baiting. For successful rat control programme, rodenticides are used in the form of poisoned food baits. For poison baiting one should be fully aware of the burrows of that area, prebaiting technique and preparation of poison baits and its proper use.

Survey of burrows. Before the poison baiting a careful survey of the infested area is to be made to examine all the burrow openings. Then these openings should be closed with soil and re-examined on next day to confirm the alive burrows.

Prebaiting. Before the use of poison baits two to three types of grains should be kept to know the most preferred grain which facilitates the attraction of rats towards poison baits. But on a large scale the total cost due to prebaiting comes to three times so is not recommended for practical application in large areas of infestation. But if used it may prove to be very fruitful in killin the rat population with poison baiting.

Preparation of poison baits. Fitzwater and Prakash (1973) suggested that rats prefer to pick up particles like food rather than flour like material, so poison baits should be in the form of tablets as given :

(a) Zinc phosphide. The crushed grains of the most preferred food, kept in earthen vessel, should be soaked in water for few hours and small amount of vegetable oil (linseed, ground nut) should be mixed to make the food bait sticky. Now required quantity of Zinc-phosphide should be mixed with a long handled spoon. Then the required quantity of water should be added to make the pills in the following ratio :

Zinc-phosphide—1 part, Food bait-49 parts and vegetable oil—As required.

(b) Barium carbonate. Selected food bait is crushed and soaked in water for about 8 hours and then is allowed to dry and mixed with poison in following ratio :

Barium Carbonate—1 part, Food bait—6 parts and Jaggery—1 kg.

(c) Red squill. The dry food bait mixed with poison and required quantity of water is added to prepare the small balls. When fresh meat is used as food

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bait, a thin paste with poison and water is prepared and then mixed with the food bait as given below :

Red squill—1 part, Food bait—9 parts and water—as required.

(d) Antu. It is prepared in the same way as the red squill and gives most effective result. For the use of this, complete coverage of that area should be made and prepared by the formula as given below :

Antu—3 parts, Food bait—97 parts and water—as required.

(e) Warfarin. It is prepared similar to as Zinc phosphide. The difference is only in the preparation of baits and the formula is as given :

Warfarin—1 part, food—19 parts and vegetable oil—as required.

It is an anti-coagulant and has to be used for at least a week. Prakash (1976) has mentioned that poison fed rat suffers by weakness due to loss of blood and death may occur after 3 to 15 days of poisoning.

(f) Tomorin. It is prepared as above in case of warfarin with a slight variation in the proportion of bait and the poison as given :

Tomorin—1 part, Food bait—39 parts and vegetable oil—as required.

(g) Sodium fluoroacetate. Its use is restricted only to expert hands because it is highly toxic in nature for human-beings also. 1.5 ounce poison is mixed with one gallon of water and used as drinking bait.

(h) Thallium sulphate. This bait is prepared with wheat of rolled oat with or without oil. The poison should be mixed at the ratio of 1% by weight for achieving good results.

Precautions for the use of bait. (1) In residences, baits should be kept only at counted (2 to 3) places to avoid the risk of human hazards.

(2) Generally 30 gm of bait is recommended in each living burrow but a slight change may be made according to the need.

(3) The baiting should be done in clear weather.

(4) The operation of baiting should be repeated till the burrows cease to be opened on next day.

(5) The workers having cut on any portion of the hand or fingers should not be allowed to handle the poison baits.

(6) The preparation of baits should be performed in a well ventilated room to avoid the lethal concentration of poisonous gas like, HCN or phosphine etc.

(7) Baits should be kept 6 to 8 cm inside the burrows for proper placing of poison.

(8) After handling the poison baits, hands should be cleaned by proper washing soap.

(9) The nails of the hands should be cleaned and smaller as in usual course for a person.

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(10) The rats killed due to poison baiting should be burried in deep soil to aviod secondary poisoning of pets, poultry, predators and other useful animals.

Antidotes

Antidotes are the medicines that counteract the poisons. The discovery of antidotes in the field of chemical control measure has dawned a new era for the life of workers. The nature of antidotes varies with the kind of poisoning to counteract properly. It would be a good thing for human-beings if proper antidote can be prepared for every poison. Prakash (1976) has reported two different antidotes for zinc phosphide and warfarin. If poisoning has been caused due to zinc phosphide first of all mustard emetic should be given to induce vomiting. Six gm potassium permanganate, dissolved in a glass of water, should be given immediately. After 10 minutes one spoon copper sulphate, dissolved in 250 c.c. water should be given and it is followed by a purgative—a tea spoonfull of Epsom salt in glass of warm water.

In case of Warfarin (anticoagulent) first of all vitamin 'K' should be administered. Blood transfusion is also recommended. The physician should also be called at once.

Eradication of House and Godown Rats

Integrated approach by combining all control means in rat eradication campaign has proved very much fruitful. It is comprised of several steps like rat proofing, traps, cleanliness, sanitation and chemical approach.

1. Rat proofing. Rat proofing checks the movement of rats and mice into or outside a house. For this purpose all openings should be completely closed and the edges of all the doors and windows should be covered with metal sheets.Ventilators should be covered with 18 gauge 1.25 cm mesh. The sever drains should be tightly fastened.

2. Traps. Traps are recommended only for small infestation. Cage trap, wooden trap, wire trap, snap trap are used to catch the rats. As soon as the rat enters into the cage, the door of the cage is automatically closed. The food bait used may be of bread, biscuits, cakes, cheese, meat etc.

3. Cleanliness and sanitation. The food materials should not be kept open in tins or other vessels. The dump of refuge should be removed from main areas or should be burnt. There should be clean up programme in rat infested localities.

4. Chemicals. Eradication with chemical baits is more effective in godowns and houses. The whole programme consists of pre-baiting and application of poison baits.

In organising an anti-rat campaign in houses, farm houses and godowns following plan of operation should be followed. The persons should be given

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preliminary training regarding survey, marking of burrows and preparation of baits.

Plan for Operation

First day. Survey to locate run way and live burrows and prebaiting in the after noon.

Second day. Inspection of whole area and pre-baiting continued.

Third day. Poison baiting with zinc-phosphide, warfarin or Barium carbonate.

Fourth day. Re-examination of area and poison baiting in opened burrows with 2% zinc phosphide.

Fifth day. Collection of dead rats, baiting continued, if necessary fumigation with HCN may be done in alive burrows.

Sixth day. Use of chemosterilants if alive burrows are still found (Srivastava, 1968).

Eradication of Rat From Field

1. Trapping. Traps are not much effective in field and their application takes much time and specialized technique. Where baiting or fumigation is not possible traps may be used.

2. Chemicals. This programme comprises of pre-baiting, location of baits, application of poisoned baits, use of fumigants and chemosterilants.

First day. Survey of alive burrows and pre-baiting.

Second day. Pre-baiting continued.

Third day. Operation of poison baits as desired with regard to species of rats.

Fourth day. Collection of dead rats and burying in soil, continue baiting if necessary.

Fifth day. Re-examination of area, if necessary fumigation should be done.

Sixth day. If alive burrows still remain, use of chemosterilant is recommended, Srivastava (1968).

Success of Rat Eradication Programme

For successful rat eradication programme, following care should be taken :

(1) Rat control operation should be well planned and twice a year.
(2) The eradication programme should be effective and economic.
(3) The information about the biology, habitat and life cycle of a particular species of the rat of that field should be available.
(4) The rat control programme should be operated in possibly larger areas.
(5) The co-operation of local people becomes quite helpful, so local organisation should also be contacted.

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Future of rat control

Literature regarding rat control reveals that although much work have been done in the laboratory condition but no hopeful success has been achieved in the field. It does not mean that results obtained from scientific works are not practicable in the field but this situation of failing in the 'Rat War' is only due to the careless steps of extension units and avoidance of farmers themselves. So, for the victory on this great enemy it is advisable for the Government to organise 'Rodent Control Exhibition' in villages in collaboration with the scientists working in this field and give them full training about each and every step of rat control. Professor Banett of Australian National University Canabara accepting the challenge of rats suggested to establish separate zoology department from Entomology department in all agricultural Universities. The Summer Institute Organised at Cenral Arid Zone Research Institute Jodhpur, by Indian Agriculture Research Institute has given some promising ideas for rat control programme. Separate Research Institute for study of the rats and their control would be of great help to the economy of the nation.

IMPORTANT QUESTIONS

» ***Long answer type questions***

1. Enumerate the species of rats, formation of burrows and nature of their food
2. Give an account of the methods of rat control.

» ***Short answer type questions***

1. Enumerate the species of rats.
2. Give an account of the habit and habitat of rats and formation of burrow.
3. Give short account of the diseases spread by rats.
4. Give short account of the eradication of house and godown rats.

» ***Very short answer type questions***

1. Define rodenticides.
2. What are the antidotes ?
3. What are the care to be taken for the success of rat eradication programme ?

» ***Objective type questions***

1. The common name of *Rattus ratus* is :
   (a) House rat (b) Norway rat
   (c) Brown spiny mouse (d) Indian bush rat
2. The common name of *Mus musculus* is :
   (a) Indian mole rat (b) Indian bush rat (c) Albino rat (d) Grass rat
3. The common name of *Mus booduga* is :
   (a) Grass rat (b) Common Indian field mouse
   (c) Soft fur field rat (d) Albino rat

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4. Which of the following statement is wrong ?
   (a) Antidotes counteract and poison
   (b) Infrasonic waves are powerful killer of rat
   (c) Warfarin is a potent rodenticide (d) Caumarin is an anti coagulent
5. Which of the following is a chemosterilant .
   (a) Warfarin (b) Ratafin (c) Racumin (d) Colchicine
6. Bamboo bow and arrow trap is used for the control of :
   (a) Monkey (b) Rat (c) Parrot (d) Tiger

Answers

1 (a) 2. (c) 3. (b) 4. (b) 5 (d) 6. (b)

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BIOSTATISTICS

1

An Introduction to Biostatistics

Statistics. Biostatistics. Statistical terms. Statistical Symbols. Exercise.

Statistics

Definition

The branch of science which deals with "methods of collection, classification, analysis and drawing inferences from data; testing of hypothesis; making recommendations etc." is called statistics.

Statistical methods

Raw data obtained in a survey or experiment must be processed properly to get correct results. The persistent factors influencing the data are segregated from the casual disturbances. The processed data becomes suitable for classification, tabulation, comparison, correlation and interpretation. All these methods put together, constitute statistical methods.

Use of statistics

Statistics has wide application in almost all sciences — social as well as physical such as biology, medicine, agriculture, veterinary, economics, psychology, business management etc. It plays a major role in life science because data of bioscience are of a variable nature. *(Z–37/Biost.)*

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Biostatistics

Definition

The use of statistics in biology is known as *biostatistics* or *biometry*. It is concerned with the application of statistical data and statistical methods to solve problems of bioscience.

Role of statistics in bioscience

It is very difficult to draw a concrete conclusion from biological experiments because of inherent differences between two individuals. Homozygous twins are even not exactly same in physiology and behaviour.

Most of the happenings in life science depends upon counting or measurements. Plants and animals obtained by any hybridization experiment agree with Mendel's law or not, can only be concluded by statistical test i.e. χ^2 test or blood pressure has no meaning unless it is expressed in numbers.

Blood pressure, pulse rate, Hb%, rate of reproduction, rate of transpiration, action of a drug on individual/group etc. varies not only from person to person but also from group to group. The extent of this variability in a character is by way of chance, i.e. biological or normal is revealed by stastistical methods.

Scope of biostatistics

Use of statistical methods are constantly increasing in biological sciences. The development of biological theories are closely associated with statistical methods. Heredity, one of the recent branches of biology is mainly based on biostatistics. Therefore, for the students of biology, the knowledge of biostatistics is a must.

Statistical Terms

Term is a word used to explain a particular identity. Important statistical terms are given below :

Population. Population may be defined as "**a group of organisms of one species, occupying a definite area**". In statistics **population is a well defined group which is being studied**. Population may be **finite** or **infinite**. If a population consists of a fixed number of values then it is said to be finite. For example, the number of patients in a ward of hospital, the number of mango tree in a garden, the number of earthworms in a small piece of land. On the other hand if it is not possible to observe all the values of a variable in a population then it is infinite. An infinite population is unlimited in size e.g the number of RBC's in human body, the number of zooplanktons in sea, and so on.

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Sample. The selected part of a population is known as sample. For example, all patients of AIDS of the planet earth represents a population, whereas individual observations on 10 or 20 or 30 (any convenient number) patients from the population refer to a sample.

Data. A set of values recorded for an event is called data. The Hb% of 10 patients suffering from Kalazar was measured as 10.2, 9.6, 8.8, 10.7, 9.9, 10.8, 11.3, 9.5, 8.9, 8.8, mg/100 ml. Here 10.2, 9.6, 8.8.....8.8 mg/100 ml is a set of values for any event i.e. Hb% and is called data.

A data collected by personal investigation from the original source, by performing some experiments is called **primary data.** Collection of data from secondary source such as from thesis, journals, magazines etc. is called **secondary data**. For life science researches (biology, medicine, veterinary, agriculture etc.) primary data is used.

Data may be **qualitative** or **quantitative**.

(a) Qualitative. According to quality or attributes the data is called qualitative. For example, tigers of Sunderban (W.B.) are to be classified in respect to one attribute say sex, in two groups, one is of male and the other is of female.

(b) Quantitative. According to magnitude the data is called quantitative. Fishes of a pond may be classified on the basis of their growth rate. Quantitative data may also be classified into two types —

(i) Continuous. Values of variate do not have break or jump. For example the increasing length and weight of a child.

(ii) Discrete. Values of variate vary by jumps. For example the oxygen consumption of rat (*Rattus rattus*) of different weight groups was measured as 500 cc/h/100 ml, 545cc/h/100 ml, 620 cc/h/100 ml, 670 cc/h/100 ml and so on.

Observation. Measurement of an event is called observation. For instance, blood pressure, temperature of body, oxygen consumption etc. are events whereas, 160 mm and 80 mm (upper and lower pressure), 106°F, 65 kg/hour/100 ml are their respective observations.

Parameter and statistic. A value calculated from a definite population such as mean (μ for population), **standard deviation** (σ), standard error of difference of mean $\sigma(\bar{X}_1 - \bar{X}_2)$ etc. are called a **parameter**.

The quantity calculated to represent a character of population is known as parameter whereas quantity calculated to present the character of the sample is called **statistics**. Parameter is a constant quantity whereas statistics is variable.

In biological experiments values calculated from a large sample is often applied to population and may be a valid estimate of population. Therefore, in biostatistics. though not desirable, parameter and statistics are often used as synonyms.

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Variable. Any quantity or quality liable to show variation from one individual to the other in the same population is known as variable. If we measure the height of some individuals of a population and obtain some values, the obtained values is variable.

A variable is a symbol, such as X, Y, Z etc., that may take any value in some specified set of numbers. Whatever the value of the variable actually observed is the actual value and is denoted by the X_1, X_2, X_3,....., X_n or Y_1, Y_2, Y_3, ..., Y_n or Z_1, Z_2, Z_3, ..., Z_n.

Depending on the break or continuity, variable are of two types —

(a) Discrete variable is one which cannot take all the values and there is a gap between one value and the other. For example, the number of fishes of five different species in a pond were obtained as 98, 305, 387, 105 and 208. So, in this case number of fishes is the discrete variable.

(b) Continuous variable is the one which can take any values and there is no interval. For example, the weight and height of human being is a continuous variable because it takes gradual increasing values.

Frequency. The number of times a value of the varibale occurs.

Frequency distribution. The raw data or ungrouped data do not give clear idea of the subject matter. Therefore, raw data is arranged in ascending or descending order of their magnitudes. This arrangement is called array. Arrayed data is kept in such a manner that each variable exhibit its repetition number i.e. frequency of variable. This is called frequency distribution.

Cumulative frequency. The cumulative frequency corresponding to any value of the variable (or a class) is the sum of all the frequencies.

Statistical Symbols

Symbol is a mark or sign with a particular meaning. Important symbols used in Biostatistics.

Important Symbols Used in Biostatistics

1.	Summation	Σ (It is capital Greek letter pronounces as sigma)
2.	(i) Mean or average	$\bar{X}$ (read as X bar) Obtained from sample
	(ii) Mean of population	μ
3.	Observed number	O
4.	Expected number	E
5.	Degree of freedom	df
6.	Number of groups or classes	k
7.	Probability	P
8.	Deviation	x

(Contd.)

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9.	Frequency	f
10.	Mode	M_o
11.	Median	M
12.	Geometric mean	GM
13.	Mean deviation	δ
14.	Standard deviation	σ (For population) or S (For Sample)
15.	Standard Error of Mean	SE_M
16.	Standard Error of standard deviation	SE_σ
17.	Student's test or 't' ratio	t test
18.	Chi-square test	χ^2
19.	Variance	σ^2
20.	Width of class interval	i
21.	Correlation coefficient	r
22.	Number of observation	N or n
23.	The no. of standard deviation from the mean	Z
24.	Pearson's correlation coefficient	Υ
25.	Spearman's correlation coefficient	ρ

Construction of frequency distribution

If there are repetitions in individual values or items of investigation then suitable frequency table can be framed. These frequency tables may be discrete or continuous in nature, but they must maintain the frequency concerned in their respective classes.

Discrete frequency distribution. All the observations are listed in ascending or descending orders.

Following raw data were obtained in a biological experiment. Rate of reproduction of 45 fishes was recorded as follows —

Raw data (A)

80	70	70	70	16	50	20	20	20
45	16	50	30	65	40	30	50	50
70	45	20	70	2	79	16	20	19
40	50	30	2	45	30	50	45	30
40	45	80	50	39	50	50	20	30

A frequency distribution table is framed on the basis of above raw data. Following steps are taken while framing frequency distribution table.

Converting raw data in arrayed data. The primary duty of a biostatistician is to convert **raw data** in **arrayed data**. This can be done by arranging the raw data into ascending or descending order. The above **raw data** arranged in **ascending order** to make **arrayed data**.

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Arrayed data (B)

2	2	16	16	16	19	20	20	20	20	20	20	30
30	30	30	30	30	39	40	40	40	45	45	45	45
45	50	50	50	50	50	50	50	50	50	65	70	70
70	70	70	79	80	80							

Presentation of data in this form is quite a tedious and time consuming job, particularly when the number of observations in an experiment is large. To make it easily understandable, we can tabulate data in a simple frequency table.

Framing a **Simple frequency table** (grouped series in discrete condition) :

(1) A table of two columns is framed. First column contains **variables** and the second column for repetition number i.e. frequency of variables.

(2) On perusal of the above arrayed data (B), we find that variable 2 is repeted twice. Therefore, frequency 2 is mentioned in second column i.e. in the frequency column. Variable 16 is obtained three times and hence 3 is mentioned in frequency column. In the same fashion frequencies of all variables are mentioned and following discrete frequency distribution table is framed —

Table 1.1.

Variable	2	16	19	20	30	39	40	45	50	65	70	79	80
Frequency	2	3	1	6	6	1	3	5	9	1	5	1	2

Framing a continuous distribution table. Arranging data in ascending or descending order is a tedious job. Moreover making discrete frequency distribution table consumes a lot of space and time. Therefore, to bring out certain salient features of data, we further simply the presentation of data and condense them into classes or groups.

Frequency distribution table in class interval can be prepared in two ways :

(a) Overlapping frequency table or exclusive method. Values of variables are grouped in such a fashion that the upper limit of one class interval is the lower limit of succeeding class interval.

(b) Non-overlapping class interval or inclusive method. Values of variables are grouped in such a fashion that the upper limit of one class interval do not overlap the succeeding class interval. For biostatistical methodology non-overlapping class interval is widely used. A non-overlapping frequency table 2.2 is prepared using the arrayed data of table 1.1.

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Table 1.2.

Non-overlapping frequency table	
Class interval	**Frequency**
1 – 10	2
11 – 20	10
21 – 30	6
31 – 40	4
41 – 50	14
51 – 60	0
61 – 70	6
71 – 80	3
	$\Sigma f = 45$

Guidelines for choosing classes

(1) The number of classes should be between 5 and 15.
(2) Data should be kept in ascending order.
(3) The width of class interval should be numerically simple like 5, 10, 15 and so on.
(4) Classes should be of equal size.
(5) The heading of observations and measurement must be clearly mentioned. Such as height in cm. or inches, age in months or years, RBCs number in mm^3/100 ml, Hb% in mg/100 ml on so on.

EXERCISE

1. What do you mean by Data, Population, Sample, Variable, Parameter, Frequency distribution, Cumulative frequency, Primary data and Secondary data.
2. Explain following notations or symbols :
   Σ, %, $\bar{X}$, x, f, P, O, E, δ, σ, k, SE_M, SE_σ, SE_S.
3. What is difference between population in general and population in biostatistics. Substantiate with suitable examples.
4. Define quantitative and qualitative variables. Give some examples of quantitative and qualitative variables.
5. Explain following notations —
   F, fm_1, fm_2, M_0, m^n, i, χ^2
6. What do you mean by population and sample.
7. Define—(i) Random sampling, (ii) Non-random sampling, (iii) Quantitative data, (iv) Qualitative data and (v) Attribute.

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8. Write short answers to these questions :
   (a) Write one difference between overlapping and non-overlapping frequency distribution.
   (b) Write one difference between parameter and statistics.
   (c) Write one difference between statistical terms and statistical symbols.
9. Answer the following questions :
   (a) How many classes should be in frequency distribution table.
   (b) What should be the width of class interval.
   (c) Classes should be of equal size or unequal size.
   (d) Height/age/RBCs number/Hb% should be mentioned in what units.
   (e) What is the other term for non-overlapping class interval.
10. In the following questions each statement is followed by four alternatives. Tick the correct one.
   (i) The branch of science which deals with "methods of collection, classification, analysis and drawing inferences from data" is called —
   (a) Econometry (b) Biometry (c) Statistics (d) None of these
   (ii) The use of statistics is known as —
   (a) Biostatistics (b) Biometry (c) Both a & b (d) None of these
   (iii) The selected part of a population is known as —
   (a) Fractured poppulation (b) Sample
   (c) Variable (d) None of these
   (iv) A set of values recorded for an event is called —
   (a) Data (b) Observation (c) Statistics (d) Prameter
   (v) Any quantity or quality liable to show variation from one individual to the other in the same population is known as —
   (a) Statistical term (b) Statistical symbol
   (c) Estimate (d) Variable
   (vi) Data obtained in a biological experiment in its original form is known as —
   (a) Arrayed data (b) Frequency (c) Raw data (d) Overlapping data
   (vii) Raw data arranged in ascending or descending order is called —
   (a) Raw data (b) Discrete data (c) Continuous data (d) Arrayed data

Answers

(i) c (ii) c (iii) b (iv) a (v) d (vi) c (vii) d

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2

Graphic Representation of Frequency Distribution

Introduction. Methods of preparation of graph. Units of representation. Exercise.

Introduction

Graphic representation of data is widely used to present data in a simple, clear and effective manner. A graph is a visual form of presentation of data where comparisons can be made between two or more phenomena. It is rightly said that wandering of a line is more powerful in its effect in mind than a tabulated statement.

Methods of Preparation of Graph

Some basic knowledge is essential to prepare frequency graph. It is prepared with the help of two lines. The horizontal line is called **Abscissa** *i.e*, X-axis representing independent variable and the vertical line called **Ordinate** i.e. Y-axis representing dependent variable. The meeting point of X and Y axis is called Zero (0) or origin point.

The right part of 'X' axis from the zero point (0) is positive (+) and left part is negative (–). Likewise the upper part of 'Y' axis from zero point is positive while the lower part is negative. 'X' and 'Y' axis intersect each other at '0' point and graph is divided into 4 parts. Each part is called Quadrant. Upper right part is called first Quadrant where 'X' and 'Y' both axis are positive. Upper left part is called second Quadrant. Here 'X' axis is negative (–) and 'Y' axis is positive (+). The lower left part is called third Quadrant

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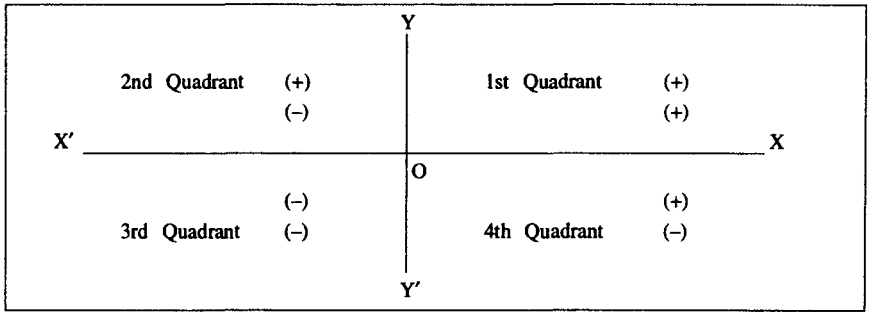
where both 'X' and 'Y' axis is negative. The lower right part is known as fourth Quadrant where 'X' axis is positive (+) and 'Y' axis is negative (–). Mostly first quadrant is used for graphical representation of statistical data, where both axes are positive.



Two axes 'X' and 'Y' intersecting each other on 'O' point producing 4 quadrant.

Units of Representation

Appropriate unit bar line is required to present the statistical data in graph. Suppose, one has to show large numbers such as 500, 1000, 2000 and above on graph, then he has to consider 1 cm long line on graph as 500 unit bar line. Now 1 cm is divided 5 times to represent 500 unit bar line. 1 cm is denoted as 5 ; 2 cm as 10 ; 3 cm as 15 and so on. For number 750 a point in between 5 and 10 is mentioned. The same method can be adopted to represent any number.

Grouped data can be represented graphically in any one of the following ways

(1) Histogram
(2) Frequency polygon, and
(3) Cumulative frequency graph or ogive

1. Histogram. This graph is used for continuous frequency distribution. The width of the class intervals are marked along with the X-axis, or abscissa. On these length, rectangles of areas proportional to the frequencies of the respective class intervals are erected.

If the class intervals are of equal lengths, then the heights of the rectangles are proportional to the corresponding frequencies and for unequal class intervals, the heights of the rectangles are proportional to the ratios of the frequencies to the width of the corresponding class.

Following grouped data is obtained in an observation of "rate of reproduction" of 50 fishes of a species. Make a Histogram, Frequency polygon and Frequency curve with the help of data provided.

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Table 2.1.

Class intervals	0–10	10–20	20–30	30–40	40–50	50–60	60–70	70–80	80–90
Frequency	3	4	7	8	9	9	2	6	2

Solution : OX-axis 1 cm = 10 class interval denoting the rate of reproduction.

OY-axis 1 cm = 1 frequency representing the frequency of rate of reproduction.

The frequency of 1st class interval 0 – 10 is 3 which is being represented by 3 cm = 30 small squares on OY axis because 10 small squares = 1 frequency. In the same fashion rectangle for each class interval and frequency is plotted and finally a histogram of the above frequency distribution is shown in Fig. 2.1.

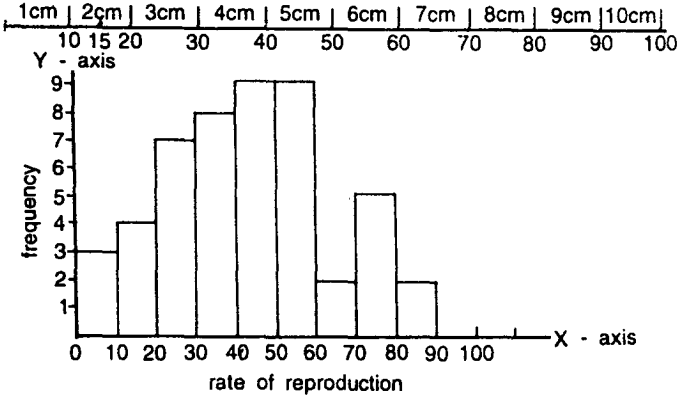

Fig. 2.1. Histogram showing rate of reproduction and their frequency of 50 fishes of a species.

2. Frequency polygon and frequency curve. The values of the variable for an ungrouped data are taken as the abscissae and their frequencies are taken as the ordinates. For a grouped data, the mid-points of the class intervals are taken as the abscissae. Then a **frequency polygon** is obtained by joining the plotted points by the straight lines. If the class intervals are of small length, then the plotted points are joined by free hand. The curve so obtained is known as frequency curve. Frequency polygon for equal class intervals can be obtained by joining all the mid-points of the upper sides of rectangles of the histogram, by straight lines. It gives a shape of polygon i.e., a figure with many angles. Fig. 2.2 is plotted with the help of same above data.

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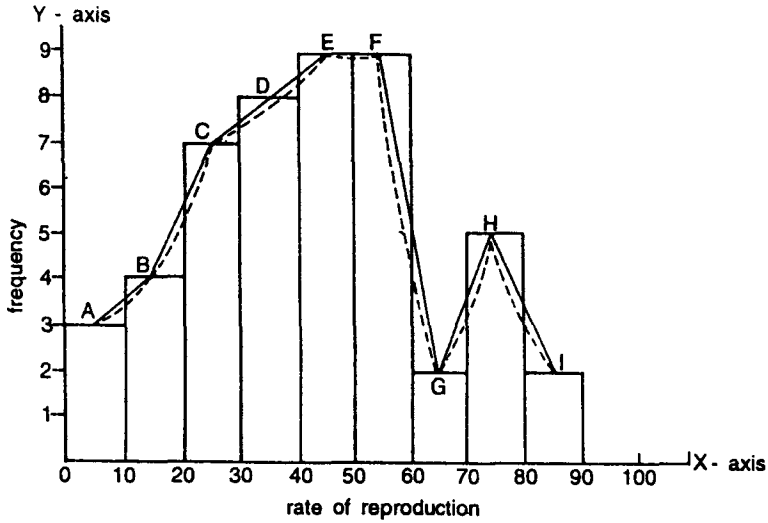

Fig. 2.2. Frequency polygon and frequency curve showing rate of reproduction and their frequency of 50 fishes of a species of fish.

Unbroken lines joining mid points A, B, C, D, E, F, G, H and I of rectangle show the frequency polygon.

Broken lines joining mid points A to I of rectangle represent the frequency curve. It is drawn by joining the mid-points of class intervals of upper horizontal lines of rectangle by free hand.

3. Cumulative frequency curve or ogive. A cumulative frequency curve can be drawn with the help of data obtained from an observation where cumulative frequency relating to age group categories of 100 albino rats is given below (Table 2.2).

Table 2.2.

Age group X	No. of albino rats (f)	Cumulative frequency (cf)
1 — 3	11	0 + 11 = 11
4 — 6	15	11 + 15 = 26
7 — 9	16	26 + 16 = 42
10 — 12	20	42 + 20 = 62
13 — 15	15	62 + 15 = 77
16 — 18	13	77 + 13 = 90
19 — 21	10	90 + 10 = 100

The graphical display of cumulative frequency distribution as shown in Fig. 2.3 for age groups of albino rats shows one important feature, the curve is always in the ascending order. Such curves are called ogive. The points are plotted by taking the upper limits of the class intervals as abscissae and the

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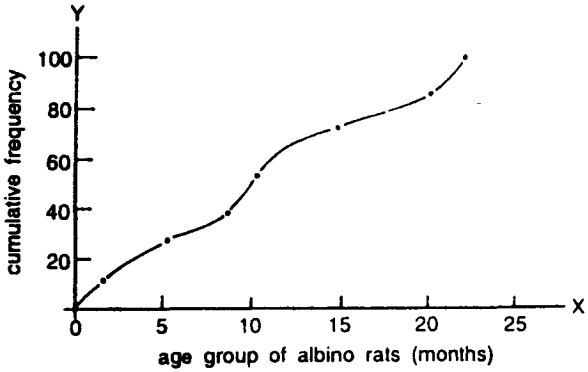

Fig. 2.3. Cumulative frequency curve or ogive.

cumulative frequencies of the corresponding class intervals as ordinates. These points are joined by a smooth curve to get a **cumulative frequency curve**, also called **ogive.**

There are two methods to construct **cumulative frequency curve** *or* **ogive.** (i) The "less than" method (ii) The "more than" method. In the "less than" method we start with the upper limit of the classes and go on adding the frequencies. However, in case of "more than" method, we start with the lower limit of classes. The first method gives a rising curve, whereas the second method shows a declining curve. Cumulative "less than" and "more than" frequency distribution of the number of grains per spike is given in Table 2.3.

Table 2.3.

No. of grains	17–19	20–22	23–25	26–28	29–31	32–34	35–37	38–40	41–43
No. of plants	8	15	18	21	26	19	12	7	4

Solution : Cumulative frequency distribution table 2.4 is prepared.

Table 2.4.

Number of grains "Less than"	**Number of plants**	**Number of grains "More than"**	**Number of plants**
Less than 19	8	More than 17	130
Less than 22	23	More than 20	126
Less than 25	41	More than 23	119
Less than 28	62	More than 26	107
Less than 31	88	More than 29	88
Less than 34	107	More than 32	62
Less than 37	119	More than 35	41
Less than 40	126	More than 38	23
Less than 43	130	More than 41	8

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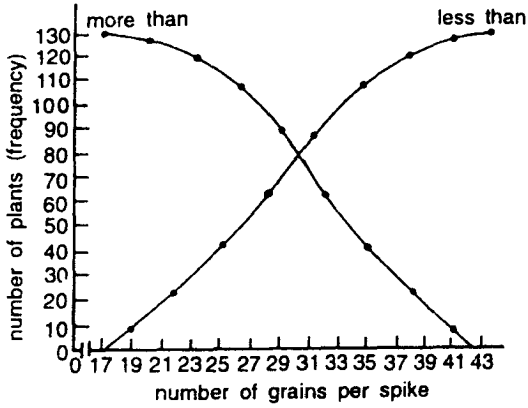

Fig. 2.4. "Less than" and 'more than' cumulative frequency curves or ogive representing distribution of the number of grains per spike as given in table 2.4.

Significance of graphic representation

Graphical representation of frequency distribution is important because :

(1) It is the simplest method of presentation of data.
(2) They give clear cut and attractive view.
(3) They make comparison of variables easy.
(4) They are helpful in ascertaining certain statistical measures.
(5) They save time and energy.

Limitations of graphic representation

(1) A graph simply shows tendency and fluctuations, and not the actual values.
(2) Complete accuracy is not possible on a graph.
(3) Graphs cannot be quoted in support of some statement.
(4) Only a few characteristics can be depicted on a graph. However, in the case of many figures, it is difficult to follow the graph.

EXERCISE

1. What is abscissa and ordinate in a graph. Mention 4 quadrants giving a figure.
2. Draw histogram, frequency polygon and cumulative frequency curve with the help of data mentioned in the following two tables :

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Table A

Class Interval	Frequency
1 – 10	3
11 – 20	14
21 – 30	21
31 – 40	25
41 – 50	40
51 – 60	40
61 – 70	47
81 – 90	50

Table B

Class Interval	Frequency
24.5 – 29.5	3
30.5 – 35.5	6
36.5 – 41.5	14
42.5 – 47.5	20
48.5 – 53.5	25
54.5 – 60.5	37
61.5 – 66.5	39
67.5 – 72.5	42

3. Following data were obtained in a hospital of Patna in respect of age and frequency of cancer. Make a frequency polygon —

Age	39 – 49	50 – 59	60 – 69	70 – 79	80 – 89
No. of cancer patients	2	3	15	21	18

4. Draw a cumulative frequency with the help of following frequency table.

Height of group in cm.	Frequency of each group	Cumulative class frequency
160 – 162	10	10
162 – 164	15	25
164 – 166	17	42
166 – 168	19	61
168 – 170	20	81
170 – 172	26	107
172 – 174	29	136
174 – 176	30	166
176 – 178	22	188
178 – 180	12 $\Sigma f = 200$	200

5. Give short answer of the following :
   (i) Histogram (ii) Frequency curve,
6. The text gives the admission figures in a University consisting of arts and science faculties only during 1986, 1987 and 1988.
   "The total number of students in 1986 was 6500. It increased by 8% in 1987 and further increased by 10% in 1988. The total female students were 1000 in 1986. It increased by 12% in 1987 and further increased by 10% in 1988. Among the female students the number of science students were 325, 396 and 473 in 1986, 1987 and 1988 respectively. Among the male students, the number of arts students were 4805, 5030 and 5326 respectively in the three years'.

(Z–37/Biost.)

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Present the above information in a tabular form. Also calculate the percentage increase of male students in 1988 as compared to 1986. **(Civil Services, 1994)**

Admission figure of a University

Year	1986		1987		1988	
Faculty	**Male**	**Female**	**Male**	**Female**	**Male**	**Female**
Arts	4805	675	5030	724	5362	759
Science	695	325	870	396	1128	473
Total	5500	1000	5900	1120	6490	1232
Total No. of students	6500		7020		7722	

[Hint : Total no. of students in 1986 = 6500. It increases by 8% in 1987 and further by 10% in 1988.

$\therefore$ Total no. of students in 1987 $= \frac{108 \times 6500}{100} = 7020$

and total no. of students in 1988 = ...

No. of female students in 1986 = 1000. It increased by 12% in 1987 and further increased by 10% in 1988.

$\therefore$ Number of female students in 1987 $= \frac{112 \times 1000}{100} = 1120$

and no. of female students in 1988 = ...

Now, we calculate the number of male students in different years as follows :

in 1986 = 6500 – 1000 = 5500; in 1987 = 7020 – 1120 = 5900 and

in 1988 = 7222 – 1232 = 6490

The number of female students of arts faculty :

in 1986 = 1000 – 325 = 675 ; in 1987 = 1120 – 396 = 724 and

in 1988 = 1232 – 473 = 759

Similarly, the number of male students of science faculty :

in 1986 = ...; in 1987 = ... and in 1988 = ...

Having calculated all these data we can now present them in a tabular form. Percentage increase of male students in 1988 as compared to 1986 .....]

[Ans. 18%]

7. Write short answers to these questions :
   (i) Write two differences between histogram and frequency polygon.
   (ii) Write two differences between frequency polygon and frequency curve.
   (iii) Write two differences between frequency polygon and cumulative frequency curve or ogive.
   (iv) Write two differences between abscissa and ordinate.
   (v) Write about unit of representation in 5 lines.
8. In the following questions each statement is followed by three alternatives. Tick the correct one.
   (i) Graphic representation of data :
      (a) Is widely used to present data in a vague manner.

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(b) is best way to present data in a simple, clear and effective manner.
(c) is not better way of presentation of data than tables.

(ii) Individual data can be represented by :
(a) Histogram (b) Frequency polygon (c) None.

(iii) Frequency distribution can be represented by :
(a) Histogram (b) Frequency polygon (c) Both a & b

(iv) Ogive can be represented by :
(a) Only frequency table (b) Cumulative frequency table (c) None of these

(v) Ogive can be represented by :
(a) Less than method only (b) More than method only
(c) Both less than and more than method (d) Methods

Answers

(i) b, (ii) c, (iii) c (iv) b (v) c

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3

Measures of Central Tendency

Measures of central tendency. Mathematical average : Arithmetic mean, Median and Mode. Exercise.

Measures of Central Tendency

Generally it is found that values of the variable tend to concentrate around some central value of observations of an investigation, which can be taken as a representative for the whole data. This tendency of the distribution is known as central tendency and the measures devised to consider this tendency are known as **measures of central tendency**. One of the most important objectives of measures of central tendency is to get a single value that describes the characteristic of entire mass of statistical data. Such a value is popularly known as average. Measures of central tendency is a method of condensing a mass of data to a single value which is typical and representing the entire data. There are three measures of central tendency.

Arithmetic Mean

Central value or average, obtained arithmetically, is known as arithmetic mean. It is the most common average, used in our day today life.

Simple arithmetic mean

It is most commonly used of all the averages. It is the value which we get by dividing the aggregate of various items of the same series by the total number of observations.

Arithmetic mean (Ungrouped data). If the values of N items are X_1 , X_2 , X_3 , X_n..... be the value of variable X, then simple arithmetic mean

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$(\overline{X})$ is obtained by dividing the sum of the values of all the items by the total number of observations. Symbolically—

$$\overline{X} = \frac{X_1 + X_2 + X_3 + \ldots\ldots + Xn}{N} \text{ or } \overline{X} = \frac{\Sigma X}{N} \text{ or } \overline{X} = \frac{1}{N} \sum_{i=1}^{N} X i$$

Where $\overline{X}$ = Arithmetic mean

$X_1, X_2, X_3 \ldots\ldots X_n$ are each individual observations. ΣX = Sum of individual observations of the variable. N = number of observations.

Worked example : Haemoglobin percentage (Hb%) of ten patients suffering from AIDS was recorded as 5.2 mg, 5.3 mg, 5.6 mg, 5.7mg, 5.4mg, 5.2 mg, 5.3 mg, 5.3 mg, 5.4 mg and 5.2 mg. Find out the mean Hb% of patients suffering from AIDS.

Solution : Following formula is applied to obtain arithmetic mean from above ungrouped data.

$$\overline{X} = \frac{\Sigma X}{N} = \frac{5.2 + 5.3 + 5.6 + 5.7 + 5.4 + 5.2 + 5.3 + 5.3 + 5.4 + 5.2}{10}$$

$$= \frac{53.6}{10} = 5.36 \text{ mg/100 ml. } \textbf{Ans.}$$

Computation of arithmetic mean for grouped data. ***(a) Discrete series.*** If data is in frequency distribution but not in class interval, then it is called as discrete series. For computation of arithmetic mean in a discrete series, each value of the variable is multiplied by their respective frequencies. Sum of all values is obtained which is divided by total number of frequencies.

Let the variable X take the values $X_1, X_2, X_3 \ldots\ldots X_n$ and let their frequencies be $f_1, f_2, f_3 \ldots . f_n$. Then the arithmetic mean $(\overline{X})$ is computed by formula :

$$\overline{X} = \frac{f_1 . X_1 + f_2 . X_2 + f_3 . X_3, \ldots\ldots + f_n . X_n}{f_1 + f_2 + f_3 \ldots\ldots + f_n} \text{ or } \frac{\Sigma f . X}{\Sigma f}$$

Where, $\overline{X}$ = arithmetic mean; $\Sigma f . X$ = sum of values of the variables and their corresponding frequencies & Σf = sum of frequencies.

Worked example : Rate of respiration of 43 fishes and their respective frequency was recorded as follows. **Find the arithmetic mean from data.**

Rate of Resp^n.	2	16	20	30	39	40	45	49	50	65	70	79	80
Frequency	3	4	7	7	1	3	5	1	2	2	5	1	2

Solution : First step is to make a table of three columns. 1st column for variable (Rate of respiration), 2nd for corresponding frequencies and 3rd for variable × frequency.

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Table 3.1.

Variable X	Frequency f	Variable × frequency $f.X$
2	3	6
16	4	64
20	7	140
30	7	210
39	1	39
40	3	120
45	5	225
49	1	49
50	2	450
65	2	130
70	5	350
79	1	79
80	2	160
	$\Sigma f = 43$	$\Sigma f.X = 2022$

$\because \quad \bar{X} = \Sigma f.X / \Sigma f \; ; \quad \therefore \quad \bar{X} = 2022/43 = 47.02$ **Ans.**

(b) Continuous series. In the case of grouped continuous series, the arithmetic mean is calculated after taking into consideration the mid-points of various classes. Hence, formula given for discrete series is also applicable to grouped continuous series.

$$\bar{X} = \frac{\Sigma f.m}{\Sigma f}$$

Where, $\bar{X}$ = Arithmetic mean

$\Sigma f.m$ = Sum of values of mid-points multiplied by their corresponding frequencies.

Σf = sum of frequencies

m = mid points of various class intervals.

Mid point is obtained by following method.

$$\text{Mid-point (m)} = \frac{\text{Lower limit of Class interval + Upper limit of CI}}{2}$$

Worked example : Rate of respiration of 50 fishes of a species and their frequencies are given in continuous series. Find out mean of this experimental data.

Rate of Resp.	1-10	11-20	21-30	31-40	41-50	51-60	61-70	71-80
Frequency	3	11	7	4	10	5	7	3

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Solution : Make a table of 4 columns. 1st column for class-interval of variable, 2nd for mid-point, 3rd for frequency and 4th for mid value multiplied by their respective frequencies.

Table 3.2.

Class-interval C I	Mid-value m	Frequency f	Mid-value × freq. $m \times f$
1—10	(1 + 10)/2 = 5.5	3	5.5 × 3 = 16.5
11—20	(11 + 20)/2 = 15.5	11	15.5 × 11 = 170.5
21—30	(21 + 30)/2 = 25.5	7	25.5 × 7 = 178.5
31—40	(31 + 40)/2 = 35.5	4	35.5 × 4 = 142.0
41—50	(41 + 50)/2 = 45.5	10	45.5 × 10 = 455.0
51—60	(51 + 60)/2 = 55.5	5	55.5 × 5 = 277.5
61—70	(61 + 70)/2 = 65.5	7	65 5 × 7 = 458.5
71—80	(71 + 80)/2 = 75.5	3	75.5 × 3 = 226.5
		$\Sigma f = 50$	$\Sigma m \times f = 1925$

$$\bar{X} = \Sigma f.m/\Sigma f = 1925/50 = 38.5 \text{ Ans.}$$

[**Note :** Here in place of (X) mid value (m) is applied in formula].

Combined mean. If $\bar{X}_1$ and $\bar{X}_2$ are the arithmetic mean of two series whose number of terms are N_1 and N_2 respectively, then the combined mean $\bar{X}$ is abtained by

$$\bar{X} = \frac{N_1\bar{X}_1 + N_2\bar{X}_2}{N_1 + N_2}$$

Worked example **:** If the mean length of a group of 40 earthworms is 65 cm and the mean length of other group of 50 earthworms is 60 cm. Find the combined mean length of the two groups.

Solution : $\bar{X} = \frac{40 \times 65 + 50 \times 60}{40 + 50} = \frac{2600 + 3000}{90} = \frac{5600}{90} = 62.2$ cm. **Ans.**

Calculation of arithmetic mean in series having open-end classes. In a few cases, the lower limit of the initial class interval and the upper limit of the last class interval are not known. Such class intervals are called open-end classes. Arithmetic mean cannot be calculated in open-end classes unless one knows the lower and upper limits of the classes. In this circumstance, an assumption is made for unknown class-limit and it depends upon the class interval.

Worked example **:** Class interval is uniform

No. of seeds	Below 10	10-20	20-30	30-40	40-50	50-60	Above 60
No. of pods	7	9	17	11	10	6	3

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Solution : In above example the class interval is uniform. Therefore, the lower limit of the initial class would be zero and the upper limit of last class would be 70. Thus the first class is 0-10 and last class 60-70.

Worked example : Class interval is not uniform

No. of Seeds	Below 10	10-30	30-60	60-100	100-150	Above 150
No. of pods	7	26	27	19	5	7

Solution : In above case the class interval is increasing by 10. Therefore, the appropriate assumption would be that the first class is 0-10 and the last class 150 – 210.

Merits and demerits of arithmetic mean. It is most commonly used for measures of central tendency though it has got both merits and demerits.

Merits. (1) It is rightly defined and is an easy and ideal measures of central tendency.

(2) It covers all the observations and is easy to calculate and understand.

(3) It is affected least by fluctuation of sampling. In other words arithmetic mean is a stable average.

(4) Arithmetic mean provides base of many other methods of statistics.

Demerits. (1) Obtained mean in a series may not be represented by any observation.

(2) It is very much affected by extreme observation.

(3) By eliminating even a single series, calculation becomes unreal.

(4) It cannot be determined by inspection nor can be represented graphically.

(5) In extremely skewed distribution arithmetic mean is not representative of the distribution.

Median

Median of a distribution is defined as the value of that variable which divides the total frequency into two equal parts when the series is arranged in ascending or descending order of magnitude.

Median for ungrouped data

Median value is the value of the $(N+1/2)^{th}$ item. Median is computed differently if number of observation (n) is **odd** and when **even**.

Computation of median when N is odd.

Worked example : RBCs count in lac/mm^3 was recorded as 6, 7, 4, 5, 5, 3, 4 in different blood samples of an animal. Compute median.

Computation. Our first step is to arranged the values of series in an ascending order e.g. 3, 4, 4, 5, 5, 6, 7.

Here total number of observations is 7 i.e **odd** number.

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$$\text{Median} = \left(\frac{N+1}{2}\right)^{th} \text{item} = \left(\frac{7+1}{2}\right)^{th} \text{item} = 4\text{th item.}$$

In the above example, 4th item = 5 ∴ Median = 5 **Ans.**

Computation of median when *N* is even. In case of even series computation of median is slightly different than odd series. Median is given by arithmetic mean of the two middle terms, $N/2^{th}$ and $\left(\frac{N+1}{2}\right)^{th}$ item

$$\therefore \quad \text{Median} = \frac{(N/2)^{th} + (N/2+1)^{th}}{2} \text{ item.}$$

Worked example **:** Oxygen consumption of 8 fishes was recorded as : 35, 44, 38, 36, 39, 40, 42 and 41 cc/100ml/ hour. Find median from the given data.

Solution : Arrange the raw data in ascending order : 35, 36, 38, 39, 40, 41, 42 and 44.

$$\text{Median} = \frac{(n+1)^{th}}{2} \text{ item.} = \frac{(8+1)^{th}}{2} \text{ item} = \frac{9}{2} = 4.5^{th} \text{ item.}$$

It tells that median lie in between 4^{th} and 5^{th} items. Average of the 4^{th} and the 5^{th} items is calculated as below :

4^{th} item = 39 and 5^{th} item = 40 ; ∴ $\text{Median} = \frac{4^{th}\text{ item} + 5^{th}\text{ item}}{2}$

$$\text{Median} = \frac{39+40}{2} = \frac{79}{2} = 39.5 \textbf{ Ans.}$$

Computation of median for grouped data : ***(a) Discrete series.*** In a discrete series the items are first arranged according to the ascending order of magnitude and respective frequencies are written against them. The frequencies are then cumulated and the position of the median is located by the same formula :

$$\text{Median} = \frac{(n+1)^{th}}{2} \text{ item} \qquad \text{where} \quad N = f_1 + f_2 + \ldots . f_n = \Sigma f_i$$

Worked example **:** Protein content of 100 fishes in (g) of a species was obtained as below. Find the median.

Protein content	5	5.5	6	6.5	7	7.5	8	8.5
Frequency	2	4	8	10	15	25	22	14

Solution : Make a table of 3 columns. 1st for variable, 2nd for frequency and 3rd for cumulative frequency.

Table 3.3.

Protein	5.0	5.5	6.0	6.5	7.0	7.5	8.0	8.5
Frequency	2	4	8	10	15	25	22	14
Cum. freq.	2	6	14	24	39	64	86	100

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$$\text{Median} = \text{size of } \frac{(\text{cumulative freq.} + 1)^{\text{th}}}{2} \text{ item} = \text{size of } \frac{(100+1)^{th}}{2} \text{ item.}$$

$$= \frac{101}{2} = 50.5^{th} \text{ item.}$$

Now items from 39 to 64 have protein 7.5 as shown by cumulative frequency $\therefore$ Median = 7.5 **Ans.**

(b) Continuous series : In this case the median cannot be found directly without recourse to the original data. It may however be estimated with sufficient accuracy by interpolation. To do this we first find the position of the median item i.e., $\frac{n+1}{2}$ and from the cumulative frequencies of the class, we determine the class in which the median item occupying this position lies. Then the Median is given by the formula.

$$\text{Median} = L_1 + \frac{N/2 - c}{f_m} \times h$$

Where, L_1 = lower limit of the class in which median lies. f_m = frequency of the class in which the median lies. c = cumulative frequency of the class preceding the median class. N = total frequency = $\sum f$ and h = width of the class interval of the median class respectively.

Worked example : Following is the fecundity of 50 fishes of a species of fish in frequency distribution in continuous series. Find the median fecundity.

Fecundity in C.I.	1-10	11-20	21-30	31-40	41-50	51-60	61-70	71-80
Frequency	3	15	2	8	11	4	1	6

Solution : Frame a table of 3 columns. 1st column for class interval, 2nd for frequency and third for cumulative frequency.

Table 3.4.

Fecundity	X	1-10	11-20	21-30	31-40	41-50	51-60	61-70	71-80
Frequency	f	3	15	2	8	11	4	1	6
Cum. freq.	c f	3	18	20	28	39	43	44	50

Here, $N = 50$; $\text{Median} = \frac{(N+1)^{\text{th item}}}{2} = \frac{(50+1)^{\text{th}}}{2}$ item $= \frac{51^{\text{th}}}{2}$ item $= 25.5^{\text{th}}$ item

From the cumulative frequency column, we find that the 25.5^{th} item falls between 31– 40 group.

Here, $L_1 = 31$; $\sum f = 50$; $c = 20$; $fm = 8$; $h = 10$

$$\text{Median} = L_1 + \frac{(N/2 - c)}{f_m} \times h = 31 + \frac{(50/2 - 20)}{8} \times 10$$

$$= 31 + \frac{(25 - 20)}{8} \times 10$$

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$$= 31 + \left(\frac{5}{8}\right) \times 10 = 31 + (0.625) \times 10$$

$$= 31 + 6.25 = 37.25 \quad \textbf{Ans.}$$

Merits and demerits of median.

Merits. (1) If found directly, it represents an actual item.

(2) It eliminates the effects of extreme items, since they are not taken into account in its calculations, except for arranging the data in increasing or decreasing order.

(3) The values of only the middle items are required to be known.

(4) It can be found even for data which cannot be measured quantitatively. For example, if Hb% of 10 frogs are arranged according to their numerical value, the median Hb% is the Hb% value of the middle frog.

(5) It is easy to calculate.

(6) The median is most suitable for expressing qualitative data such as colour, health, intelligence etc.

Demerits. (1) It may not be representative when the distribution is irregular. For example heights of different plants of selected area of a forest are : 1, 5, 9, 12, 6, 60, 61, 72, 78.

Arrange the data in ascending order of magnitude — 1, 4, 6, 9, 12, 60, 61, 72, 78. The median height is $\left(\frac{9+1}{2}\right)^{th}$ item $= \frac{10}{2} = 5^{th}$ item is 12 which is not at all a proper representative of the average height of plants.

(2) It cannot be located with precision when the items are grouped. Then it can only be estimated and the estimated value may not be found in the series.

(3) The data must be kept in ascending or descending order. This involves considerable work if the number of items is large.

(4) The aggregate value of the items cannot be obtained when the median and the number of items are known.

(5) It is not very useful in further analysis, because it is difficult to handle mathematically.

Mode

Mode of a frequency distribution is defined as "**that value of the variable for which the frequency is maximum.**"

The definition of mode indicates that mode cannot be determined from individual series as it depends on the frequency of occurrence of the items.

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Hence to get the value of mode the series must be converted into a frequency distribution.

Mode (for a discrete series). If the distribution is regular and only one maximum frequency is there (data is unimodal) then the mode value can be obtained by mere inspection.

Inspection method.

Worked example : Water percentage of 15 fishes of a species of fish was recorded as 60, 64, 62, 76, 70, 74, 70, 84, 82, 72, 76, 84, 78, 84 and 86. Find the mode of this series.

Solution : As stated above the series must be converted into a frequency distribution and get a grouped data. First of all data is arranged in ascending order. Not even single value is spared. It comes as 60, 62, 64, 70, 70, 72, 74, 76, 76, 78, 82, 84, 84, 84 and 86. Make a grouped frequency distribution table.

Water %	60	62	64	70	72	74	76	78	82	84	86
Frequency	1	1	1	2	1	1	2	1	1	3	1

On perusal of above table we find that repetition of 84 is maximum times i.e. 3 times. None of other items appear so frequently. Therefore, 84 is the mode of the series.

Sometimes a series have more than one mode (bimodal or multimodal). Then mode is obtained by grouping method.

Grouping method. When the discrete series is bimodal or multimodal then grouping of frequencies of series is done to ascertain mode. Grouping has been done as follows :

First of all table of eight vertical columns is framed.

(1) Values of variable is mentioned in first column.

(2) Frequencies of all variables are noted in second column.

(3) Sum of 2–2 frequencies is noted in 3rd column.

(4) Sum of 2–2 frequencies ignoring the first frequency is noted in fourth column.

(5) Sum of 3–3 frequencies is noted in fifth column.

(6) Sum of 3–3 frequencies ignoring the first frequency is noted in sixth column.

(7) Sum of 3–3 frequencies excluding the first two frequencies is noted in seventh column.

(8) According to need, grouping of 4–4 or 5–5 or even more can be done in the same fashion.

After completing the table, detection of maximum frequency is done in each column of group. The variables of maximum frequency are bracketed in

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analysis table. After completion of table for each group, these bracketed figures are counted. Variables having maximum bracketed items are noted as Mode.

Worked example : Weight in (g) of 50 Grasshoppers and their frequency was recorded as :

Weight of grasshoppers	21	22	23	24	25	26	27	28	29	30
Frequency	4	2	6	4	9	9	7	5	1	3

Find out the Mode of the series.

Solution : Usually the item having maximum frequency is the Mode of the series. But here item 25 and 26 both have maximum and same frequency i.e., 9. Now the problem is, which item, 25 or 26, should be considered as Mode ?

In this circumstance method of grouping is used. With the help of grouping method, following table 3.5 has been prepared.

Table 3.5.

Wt. of grasshopper	Frequency						Items having maximum frequency
Variable	*f*	In groups of Two		In groups of Three			
	I	II	III	IV	V	VI	
21	4	] 6					0
22	2		8	12			0
23	6	] 10			12		0
24	4		13			19	1
25	9	] 18		22			4
26	9				25		6
27	7	] 12	16	13		21	3
28	5				10		1
29	1	] 5	6				0
30	4						0

Method adopted to frame grouping table. Firstly all values of variables are mentioned in a column. Then frequencies are given in column I. In column II and III the frequencies of column I are grouped in two's. In column II beginning from the first item. 1st + 2nd, 3rd + 4th, 5th + 6th, 7th + 8th and 9th + 10th. In column III frequencies are shown in two's but with a difference. The pairing is done from 2nd item, 1st item is left deliberately. Here beginning from the 2nd + 3rd, 4th + 5th, 6th + 7th, 8th + 9th. The last item could not be paired and was left untouched. In column IV the grouping is done in three's. Starting from the first item. 1st+2nd+3rd; 4th+5th+6th; 7th+8th+9th. In this case also last item could not be considered. In column V, the grouping is done in **three's but 1st item is ignored** i.e., 2nd + 3rd + 4th, 5th + 6th + 7th, 8th + 9th + 10th. In column VI the grouping is done in **three's but first two items**

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are ignored i.e., 3rd + 4th + 5th, 6th + 7th + 8th. Here last two items are left unused because third partner is not there. Thus a table 3.5 was prepared.

Total frequencies obtained from table 3.5 is analysed in table 3.6.

Table 3.6.

Columns	Items having frequencies maximum items
I	25, 26
II	25, 26
III	26, 27
IV	24, 25, 26
V	25, 26, 27
VI	26, 27, 28
Total	1 4, 6, 3, 1

In column I maximum frequency is 9. 9 is repeated two times. One 9 represents 25 and 2nd 9 represents 26. In column II maximum frequency is 18 which represents 9 of column I. First 9 representing 25 and 2nd 9 representing 26. In same fashion modal value for III, IV, V & VI are mentioned.

On perusal of above inspection table it appears that item no. 26 is repeated maximum times i.e. 6 times and hence Mode = 26.

Mode for continuous series. In the case of bimodal or trimodal condition we prepare grouping and analysis table and find out the modal class. Then apply the formula.

$$\text{Mode} = \left(\frac{f_1 + f_o}{f_1 - f_0 - f_2}\right) \times i \quad \text{or} \quad L_1 + \left[\frac{\Delta_1}{\Delta_1 + \Delta_2}\right] \times i$$

Where,

L_1 = Lower limit of modal class.

L_2 = Upper limit of modal class.

f_0 = Frequency of the preceding modal class.

f_1 = Frequency of modal class.

f_2 = Frequency of the succeeding modal class.

Δ_1 = The difference between the frequency of the modal class and the frequency of the premodal class $(f_1 - f_0)$

Δ_2 = The difference between the frequency of the modal class and the frequency of the succeeding modal class $(f_1 - f_2)$.

i = Width of the class interval.

Worked example : Length of 15 Earthworms were recorded as 30, 32, 31, 38, 35, 37, 35, 42, 41, 36, 38, 42, 39, 40 and 44 cm. Calculate Mode of above observations.

Solution : Make a table of two columns. One **for variable** in class interval and the other **for frequency** and then use above formula.

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Table 3.7.

Class interval	30—34	35—39	40—45
Frequency	$3f_o$	$7f_1$	$5f_2$

$\Delta_1 = f_1 - f_0 = 7 - 3 = 4$

$\Delta_2 = f_1 - f_2 = 7 - 5 = 2$

Here modal class is considered as $35 - 39$ because this class has got maximum frequency.

$$L_1 = 35,\ L_2 = 39,\ f_0 = 3,\ f_1 = 7,\ f_2 = 5,\ i = 5$$

$$\text{Mode} = L_1 + \left[\frac{\Delta_1}{\Delta_1 + \Delta_2}\right] \times i = 35 + \left(\frac{4}{4+2}\right) \times 5$$

$$= 35 + \frac{20}{6} = 35 + 3.33 = 38.33 \quad \textbf{Ans.}$$

Empirical formula for mode. Mode is also computed by the empirical relation.

Mode = 3 Median — 2 Mean

Thus, a knowledge of Mean and Median enables us to calculate the Mode roughly. Note that the above relation is only approximately true and should rather be used as a check on the values of mean, median and mode and not for finding any one of them when the other two are known.

Worked example : Find the Mode of the following distribution.

C.I.	0-6	6-12	12-18	18-24	24-30	30-36	36-42	42-48	48-54	54-60	60-66	66-72	72-78
Cum. freq.	2	6	13	18	26	29	33	38	46	50	58	59	60

Solution : For finding mode by applying the formula : **Mode = 3 Md^n − 2 mean**. Here we have to make a table of three columns. 1st for variable, 2nd for frequency. (Find frequency of each variable from given cumulative frequency) and 3rd column for cumulative frequency.

Table 3.8.

C.I.	0-6	6-12	12-18	18-24	24-30	30-36	36-42	42-48	48-54	54-60	60-66	66-72	72-78
Freq.	2	4	7	5	8	3	4	5	8	4	8	1	1
Cum. freq.	2	6	13	18	26	29	33	38	46	50	58	59	60

$$\text{Median number} = \text{value of } \left(\frac{N+1}{2}\right)^{\text{th item}} = \text{value of } \left(\frac{60+1}{2}\right)^{\text{th item}}$$

$$= 30.5^{th} \text{ item.}$$

As 30.5^{th} item lies under 33, Hence median class 36-42.

$$\text{Here, Median} = L_1 + \left[\frac{\Sigma f/2 - F}{fm}\right] \times i = 36 + \left[\frac{60 - 29}{2}\right] \times 6 = 37.5$$

For mean we have to make a table of four columns.

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Table 3.9.

Variable	0-6	6-12	12-18	18-24	24-30	30-36	36-42	42-48	48-54	54-60	60-66	66-72	72-78
Mid Point	3	9	15	21	27	33	39	45	51	57	63	69	75
Freq.	2	4	7	5	8	3	4	5	8	4	8	1	1
f. X.	6	36	85	105	116	99	156	225	408	228	504	69	75

$$\Sigma f . X = 2212 \; ; \text{Mean} = \frac{\Sigma f . X}{\Sigma f} = \frac{2212}{60} = 36.8$$

Mode = 3 Median —2 Mean $= 3 \times 37.5 - 2 \times 36.8 = 1125.5 - 73.6 = 38.9$

Ans.

Merits and demerits of mode

Merits. (1) It avoids the effects of extreme (and hence abnormal) items.

(2) Often it can be ascertained by mere inspection.

(3) Only the values occurring with high frequencies are required to be known for its determination. All values need not be known.

(4) It refers to a measurement which is the most usual and hence the most likely variate.

(5) Bimodal distribution may give a good indication of the heterogeneity of a population.

Demerits. (1) It is not well defined and is rarely used for higher life science researches.

(2) Arithmetic explanation of mode is not possible.

(3) Sometimes it is indefinite.

(4) It becomes difficult in multi-modal distribution.

(5) It is not based on all the observations of a series.

Relationship between mean, median, and mode

There is empirical relationship between **Mean, Median** and **Mode** of a series of items. If distribution of item values be symmetrical then the Mean, Mode and Median coincides, otherwise the distance between the Mode and the Median is usually twice the distance between the Median and the Mean. Thus–

Mode – Median = 2 (Median – Mean) or, Mode – Mean

= 3 (Median – Mean)

Note : Symmetrical Distribution : A distribution in which Mean, Median and Mode coincide is called a symmetrical distribution.

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EXERCISE

1. Define and explain Arithmetic mean.
2. Mention formula applied to calculate arithmetic mean for individual data, discrete series and continuous series.
3. Define and explain median and mode. Mention formula for individual data and grouped data (discrete and continuous series) to compute median and mode.
4. Calculate, mean and median from the given ungrouped data :
   (i) 10, 8, 20, 22, 39 and 18. [**Ans.** $\overline{X}$ = 19 5, median = 19]
   (ii) 19, 21, 17, 16, 19, 21 23 and 23 [**Ans.** $\overline{X}$ = 19.8 median = 20]
   (iii) 17, 19, 13, 17, 13, 11 and 21. [**Ans.** $\overline{X}$ = 15.8, median = 17]
   (iv) 15.8, 13.3, 15.2, 13.3, 17.8, 8.1 and 18.9. [**Ans.** $\overline{X}$ = 16.05, median = 15 8]
   (v) 1060, 1060, 1070, 1130, 1370, 1190, 1270 and 1170. [**Ans.** $\overline{X}$ = 1165, median = 1150]
   (vi) No. of animals per cage 3, 7, 8, 11, 13, 15, 16, 17, 18, and 20. [**Ans.** $\overline{X}$ = 12.8, median=14]
   (vii) Haemoglobin per cent in *g*/100 *ml* 6.0, 6.5, 7.5, 8.2, 8.5, 8.7, 8.8, 8.9, 9 and 9.5. [**Ans.** $\overline{X}$ = 8.16, median = 8.06]
5. Compute N (no. of observation) when $\overline{X}$ (mean) = 5 and $\Sigma\overline{X}$ = 30. [**Ans** 6]
6. The following data was obtained in a grassland community. Calculate mean, median and mode in ungrouped and grouped series.

   Number of seeds per plant (*Indigofera* species) : 39, 55, 35, 45, 49, 52, 48, 33, 48, 47, 50, 51, 53, 50, 55, 53, 54, 53, 50, 48, 49, 31, 33, 50, 55, 50, 51, 50, 53, 55, 52, 49, 51, 50, 50, 44, 51, 50, 58, 59, 57, 59, 60, 58, 51. [**Ans.** mean = 49 87, Median = 52.40]
7. Calculate mean, median and mode from the data given in following three tables :

Table A.

Class interval	16-20	21-25	26-30	31-35	36-40	41-45	46-50	51-55	56-60	61-65
Frequency	4	4	9	7	13	3	3	2	2	3

Table B.

Class interval	30-39	40-49	50-59	60-69	70-79	80-89	90-99	100-109	110-119
Frequency	5	4	9	8	9	10	4	3	2

Table C.

Class interval	50-54	55-59	60-64	65-69	70-74	75-79	80-84	85-89	90-94	95-99
Freq.	2	1	3	1	7	31	6	7	1	3

Ans.

Table A			**Table B**			**Table C**		
Mean	=	77.24	Mean	=	66.3	Mean	=	77.09
Median	=	36.38	Median	=	75 5	Median	=	77.74
Mode	=	38	Mode	=	84.5	Mode	=	77

8. The frequency distribution according to the age group of persons is as follows. Calculate the arithmetic mean of their ages.

Groups	5-15	15-25	25-35	35-45	45-55	55-65
No. of persons	4	7	12	9	5	3

[**Ans** 33.25]

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9. In an experiment frogs were observed to prey on insects in unit time. Calculate the average number of insects consumed by a frog.

No. of Insects	70-90	90-110	110-130	130-150	150-170	170-190
No. of frogs	40	55	60	70	100	65

[Ans. 136.92]

10. Define mode. Describe various methods of its calculation with suitable examples. Find mode of 7, 8, 9, 4, 6, 7, 9, 3, 6, 9, 8, 9, 7, 8, 9, and 11.

[Hint : Prepare frequency distribution table. Mode is that value where maximum frequency falls.] **[Ans.** 9]

11. A pig farm is assumed to depreciate 40% in flesh production in the first year, 25% in the second year and 10% per annum for the next 3 years, each percentage being calculated on the diminishing value, what is the average percentage depreciation for the five years ?

[Ans. 20%, 15.85%]

12. The height of 12 students in a class is like 148.0 cm, 148.5 cm, 150.0 cm, 151.0 cm, 156.0 cm, 155.5 cm, 151.6 cm, 153.4 cm, 159.6 cm, 154.4 cm, 150. cm, 150.1 cm, calculate the mean height. **[Ans.** 152.3 cm]

13. Explain where and how the following calculations are used–(a) Mode (b) Median (c) Arithmetic mean.

14. Define Mode, Median and Mean. Calculate the mean from the given table and arrange it to show the frequency of number.

28, 32, 45, 54, 60, 61, 70, 63, 70, 72, 76, 54, 63, 76, 32, 54, 60, 45, 72, 98. **[Ans.** 58.75]

15. Calculate the arithmetic mean of the number of leaves and no. of plants.

No. of leaves (X)	5	10	15	20	25
No. of plants (f)	3	5	7	3	2

[Ans. 14]

16. Find Median from the following data recorded on number of seeds per pod : 5, 19, 42, 11, 50, 30, 21, 0, 52, 36, 27, **[Ans.** 27]

17. Find the median of the following discrete series.

Variate	4, 5, 6, 7, 8, 9, 10.	11.	12.	13.	14.	15.	16.	17.
Freq.	2	5	8	9	12	14	14	15	11	13	9	7	4	3

[Hint : Make a table of 3 columns. variable, freq, and cumulative freq.

Median = Size of $\left(\frac{\text{cum freq.} + 1}{2}\right)^{\text{th}}$ item and find the Median] **[Ans.** 10]

18. Prepare a grouping table for the following discrete series.

Length of Earthworms in cm.	50	52	54	56	58	60	62	64	66	68
No. of Earthworms.	5	16	20	15	19	25	15	20	10	5

[Hint : If you fail to make it consult following table & try to understand].

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No.	Height in cms.	Columns					
		1	2	3	4	5	6
		Maximum frequency	1+2 3+4 5+6 7+8 9+10	2 + 3 4 + 5 6 + 7 8 + 9	1 + 2 + 3 4 + 5 + 6 7 + 8 + 9	2 + 3 + 4 5 + 6 + 7 8 + 9 + 10	3 + 4 + 5 6 + 7 + 8
1	50	5					
2	52	16	21		41		
3	54	20		36		51	
4	56	15	35				
5	58	19		34			54
6	60	25	44		59		
7	62	15		40		59	
8	64	20	35				60
9	66	10		30	45		
10	68	5	15			35	

19. In a biological experiment following continuous series was obtained. Find the Mode of the series.

Class inter.	0-10	11-20	21-30	31-40	41-50	51-61	61-70	71-80	81-90	91-100
Freq.	6	4	6	9	12	15	10	8	4	1

[Apply Formula, Mode $= L_1 + \left[\frac{f_1 + f_o}{f_1 - f_o - f_2}\right] \times i$ **[Ans.** 53.75]

20. A set of measurements has a mean of 80. A constant value 10 is added to each measurement. What is the mean of the resulting measurements ? **[Ans.** 90]

21. Fill up the blanks with appropriate answers :
    (i) the most frequently occuring observations in a set of data is called .....
    (ii) The sum of all observations divided by the number of observations is known as .....
    (iii) The grades of a student on six examinations were 85, 91, 72, 87 and 78. The median of grades is .....
    (iv) ..... may be defined as the sum total of the values of observations divided by the number of observations.
    (v) The highest frequency of a value in a sample of variable is termed as ..... mean/ median/ average.
    (vi) The most commonly occuring value of variable is termed .....
    (vii) ..... may be defined as the values of that item which divides an arranged series into two equal parts.
    (viii) ..... is rarely used for medical and higher biological research.
    (ix) Median is a better indicator of an ..... than mean when one or more of the lowest or the highest observations are wide apart.
    (x) To obtain median, data must be kept in ..... or ..... order.

Ans. : (1) Mode (ii) Mean (iii) 81.5 (iv) Mean (v) Mode (vi) Mode (vii) Median (viii) Mode (ix) average (x) ascending or desending. *(Z–37/Biost.)*

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22. In the following questions each statement is followed by four alternatives. Tick the correct one.

(i) While crossing a river, which one of the following informations regarding its depth is most essential ?

(a) Average depth (b) Mean depth
(c) Range of the depth. (d) Standard error of the depth.

(ii) Which one of the following ignores the values of extremities of a series ?

(a) Mean (b) Median (c) Mode (d) Median and Mode.

(iii) Which one is the correct relationship ?

(a) Mode = Mean – 2/3 (Mean - Median)
(b) Mode = Median – 2/3 (Median - Mean)
(c) Mode = Mean – 3 (Mean - Median)
(d) Mode = Mean – 3 (Median - Mean)

(iv) If N is the number of the observations, the formula $N + 1/2$ gives :

(a) Mean (b) Median (c) Mode (d) None of these

(v) The highest frequency of a value in a sample of variables is termed as :

(a) Mean (b) Mode (c) Average (d) Median

(vi) The arithmetic mean of population is symbolised by :

(a) μ (b) Y (c) $\overline{X}$ (d) $\overline{x}$

(vii) The arithmetic mean computed from sample of population is symbolised by :

(a) $\overline{x}$ (b) $\overline{X}$ (c) y (d) μ

(viii) $\overline{X} = \frac{\Sigma f . X}{\Sigma f}$ expression is used to calculate mean in :

(a) individual series (b) only discrete series
(c) Only continuous series (d) Both discrete and continuous series.

(ix) Arithmetic explanation of median is :

(a) Possible (b) Not possible
(c) Sometimes possible (d) Sometimes not possible.

(x) Arithmetic explanation of mode is :

(a) Possible (b) Not possible
(c) Possible in continuous series (d) Possible in individual series.

Answers

(i) c (ii) c (iii) c (iv) b (v) b (vi) a (vii) b (viii) d (ix) b (x) b.

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4

Measures of Variability

Meaning of variability. Standard deviation. Coefficient of standard deviation. Exercise.

Meaning of Dispersion or Variability

In statistics, dispersion is used commonly to mean scatter, deviation, fluctuation, spread or variability of data. Dispersion is used to denote a lack of uniformity in item values of a given variable.

Definition

The degree to which the individual values of the variate scatter away from the average or the central value, is called a **dispersion or variability**.

The measure of variation is one of the important tools of statistics for biologists because biological phenomena are more variable than that of physical and chemical sciences. Length, weight, Hb%, RBCs number, rate of oxygen consumption etc. of two individuals of same species, of same age and sex will differ definitely. Same plant of sweet pea produces different number of seeds in different pods. Same person exhibit different pulse rate and heart beat in different physiological conditions. Cure rate with the same drug varies in different patients, even of same age and sex.

Standard Deviation

Standard deviation may be defined as "**the square root of the arithmetic mean of the squares of deviations from the arithmetic mean.**

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Computation of standard deviation S or (σ) for (a) ungrouped data

Following six steps are observed before the computation of standard deviation : (i) Calculate the mean (ii) Find the difference of each variable from the mean (iii) Square the differences of observations from the mean (iv) Add the squared values to get the sum of squares. (v) Divide this sum by the number of observations minus one to get mean - squared deviation, called variance. (vi) Find the square root of this variance to get root-mean squared deviation, called **standard deviation**. Having squared the original, reverse the step of taking square root.

Apply following formula to calculate Standard deviation.

$$S \text{ or } \sigma = \sqrt{\frac{\Sigma x^2}{N}}$$

$$\text{or } \sigma = \sqrt{\frac{\Sigma x^2}{N-1}}$$

Where S = Standard Deviation ; x = deviation obtained from mean i.e. $X - \bar{X}$

N = Total number of observations.

[**Note :** S is computed by using *N–1 in the denominator of above formula* when the total number of observations are less than 30. If the size of sample is more than 30 then use first mentioned formula :

$\sigma = \sqrt{\frac{\Sigma x^2}{N}}$ is applied

Worked example **:** Haemoglobin percent g/100 ml of liver fed *Wallago attu* was recorded as 23, 22 20, 24, 16, 17, 18, 19 and 21. Calculate the Standard Deviation.

Solution : As suggested above prepare a table of 4 columns. First column for values of variables i.e. X. 2nd column for observation – mean $(X - \bar{X})$. 3rd for deviation (x) and 4th for deviation square (x^2).

Calculate the Mean $\bar{X} = \frac{180}{9} = 20$

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Table 4.1.

Variable X	Observation − Mean $X-\bar{X}$	Deviation x	Deviation square x^2
16	16 — 20	− 4	16
17	17 — 20	− 3	9
18	18 — 20	− 2	4
19	19 — 20	− 1	1
20	20 — 20	0	0
21	21 — 20	+ 1	1
22	22 — 20	+ 2	4
23	23 — 20	+ 3	9
24	24 — 20	+ 4	16
$\Sigma X = 180$			$\Sigma x^2 = 60$

Given formula is applied : $S = \sqrt{\frac{\Sigma x^2}{N-1}}$ (Sample size is less than 30).

Put the values, $S = \sqrt{\frac{60}{9-1}} = \sqrt{\frac{60}{8}} = \sqrt{7.5} = 2.75$ **Ans.**

Computation of standard deviation for grouped data [(discrete series)]

$$S = \sqrt{\frac{\Sigma f x^2}{\Sigma f}} \quad \text{or} \quad S = \sqrt{\frac{\Sigma f x^2}{\Sigma f - 1}}$$

Worked example : Weight of ovary of 50 fishes is given below in a simple frequency distribution table. Find the standard deviation.

Ovary Weight	2	2.5	2.7	2.9	3	3.1	3.3	3.7	3.9	4	4.6	4.8	4.9	5	5.5	5.9	6	6.1	6.7	6.9
Freq.	2	1	1	2	3	1	3	2	4	3	2	3	3	3	2	3	3	3	3	3

Solution : A Table of six columns is prepared :

First column for Variable i.e., ovary weight. 2nd column for frequency. 3rd column for frequency multiplied by variable. 4th column for deviation obtained by $(X - \bar{X})$ formula. 5th column for deviation square. 6th column for frequency multiplied by deviation square.

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Table 4.2.

X	f	$f.X$	x	x^2	fx^2
2	2	4	–2.62	6.864	13.736
2.5	1	2.5	–2.12	4.494	4.494
2.7	1	2.7	–1.92	3.841	3.841
2.9	2	5.8	–1.72	2.958	5.916
3	3	9.0	–1.62	2.624	7.872
3.1	1	3.1	–1.52	2.310	2.310
3.3	3	9.9	–1.32	1.742	5.226
3.7	2	7.4	–0.92	0.846	1.692
3.9	4	15.6	–0.72	0.518	2.072
4.0	3	12.0	–0.62	0.384	1.152
4.6	2	9.2	–0.02	0.0004	0.0008
4.8	3	14.4	0.17	0.028	0.084
4.9	3	14.7	0.28	0.078	0.234
5.0	3	15.0	0.37	0.136	0.408
5.5	2	11.0	0.87	0.756	1.512
5.9	3	17.7	1.27	1.612	4.836
6.0	3	18.0	1.37	1.876	5.628
6.1	3	18.3	1.47	2.160	6.48
6.7	3	20.1	2.07	4.284	12.852
6.9	3	20.7	2.68	7.182	21.546
		$\Sigma f.X = 231.1$			$\Sigma fx^2 = 101.89$

Solution :

$$\text{Mean} = \frac{\Sigma fX}{\Sigma f} = \frac{231.1}{50} = 4.622$$

$$S = \sqrt{\frac{\Sigma fx^2}{\Sigma f}} = \sqrt{\frac{101.89}{50}} = \sqrt{2.0378} = 1.427 \textbf{ Ans.}$$

Computation of standard deviation by direct method

Standard deviation (S) can also be calculated by following formula where we do not need to obtain deviation : $S = \sqrt{\frac{\Sigma fX^2 - \bar{X}^2}{\Sigma f}}$

Worked example : A sample of ten common limpet shells (*Patella vulgaris*) from a rocky shore having the following maximum basal diameters

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in millimeters : 36, 34, 41, 39, 37, 43, 36, 37, 41, 39 are obtained. Find out basal diameter and St. deviation of the shell.

Solution : In order to calculate the mean basal diameters and the Standard deviation, it is necessary to calculate $\Sigma f/f.X^2$ and $\bar{X}^2$ as mentioned in the Table 4.3.

Table 4.3.

X	f	fX	$f.X^2$
34	1	34	1156
36	2	72	2592
37	2	74	2738
39	2	78	3042
41	2	82	3362
43	1	43	1849
	$\Sigma f = 10$	$\Sigma fX = 383$	$\Sigma fX^2 = 14739$

Therefore $\bar{X} = \frac{\Sigma fX}{\Sigma f} = \frac{383}{10} = 38.3$

$\therefore \quad \bar{X}^2 = 1466.9$

Since $S = \sqrt{\frac{\Sigma fX^2}{\Sigma f} - \bar{X}^2}$

$$= \sqrt{\left(\frac{14739}{10} - 1466.9\right)}$$

$$= \sqrt{1473.9 - 1466.9}$$

$$= \sqrt{7}$$

$= 2.65$ or 2.7 **Ans.**

In this population of the *Patella vulgaris* the mean basal diameter of the shell is 38.3 mm, with a standard deviation of 2.7 mm (correct to one decimal place). If these values are applied to a larger population of the *Patella* then it may be assumed, on statistical grounds, that approximately 68% of the population will have a basal diameter of the shell of 38.3 mm plus and minus 1 standard deviation (2.7 mm), that is they will lie within a range 35.6 – 41.0 mm; approximately 95% of the population will have a basal diameter of the shell of 38.3 plus and minus 2 Standard deviation (5.4 mm), that is they will lie within the range 32.9 — 43.7 mm, and practicelly 100% will lie within plus and minus 3 Standard deviations.

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Computation of Standard deviation for grouped data (Continuous series)

Worked example : Ovary wt. of 50 fishes and their frequency is given in class interval. Find Standard deviation.

Wt. of ovary	2 — 2.9	3 — 3.9	4 — 4.9	5 — 5.9	6 — 6.9
Frequency	6	13	11	8	12

Solution : It is computed by following six steps :

Step 1 : Find mid point (m) of each class interval.

Step 2 : Find mean of the series applying formula $\overline{X} = \frac{\Sigma f.X}{\Sigma f}$

Step 3 : Find deviation of each observation $(X - \overline{X})$.

Step 4 : Square each deviation.

Step 5 : Multiply each squared deviation with their frequency.

Step 6 : Sum all the multiplied value of f and x^2.

Now a table of 7 columns is framed.

Table 4.4.

Class Interval	Mid point m	Frequency f	$f.m$	Deviation $X - \overline{X} = x$	Deviation Square x^2	fx^2
2 - 2.9	2.45	6	14.7	-2.14	4.579	27.47
3 - 3.9	3.45	13	44.85	-1.14	1.299	16.88
4 - 4.9	4.45	11	48.95	-0.14	0.019	0.21
5 - 5.9	5.45	8	43.6	+0.86	0.739	0.91
6 - 6.9	6.45	12	77.4	+1.86	3.459	41.4
		$\Sigma f = 50$	$\Sigma f.m = 229.5$		$\Sigma x^2 = 10.088$	$\Sigma fx^2 = 92.02$

$$\overline{X} = \frac{\Sigma f.X}{\Sigma f} = \frac{229.5}{50} = 4.59$$

$$S = \sqrt{\frac{\Sigma f x^2}{\Sigma f}} = \sqrt{\frac{92.02}{50}} = \sqrt{1.84} = 1.35 \text{ Ans.}$$

Co-efficient of standard deviation is calculated by following formula : Co-efficient S = S/$\overline{X}$. Here co-efficient $S = \frac{1.35}{4.59} = 0.29$ Ans.

Merits and demerits of Standard deviation

Merits. (i) Standard deviation summarises the deviation of a large distribution from mean in one figure used as a unit of variation. (ii) It indicates whether the variation of difference of an individual from the mean is real or

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by chance. (iii) Standard Deviation helps in finding the suitable size of sample for valid conclusions. (iv) It helps in calculating the Standard error.

Demerits. Standard deviation gives weightage to only extreme values. The process of squaring deviations and then taking square root involves lengthy calculations.

Combined Standard Deviation

If two frequency distributions have means $\bar{X}_1$ and $\bar{X}_2$ and Standard deviations S_1 and S_2 respectively. Then, the combined S.D., denoted by S_{12}, of the two distributions is obtained by using :

$$S_{12} = \frac{\sqrt{N_1 (S^2_1 + D^2_1) + N_2 (S^2_2 + D^2_2)}}{N_1 + N_2}$$

Where, N_1 = Total frequency or the number of observation in first frequency distribution.

N_2 = Total frequency or the number of observations in second frequency distribution.

$D_1 = (\bar{X}_{12} - \bar{X}_1)$ = The difference between combined mean and the mean of the first frequency distribution.

$D_2 = (\bar{X}_{12} - \bar{X}_2)$ = The difference between combined mean and the mean of the second frequency distribution.

The above formula can be extended to any number of distributions. For example, in the case of three distributions, it will be :

$$S_{123} = \frac{\sqrt{N_1 (S^2_1 + D^2_1) + N_2 (S^2_2 + D^2_2) + N_3 (S^2_3 + D^2_3)}}{N_1 + N_2 + N_3}$$

Here,

$$D_1 = (\bar{X}_{123} - \bar{X}_1) ; D_2 = (\bar{X}_{123} - \bar{X}_2) ; D_3 = (\bar{X}_{123} - \bar{X}_3)$$

$\bar{X}_{123}$ = The combined mean of the three distributions. Other symbols have their usual meanings.

Worked example : In a distribution (Length of a species of fish in cm) score had mean = 52 and SD (S) = 15. For improving the length, a drug was administered which increased a score of 5 cm. in general. Find the Standard deviation of improved scores.

Solution : In the property of SD it remains unchanged if each score is increased or decreased by a constant value. Here a constant score of 5 is added to each score and, therefore, new Standard deviation (S) will remain the same as 15.

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Worked example : The growth rates for two varieties of wheat plants A and B, the mean and S scores are as :

Variety A	Mean	S	No. of plants
	75	20	40
Variety B	65	25	60

Find (i) The combined mean scores. (ii) The combined S of the scores of the two varieties.

Solution : Symbolically, the given data can be put as :

$N_1 = 40 \quad \bar{X}_1 = 75 \quad S_1 = 20 \; ; \quad N_2 = 60 \quad \bar{X}_2 = 65 \quad S_2 = 25$

Using the following formula, the combined mean score is calculated.

$$\bar{X}_{12} = \frac{N_1\bar{X}_1 + N_2\bar{X}_2}{N_1 + N_2} = \frac{40 \times 75 + 60 \times 65}{40 + 60} = 69$$

Therefore, $D_1 = (\bar{X}_{12} - \bar{X}_1) = 69 - 75 = -6 \; ; D_2 = (\bar{X}_{12} - \bar{X}_2) = 69 - 65 = +4$

Now, using following formula, the combined S of scores of the two varieties of wheat can be obtained :

$$S_{12} = \sqrt{\frac{N_1 (S_1^2 + D_1^2) + N_2 (S_2^2 + D_2^2)}{N_1 + N_2}}$$

$$= \sqrt{\frac{40 (400 + 36) + 60 (625 + 16)}{100}} = \sqrt{559} = 23.64 \quad \textbf{Ans.}$$

EXERCISE

1. What do you mean by dispersion or variability or scatter? Define variability and discuss its merits and demerits.
2. Measures of variability ? Name measures of variability of individual observations.
3. What is Standard deviation ? Define St. deviation of ungrouped and grouped data.
4. While measuring the length of sugarcane plants an agriculturist measured 50 plants with a maximum length of 50 cm. The mean score was 24 and $S = 10$. Let the maximum length of plant raise upto 100 cm, and the scores of each measurement of plant also doubled. Find the Standard deviation of these new scores. **[Ans. 20]**
5. What are the mathematical properties of SD? How is it a better measure of dispersion than range ?
6. Define Standard deviation (S) and give its mathematical expression.
7. Define the term Standard deviation with the help of suitable example. Show the method of calculating it. What are its merits and demerits ?
8. Determine the Standard deviation of the first ten natural numbers. **[Ans. 2.87]**
9. In the following questions each statement is followed by four alternatives. Tick the correct one.
   (i) Standard deviation was first suggested by .....in 1883.
   (a) Garret (b) Guilford
   (c) Spearman (d) Karl Pearson

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(ii) Standard deviation may be defined as :
(a) Difference between the highest value and lowest value in a set of data.
(b) The Range of variable between 25th percentile and 75th percentile divided by 2.
(c) The positive square root of the arithmetic mean of the squares of deviations of the observation from the Arithmetic mean.
(d) Ratio of standard deviation (S) of the sample divided by the square root of the total number of observations.

(iii) Which one of the following formula is used for computation of Standard deviation from ungrouped data (Individual series).
(a) $S=\sqrt{\frac{\Sigma X^2}{N}}$ (b) $S=\sqrt{\frac{\Sigma x^2}{N}}$ (c) $S=\sqrt{\frac{\Sigma f.dx^2}{\Sigma f}}$ (d) None

(iv) Which one of the following formula is applied for computation of Standard deviation for grouped data (discrete series) :
(a) $S=\sqrt{\frac{\Sigma f.dx^2}{\Sigma f}}$ (b) $S=\sqrt{\frac{\Sigma x^2}{N}}$ (c) $S=\sqrt{\frac{\Sigma X^2}{N}}$ (d) None

(v) Which one of the following formula is used for computation of SD for grouped data (continuous series) :
(a) $S=\sqrt{\frac{\Sigma f.dx^2}{\Sigma f}}$ (b) $S=\sqrt{\frac{\Sigma x^2}{N}}$ (c) $S=\sqrt{\frac{\Sigma X^2}{\Sigma f}}$ (d) None

(vi) Length of 9 Earthworms was recorded as 23 cm, 22cm, 24 cm, 16cm, 17cm, 18cm, 19 cm & 21 cm. Compute SD & tell which one of the following answer is correct :
(a) 2.98 cm (b) 3.85 cm (c) 2.58 cm (d) None

(vii) Which of the following formula is used to obtain coefficient of Standard deviation :
(a) $\frac{S}{X}$ (b) $\frac{S.N}{\bar{x}.N}$ (c) $\frac{\delta}{\sqrt{N}}$ (d) $\frac{\delta.N}{\sqrt{N}}$

(viii) Standard deviation expressed as a percentage of mean is called :
(a) Coefficient of variation (b) Mean deviation
(c) Standard error (d) None

(ix) The Standard deviation of the given data 10, 10, 10, 10, 10, is :
(a) 1 (b) 10 (c) 0.1 (d) 0

(x) Standard deviation of hypothetical population is denoted by :
(a) σ (b) ρ (c) X (d) r

10. State whether the following statement is true or false :
(i) The variability in a sample remains unchanged if the value of each observation was decreased. [**Ans.** : True]
(ii) While crossing a river, information about the standard deviation is a must. [**Ans.** : False]
(iii) Computation of standard deviation is not possible unless the data is in frequency distribution. [**Ans.** : False]
(iv) Standard deviation is the only means to know variability [**Ans.** : False]
(v) St. deviation can be obtained from both individual and grouped series [**Ans.** : True]

Answers

(i) d (ii) c (iii) b (iv) a (v) a (vi) c (vii) a (viii) a (ix) d (x) a

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5

Normal Distribution

Introduction. Normal probability distribution. Normal distribution curve. Area under standard normal curve. Relationship between normal distribution curve and standard deviation. Properties of normal distribution curve. Importance of the normal distribution curve. Worked examples. Exercise.

Introduction

Sometimes the knowledge of theoretical probability distribution which are not based on real observations become essential for application of statistical methods. In a series, values of a random variable is known as theoretical probability distribution. There are three types of theoretical probability distribution.

(1) Normal probability distribution

(2) Poisson distribution

(3) Binomial distribution.

We are concerned here only with Normal probability distribution according to the unified syllabus.

Normal Probability Distribution

A continuous distribution is one in which the random variable X can assume any value between certain limits a and b. In other words in a population many characteristics show a complete gradation without any break, from one extreme to the other. This is signified most closely by characteristics such as mass, linear dimension, shape and colour of organisms.

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If measures of distribution are arranged in linear fashion and vary continuously on both the sides from the central value, then the distribution is called normal distribution.

In normal distribution measures are concentrated closely around the centre and taper off from this central high point to the left and right. There are relatively few measures at the "low score" end of the scale, an increasing number upto a maximum at the middle position, and a progressive falling off towards the "high score" end of the scale.

Normal Distribution Curve

Normal (or Gaussian) distribution is the most important continuous probability distribution in statistics and is defined by the probability density function (or simply density function).

The Normal Distribution is concerned with all numbers whether complete or in a fraction. For example, if we study the height of Americans, the height of most of the Americans will fall between 162 to 192 cm. Height of very few Americans will fall between 152 to 167 cm (lower end of the scale) and between 282 to 215 cm (higher end of the scale).

One can understand it more clearly by drawing a graph representing variables on horizontal line and their frequencies on vertical line for a frequency distribution. Let us plot a graph for the body weight in g and their frequencies of 149 fishes given below :

Table 5.1.

Wt. of fishes	15	17	19	21	23	25	27	29	31	33	35
Frequencies	9	11	13	15	17	19	17	15	13	11	9

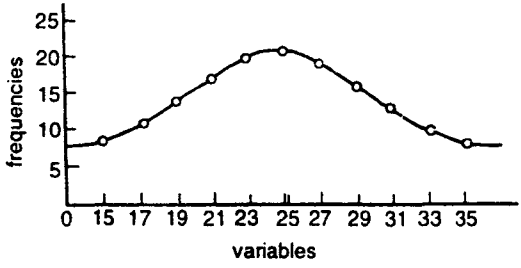

Fig. 1. Normal distribution curve.

The curve plotted with the help of data (Table 5.1) of normal distribution presents a bell shaped symmetrical curve called "normal distribution curve". The normal distribution curve is also known as the "Gaussian curve". This curve is continuous for continuous variable. It shows that the mean value of

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the variable lie at the peak of the curve and the largest number of observations lie at this point.

Area Under Standard Normal Curve

A graph of the standard normal curve $y = p(z)$ is shown in the Fig. 5.2. The percentage distribution of area under the curve is also indicated in the figure.

The area includes between the vertical lines $z = -1$ and $z = +1$; $z = -2$ and $z = +2$; $z = -3$ and $z = +3$ and respectively 68·27%, 95·45% and 99·73% of the total area which is 1.

As the ordinate divides the area under the normal curve into two equal parts, the median of distribution coincides with the mean. The points of inflection of the normal curve are equidistant from the mean. The variates of variable having lower values lie on the left side of the mean while variates of variable having higher values lie at the right side of the mean on horizontal line.

Relationship Between Normal Curve Area and Standard Deviation

Figures 5.2 and 5.3 bear three uprights at the points corresponding to 1, 2 and 3 times of the Standard deviation of the variables on each side of the mean. The Figure shows following features :

(1) The 1st and 3rd quartiles are equidistant from the Median and at a distance of 0.6745 σ. Thus the semi-inter quartile range is equal to 0.6745 of the Standard deviation.

(2) Mean $\pm$ 1 σ covers 68.27% area i.e. relative frequency. This suggests that in a normal distribution 68.27% of the observations lie within a distance equal to the Standard deviation on each side of the Mean i.e. 34.135% area will lie on either side of the mean.

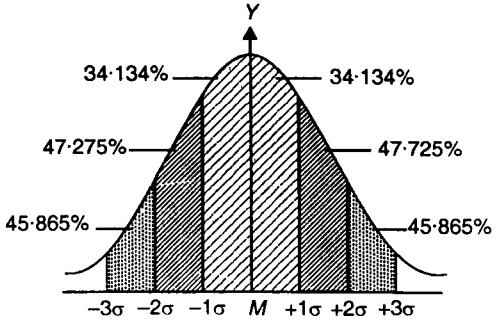

Fig 2 Area under standard normal curve . showing probability or relative frequency of an observation falling beyond mean $\pm$ 2 SDs and $\pm$ 3 SDs respectively

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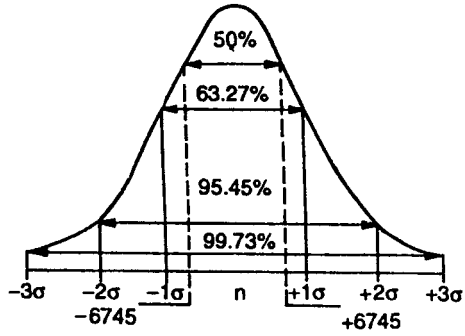

Fig. 3. Relationship of the normal distribution curve and standard derivation.

(3) Mean ± 2 σ covers 95.45% area i.e. relative frequency.

(4) Mean ± 3 σ covers 99.73% area i.e. relative frequency. It covers almost entire area of the curve. Only 0.27% area remains outside the curve.

(5) 50% of observations lie in an area bounded by a distance of 0.6745 σ on each side of the Mean (shown as dotted line in Fig. 5.3).

Besides above points, following facts are also considerable in context of curve area :

$\bar{X} \pm 1.96\,\sigma$ covers 95% area ; $\bar{X} \pm 2.57\,\sigma$ covers 99% area ; $\bar{X} \pm 0.6745\,\sigma$ covers 50% area.

Properties of Normal Distribution Curve

(1) Normal distribution is a continuous probability distribution having two parameters m & σ.

(2) The normal curve is bell-shaped and symmetrical about the line $x = m_1$ and the two tails of the curve on both sides of $x = m$ extends to infinity.

(3) It associates with continuous variables such as height, weight, age, fecundity, rate of respiration, Hb% etc.

(4) There is only one maximum peak (Unimodal). The normal curve is symmetrical and asymptotic (touches at infinity).

(5) The height of the normal curve is maximum at its Mean. Hence the Mean and Mode of normal distribution coincide. As the peak of the normal curve divides the distribution into two equal parts the Mean and Median also coincide. Thus for a normal distribution all measures of Central tendency i.e., Mean, Median and Mode are equal (Mean = Median = Mode).

(6) The area between the curve and the two uprights drawn at any point gives the fraction of the total number of observations between these points.

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(7) Most of the observations are clustured around the mean and there are relatively a few observations at the extremes.

(8) The normal distribution curve has a fixed mathematical characteristic feature independent of the scale (unit of measurement) magnitude and unit of Mean and Standard deviation.

Importance of the Normal Distribution

Normal Distribution plays a very important role in statistical theory and, in particular, in sampling theory. It has been found that :

(1) Data obtained from life science (Medical, Veterinary, Agriculture and Biological) measurements approximately follow Normal Distribution.

(2) Distribution like Binomial or Poisson can be approximated to Normal Distribution.

If the number of trials n is indefinitely large and neither p nor q is very small, then Binomial Distribution tends to Normal Distribution.

If the parameter m is indefinitely large (i.e., if $m \to \alpha$), then Poisson Distribution tends to Normal Distribution.

(3) Any statistic (i.e., sample mean, sample S.D., etc.), for large samples approximately follows Normal Distribution and as such it can be studied with the help of normal curve.

(4) Normal curve is used to find confidence limits of the population parameters.

(5) Normal Distributions are largely applied in statistical quality control in industry for finding control limits.

Worked Example : (1) Find the area under the normal curve in the following cases using table.

(i) between Z=0 and Z=1.4 (ii) between Z =—0.56 & Z=0

Solution : (i) In the table given at the end of the book, proceed downward under column marked Z on top until 1·4 is reached, and then proceed right, to column marked 0 on top.

The result obtained is 0·4192 which is the required area. Here 0·4192 represents the probability that Z lies between 0 and 1·4, i.e., $P(0 \leq Z \leq 1{\cdot}4) = 0{\cdot}4192$

(ii) Required area = (area between Z=—0.56 and Z=0)

= (area between Z = 0 and Z = 0·56) (By summetry)

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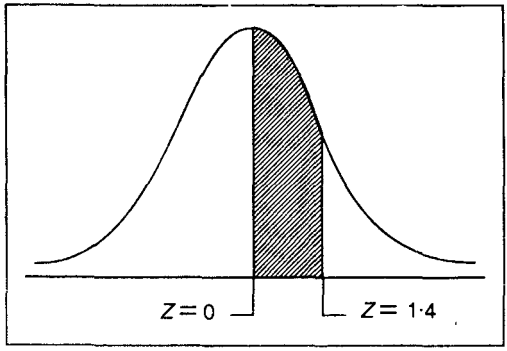

Fig. 5.4. Area between Z = 0 and Z = 1.4 under the normal curve.

To find the area between $Z = 0$ and $Z = 0{\cdot}56$ from the table given at the end of the book, proceed downward under column marked Z until 0·5 is reached. Then proceed right to column marked 6 on top.

The result obtained is 0·2123 which is the required area and it represents the probability that Z lies between $-0{\cdot}56$ and 0, i.e., $P(-0{\cdot}56 \leq Z \leq 0) = 0{\cdot}2123$.

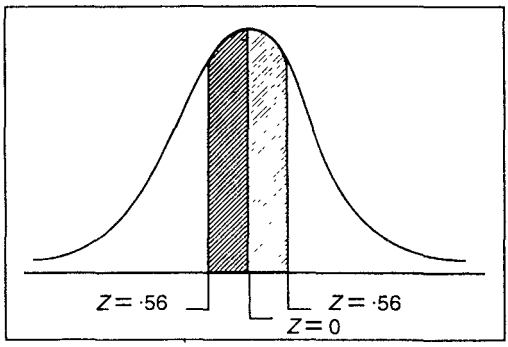

Fig. 5.5 Area between Z = 0 and Z = 0.56 under the normal curve.

(2) Find the probability that the standard normal variate is (i) greater than 1·76 ; (ii) less than $-0{\cdot}8$.

Solution : (i) Required probability $P(Z = 1{\cdot}76)$ = area under the normal curve to the right of $Z = 1{\cdot}76$ = (area to the right of $Z = 0$) = (area between $Z = 0$ and $Z = 1{\cdot}76$) $= 0{\cdot}5 - 0{\cdot}4607 = 0{\cdot}0392$. *(Z–37/Biost.)*

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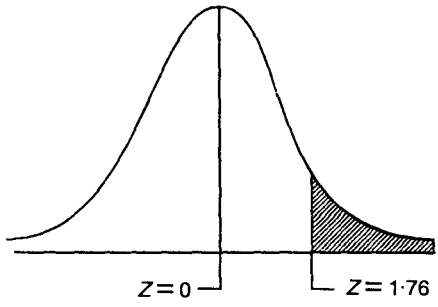

Fig. 5.6. Area between Z = 0 and Z = 1.76 under the normal curve.

(ii) Since the standard normal curve is symmetrical about $z = 0$
so, (area under the normal curve to the left of $Z = 0$) = (area under the normal curve to the right of $Z = 0$) $= \frac{1}{2} = 0{\cdot}5$

Required probability $P(Z < -0{\cdot}8)$
= area under the normal curve to the left of $z = -0{\cdot}8$
= (area to the left $Z = 0$) - area between $Z = -0{\cdot}8$ and $Z = 0$
$= 0{\cdot}5 -$ (area between $Z = 0$ and $Z = 0{\cdot}8$)
$= 0{\cdot}5 - 0{\cdot}2881 = 0{\cdot}2119$

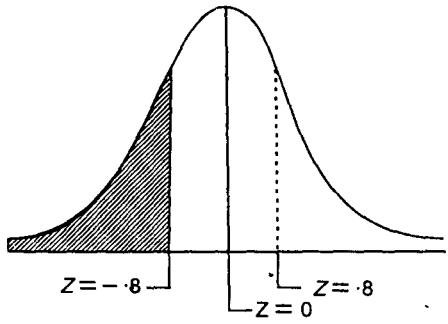

Fig. 5.7. Area between Z = 0 and Z = 0.8 under the normal curve.

(3) The mean weight of 500 fishes of a species of a pond is 151 g and the Standard deviation is 15 g. Assuming that the weights are normally distributed, find how many fishes weigh (i) between 119·5 and 155·5 g ; (ii) more than 160 g.

Solution : Here m = mean = 151 g., σ or SD = 15 g

We have $Z = \frac{x - m}{\sigma}$ = value of x in standard units (or standardized value of x)

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(i) 119·5 g in standard unit $= \frac{119 - 115}{15} = -2{\cdot}10$

and 115·5 g in standard units $= \frac{115{\cdot}5 - 151}{15} = 0{\cdot}30$

$\therefore$ Proportion of fishes whose weights lie between 119·5 and 155·5 g.
= (area under the standard normal curve between $Z = -2{\cdot}10$ and $Z = 0{\cdot}30$)
= (area between $Z = -2{\cdot}10$ and $Z = 0$) + (area between $Z = 0$ and $Z = 0{\cdot}30$)
= (area between $Z = 0$ and $Z = 2{\cdot}10$) + (area between $Z = 0$ and $Z = 0{\cdot}30$)
$= 0{\cdot}4821 + 0{\cdot}1179$ [using table] $= 0{\cdot}6000$ or $0{\cdot}6$
Hence, the required number of fishes whose weights lie between 119·5 and 155·5 g $= 0{\cdot}6 \times 500 = 300$.

(ii) 160 g in standard units $= \frac{160 - 151}{15} = \frac{9}{15} = 0{\cdot}60$

$\therefore$ Proportion of fishes whose weights are more than 160 g.
= area under the standard normal curve to the right of $Z = 0{\cdot}60$
= (area to the right of $Z = 0$) = (area between $Z = 0$ and $Z = 0{\cdot}60$)
$= 0{\cdot}5 - 0{\cdot}2258$ [using table] $= 0{\cdot}2742$
Hence, the required number of fishes weighing more than 160 g
$= 0{\cdot}2742 \times 500 = 137$ (approx).

EXERCISE

1. Explain the concept of '*Theoretical Distribution*' with reference to a discrete random variable.
2. Define Normal Distribution and Normal Distribution curve.
3. Draw a Normal Distribution curve to the following data :

Variable	10	20	30	40	50	60	70	80	90
Frequency	3	4	7	8	9	9	2	6	2

4. Write short answers to these questions.
   (i) Write short notes on "Normal distribution".
   (ii) Draw a rough sketch of the standardized normal curve.
   (iii) State the properties of the Normal Distribution.
   (iv) State the properties of a normal curve.
   (v) Mention area under standard Normal curve.
5. Fill up the blanks with appropriate term.
   (i) In a series, values of a random variable is known as ..... .
   (ii) There are ..... types of theoretical probability ..... .
   (iii) A continuous Distribution is one in which the random variable ..... can assume any value between certain ..... .
   (iv) If the measures of distribution are arranged in linear fashion and vary continuously on both the sides from the central value, then the distribution is called ..... .
   (v) In normal distribution measures are concentrated closely around ..... and tapers off from centre to the ..... and right.
   (vi) A graph representing variables on horizontal line and their frequencies on vertical line for a frequency distribution represents ..... .

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(vii) The % distribution area under the ..... can be represented.

(viii) In Normal distribution curve ordinate divides the area into two ..... , the median of distribution concides with the .....

(ix) The points of inflection of the normal curve are ..... from the ..... .

(x) In context of relationship between normal distribution curve area and Standard deviation $X \pm$ ..... σ covers ..... ; $X \pm 2{\cdot}57\,\sigma$ covers ..... area.

6. In the following questions each statement is followed by four alternatives. Tick the correct one.

(i) The curve plotted in a discrete series is bell shaped then it is

(a) Poisson distribution (b) Binomial distribution

(c) Normal distribution (d) None of these.

(ii) All measures of central tendency are equal and stable on the highest peak axis i.e.

(a) Mean > Median = Mode (b) Mean = Median > Mode

(c) Mean < Median < Mode (d) Mean = Median = Mode

(iii) In normal distribution curve :

(a) Maximum observations of distribution lie in the middle of curve

(b) Maximum observations of distribution lie in the left side of the curve

(c) Maximum observations of distribution lie in the right side of the curve.

(d) Minimum observation lie in the middle of the curve

(iv) In context of relationship between normal distribution curve and standard deviation the 1st and 3rd quartiles are :

(a) Equidistanct from the median.

(b) 3/4 distant from the median.

(c) on the median

(d) 1/4 distant from the median

(v) Normal distribution curve mean $\pm 1\,\sigma$ covers.

(a) 95·45% (b) 68·27% (c) 99·77% (d) 0·27%

(vi) Normal distribution curve Mean $\pm 2\sigma$ covers.

(a) 99·45% (b) 68·27% (c) 99·77% (d) 0·27%

(vii) Normal distribution curve Mean $\pm 3\sigma$ covers.

(a) 95·45% (b) 99·73% (c) 10 01% (d) 0·27%

(viii) The normal distribution curve is

(a) Bell shall (b) Asymmetrical

(c) Trimodal (d) None of these

(ix) Data obtained from bioscience

(a) Normally not follow normal distribution

(b) Occassionally follow normal distribution

(c) Normally follow normal distribution

(d) Never follow normal distribution

(x) If the number of trials n is indefinitely large and neither p or q is very small, then binomial distribution tends to :

(a) Poisson distribution (b) Asymmetrical distribution

(c) No distribution (d) Normal distribution

Answers

(i) c (ii) d (iii) a (iv) a (v) b (vi) a (vii) b (viii) a (ix) c (x) d.

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LOGARITHMS

	0	1	2	3	4	5	6	7	8	9	1	2	3	4	5	6	7	8	9
10	0000	0043	0086	0128	0170	0212	0253	0294	0334	0374	5	9	13	17	21	26	30	34	38
											4	8	12	16	20	24	28	32	36
11	0414	0453	0492	0531	0569	0607	0645	0682	0719	0755	4	8	12	16	20	23	27	31	35
											4	7	11	15	18	22	26	29	33
12	0792	0828	0864	0899	0934	0969	1004	1038	1072	1106	3	7	11	14	18	21	25	28	32
											3	7	10	14	17	20	24	27	31
13	1139	1173	1206	1239	1271	1303	1335	1367	1399	1430	3	6	10	13	16	19	23	26	29
											3	7	10	13	16	19	22	25	29
14	1461	1492	1523	1553	1584	1614	1644	1673	1703	1732	3	6	9	12	15	19	22	25	28
											3	6	9	12	14	17	20	23	26
15	1761	1790	1818	1847	1875	1903	1931	1959	1987	2014	3	6	9	11	14	17	20	23	26
											3	6	8	11	14	17	19	22	25
16	2041	2068	2095	2122	2148	2175	2201	2227	2253	2279	3	6	8	11	14	16	19	22	24
											3	5	8	10	13	16	18	21	23
17	2304	2330	2355	2380	2405	2430	2455	2480	2504	2529	3	5	8	10	13	15	18	20	23
											3	5	8	10	12	15	17	20	22
18	2553	2577	2601	2625	2648	2672	2695	2718	2742	2765	2	5	7	9	12	14	17	19	21
											2	4	7	9	11	14	16	18	21
19	2788	2810	2833	2856	2878	2900	2923	2945	2967	2989	2	4	7	9	11	13	16	18	20
											2	4	6	8	11	13	15	17	19
20	3010	3032	3054	3075	3096	3118	3139	3160	3181	3201	2	4	6	8	11	13	15	17	19
21	3222	3243	3263	3284	3304	3324	3345	3365	3385	3404	2	4	6	8	10	12	14	16	18
22	3424	3444	3464	3483	3502	3522	3541	3560	3579	3598	2	4	6	8	10	12	14	15	17
23	3617	3636	3655	3674	3692	3711	3729	3747	3766	3784	2	4	6	7	9	11	13	15	17
24	3802	3820	3838	3856	3874	3892	3909	3927	3945	3962	2	4	5	7	9	11	12	14	16
25	3979	3997	4014	4031	4048	4065	4082	4099	4116	4133	2	3	5	7	9	10	12	14	15
26	4150	4166	4183	4200	4216	4232	4249	4265	4281	4298	2	3	5	7	8	10	11	13	15
27	4314	4330	4346	4362	4378	4393	4409	4425	4440	4456	2	3	5	6	8	9	11	13	14
28	4472	4487	4502	4518	4533	4548	4564	4579	4594	4609	2	3	5	6	8	9	11	12	14
29	4624	4639	4654	4669	4683	4698	4713	4728	4742	4757	1	3	4	6	7	9	10	12	13
30	4771	4786	4800	4814	4829	4843	4857	4871	4886	4900	1	3	4	6	7	9	10	11	13
31	4914	4928	4942	4955	4969	4983	4997	5011	5024	5038	1	3	4	6	7	8	10	11	12
32	5051	5065	5079	5092	5105	5119	5132	5145	5159	5172	1	3	4	5	7	8	9	11	12
33	5185	5198	5211	5224	5237	5250	5263	5276	5289	5302	1	3	4	5	6	8	9	10	12
34	5315	5328	5340	5353	5366	5378	5391	5403	5416	5428	1	3	4	5	6	8	9	10	11
35	5441	5453	5465	5478	5490	5502	5514	5427	5539	5551	1	2	4	5	6	7	9	10	11
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ANIMAL BEHAVIOUR

1

Introduction and Significance of Study of Animal Behaviour

Introduction

Ethology is the study of animal behaviour and it is one of the recent branches of Zoology. Initially it was studied by non professionals, generally by nature lovers. Only for past few decades it has drawn attention of scientists. **Ethology** is the **scientific, biological** and **specific** study of **behaviour of animals.**

The word behaviour is used in a very broad sense in ethology. It refers to all **externally recognizable changes** that bring about communication and can release behaviour patterns in other animals, viz movement patterns of whole body or portions, facial expressions, body postures, vocalization, as well as changes in colouration, release of odour are all included in behaviour. The behaviour is not restricted to movements, even the **freeze reaction** in pigeon after seeing an approaching cat; or **standing motionless** on specific area by male antelope indicating his ownership of that area as its territory; and **remaining still** by prey towards a passing predator are also part of behaviour. **Chemicals** play an interesting role in behaviour e.g. a female butterfly releases an odour (pheromone) which attracts a male is also an integral and important part of their **reproductive behaviour.** The **term Ethology (from the Greek word Ethos-habit, convention**), as is used today for the biological study of behaviour, is quite old. It first appeared in the middle of the 18th century in publications of the French Academy of Sciences, later by 19th century, the term was used to express the life styles

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of animals. The use of the term ethology or the study of behaviour in its correct perspective was introduced in 1950 by **Niko Tinbergen**.

In early years, instead of **ethology**, the synonym-**Animal Psychology** (in German: Tierpsychologie) was also used. In USA and UK ethology is usually referred to by the term **Animal Behaviour**. However, presently the most widely accepted term is Ethology.

Animal behaviour is a continuing source of awe and mystery that sparks the imagination of scientists and public alike. This subject, though recently introduced as a **scientific branch**, has been **known to a commoner** for many years and to some extent all of us are experts of behaviour. The way a **person walks, talks** or the minutest movement of a muscle in the face like **frown, smile, blush** can tell so much about the **mood** he or she is in. If we own pets we learn to interpret their actions; we can distinguish a **friendly dog** from an angry one, a **hungry cat** from the one that wants to be out in search of mate. The behaviour of pets and **domestic animals** are observed carefully, by their **owners**. The **farmers** know much about farm animals and pests. Most people's knowledge ends at about this point because learning about the behaviour of animals in greater details is a time consuming and scientific process. When we enjoy the **fascinating wildlife films** on television, it is worth knowing that, it may have taken hundreds of hours of careful watching before these points of interest were captured on film. We have always been interested in the behaviour of the **animals that surround** us for our **benefit** and **recreation** and also because we are inherently very **inquisitive**. The **sense of wonder** has always been at the root of **scientific enquiry**.

A question arises that **why is it necessary for us to study animal behaviour**? It is because, the vast majority of people, wherever they live and whatever may be their occupation, come in contact with animals. It is obvious that the **hunter** has to know the ways of his **quarry** (animal which is hunted); that the **farmer** must be aware of the habits of his **farm yard animals**. **Cattle breeding, poultry, piggery, fishery, apiculture** and **sericulture** have been developed as industries for the benefit of human beings, only after understanding behaviour of respective animals. Knowledge of behaviour of creatures like **insects** and **rodents** that **damage our crop** has helped mankind in controlling them. Even the modern **city dwellers** have close encounters with animals; they may want to **ward off** the **cockroaches** and **termites** from their houses or **keep a dog, cat or birds** for recreation; for healthy keeping of pets their behaviour must be understood. Man also visits **zoo or amusement parks** to get **pleasure** of observing animals. Lastly, we must **share our world** with **fellow creatures** and that is possible only by understanding their ecology and behaviour to ensure that animals can be preserved and managed for our future generations atleast for them to see, this effort in turn would automatically maintain delicate **ecological balance** on this earth, which has already entered into an era of **environmental crisis**.

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The other questions that come to our mind are **how do animals behave, why do animals behave and why behaviour is important for animals** ? We all know that the conditions are by no means favourable everywhere on earth and every living being has somehow adapted for maintaining itself in suitable surroundings, for example, small creatures like **bacteria** will not enter into a **drop of acid** placed in their culture medium, they will move away from it; the whole surface of **amoeba** is sensitive to negative or positive **stimuli**; and it would respond accordingly. All animals behave for their benefit and survival. Behaviour can be observed right from the simplest, single celled **protozoans** to most intelligent and highly developed **primates**. Behaviour constitutes an extremely important aspect for **species survival**. The male **stickleback** (a small fish) habitually builds a tubular nest of grass and weeds on the bed of the river, after inducing one or more females to spawn in it, the male fertilizes the eggs and guards them by swimming around the nest and intermittently would be seen **fanning the eggs** with the help of pectoral fins. By doing this, it directs water towards the fertilized eggs to **ensure fresh supply** of adequate dissolved **oxygen**. As the eggs grow they require more oxygen, so the male increases its intensity of fanning and forms a number of extra openings in the roof of the nest to make ventilation more efficient. If the male is removed, the eggs will die. This is a simple and direct example to indicate how **behaviour is necessary for survival**. In fact, animals **feed, drink, fight** and **flee to survive; fleeing from danger, fight for limited resources, caring for young ones, feeding fledglings, helping conspecifics and mating to leave the progeny, are all important behavioural forms for species survival.**

There are many questions regarding animal behaviour that still remain unanswered. Nature is simply **fascinating** and some of the things that animals do, are **curious, striking** and **mind boggling**. Why do animals migrate ? How do they find their way ? Why do bees visit some flowers more than others? Do animals sacrifice their lives for others? At one point study of behaviour appears very simple but actually it takes years to come to a conclusion regarding a behaviour.

Two causations or explanations can be assigned to a particular behaviour of animal. One is the **proximate causation** and the other is **ultimate**, if there is a question like **why does a dog eat** ? The **proximate** causation would be **"because it is hungry, it must eat"** which is an immediate short and narrow sighted explanation whereas, the **ultimate** causation has the evolutionary explanation that the dog eats, because it must not die of hunger, it must **survive to reproduce** and leave its progeny for the perpetuation of species. It has not been easy to define behaviour in totality. Behaviour has been defined differently by various workers :

(1) **Observable** and **quantifiable events** constitute behaviour. It is a directional activity necessary for **survival.**

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(2) The behaviour of an animal is defined as the **totality of its movements, sound emissions** and **body postures**; also the externally noticeable changes such as **colour change, secretions of odorous substances** that serve bilateral communication and can therefore, release other behaviours in the partner.

(3) Behaviour is the **response** of living matter to some form of **stimulus.**

(4) Behaviour **includes** all those processes by which an animal **senses** the **external world** and **adopts** itself to that **environment.**

(5) **Movement of whole animal** because of some **external stimulus** is known as its behaviour or activities of an animal's **effector organs** (muscles) is called behaviour.

(6) Behaviour is always a **combined result** of the **actions** of many **body organs.**

(7) Behaviour includes all movements, gestures, postures, changes of colour and **vocalization** displayed by an animal.

A synthesis of above mentioned definitions could be that, **behaviour is the scientific study of the totality of visible movements (including freeze or arrest reaction or standing still), body position (posture) and its orientation in space, emotions, expressions (gestures), vocalization, production of odorous substances, colour change and pilo-erection (raising of hair) brought about by coordinated activities of nervous, endocrine and muscular systems of an organism.** Behaviour is actually a consequence of stimulus and response, the receptors identify the stimulus, conductors coordinate the response and effectors carry out behaviour.

The science of animal behaviour was considered in its infancy, it has been studied extensively for last 50 years only. It still has a very long way to go because it is not so easy to observe the behaviour of various animals, they behave in a bewildering veriety of ways; in fact, the range of animal behaviour patterns is as great as the variety of animals found on this earth with many different shapes, sizes and colours which took generations of Zoologists to describe and classify them. None of the species are identical nor do they behave alike. Not only this, there can be many different types of behaviours in one individual of a species.

Many trained researchers all over the world are spending their energy and time in carrying out research work, and although they are making good progress, still there is much more to observe. Earlier we had to rely on what we immediately saw, but now we have still and video cameras with time lapse and slow motion. Scientists have recorded amazingly precise films on tigers, cheetah, elephants, chimpanzees, gorillas, bees, ants. Sounds can not only be heard but also recorded on tape to be heard again and again. Scientists have successfully recorded and studied the songs of cricket and birds, songs of humpback whales have attracted much attention.

The complexity of animal behavioural study does not depend on elaborate mathematical treatments, delicate instruments and expensive chemicals or giant

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computers, the paraphernalia that people usually associate with science. Although these devices have their place, they are after all only a means of writing facts from nature. An experienced student of animal behaviour is equipped with binoculars, stopwatch and camera, hidden in a blind and can gather facts about his subject in few days time, to keep him pondering for an year.

One thing that must be brought to your knowledge here is that while writing or describing about animal's behaviour, we the human beings have the tendency of using the expressions of our own emotions, or try to attribute **human characteristics to animals** for example, we would use words like, angry, **sad** or **amused** to explain the **moods** of our pet. This is an **anthropomorphic** way of describing animal's behaviour and is not considered proper in scientific writings. This is also not a scientifically consistent line of enquiry, we can not say that an animal fights because it is **angry** or that it escapes because it is **afraid**, but the same thing can be described as : animal attacks to express its **aggression** and it retreats accepting its failure to face the aggressor. Earlier worker **like Edmund Brehm** (1712) in his book titled **Brehms Tierleben (Brehm's Animal Life)** explained animal behaviour using anthropomorphic terms like **clever, mean, sly, gentle** and **proud**. Though anthropomorphic terms make the presentation interesting, yet their use is not recommended.

Due to inquisitive human mind, dedication, and elaborate research it has become possible to define several areas of ethology. Today ethology has many specialized branches and there is much overlap with other areas of biology such as ecology, physiology, genetics, sociology and anthropology.

Branches of Ethology

ECOETHOLOGY is a comparatively new branch of ethology in which the relationships between the. behaviour of a species and other living and non-living components of environment are investigated. Ecoethology can proceed in one of two ways; it can emphasize or focus either on a group of species or on a particular habitat. In focussing on the habitat, one would be interested in the parallel behavioural adaptations that are found in certain habitats, for example, deserts or tropical rain forests. This is of interest even in species that are not closely related, with an interest in how the various species differ from one another and how such differences can be considered adaptations to various habitats, i.e., what is the "biological" significance of a behaviour or study of similar adaptations by animals of different species living in the same habitat. Especially interesting results can be expected when within a related group of species there is one that lives in an entirely different habitat and whose behaviour deviates substantially from the behaviour typical for the group or study of difference in behaviour within a single species found in different habitats.

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BEHAVIOURAL PHYSIOLOGY OR ETHOPHYSIOLOGY deals with the physiological basis of behaviour. Two of its main branches are concerned with the there large control systems (nervous, muscular, endorcrine)of an organism that are also important in the area of behaviour. NEUROETHOLOGY deals with the sensory process and the central nervous system that underlie a particular behaviour. ETHOENDOCRINOLOGY deals with the relations between hormones and behaviour.

Behaviour Genetics is called ETHOGENETICS, and it investigates the genetic basis of behaviour, using simple concepts of single or multiple gene inheritence. Its goal is to prove empirically the relationship between genetic factors and their influence on behaviour.

Two areas of ethology deal with the change of behaviour over time. The PHYLOGENY OF BEHAVIOUR traces the evolutionary origin and development of behavioural characteristics, and the ONTOGENY OF BEHAVIOUR studies the development of behaviour in an individual. A sub area of this latter branch is BEHAVIOURAL EMBRYOLOGY, which is concerned with the prenatal development of behaviour patterns.

The most recent area is HUMAN ETHOLOGY, whose goal is to study human behaviour with ethological methods. It emphasizes phylogenetically transmitted and genetically determined regularities and variability of human behaviour.

A revolution happened in biology during the 1960s and 1970s. Behavioural biologists began to realize how remarkably well animal social behaviour is attuned to environmental and social circumstances. This led to an explosive surge of theoretical and empirical investigations devoted to the adaptive significance of complex animal social systems, this formed SOCIOBIOLOGY which is a fascinating area in ethology and has already had a substantial influence on contemporary biological thoughts. With respect to subject matter, sociobiology stands between ethology and population biology, a research area that deals with the temporal and spatial distribution of individuals and their relationships to the living and nonliving environment. Like ethology, sociobiology is a comparative science. It examines the biological and evolutionary basis of various aspects of social behaviour and deals primarily with the selective advantage of specific social structures. To some extent, sociobiology deals with the mechanisms that determine the social organization of a species or population, and/or how it is maintained. Sociobiology is an amalgamation of behavioural science, modern population ecology, and evolutionary theory. Its central concern is to understand how and why animal social behaviour has evolved. Although sociobiology focuses on ultimate causation, proximate mechanisms do not lie entirely beyond its purview. Sociobiology does not have discrete boundaries, it is interwoven with many disciplines, including physiology, embryology and ultimately anthropology, psychology and even history. Sociobiology has its root in **Darwin's** (1859)

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contention that behaviour, like morphology and physiology, evolved through natural selection. **David Lack** (1968) also proposed the view that many aspects of behaviour could be analysed and understood from an evolutionary perspective. **E.O. Wilson** (1975) wrote an excellent book *"Sociobiology : The New Synthesis"* which laid the stone for an interdisciplinary approach to both animal and human behaviour. Sociobiology is a new and exciting field of study that promises to go far in answering the question of why animals behave as they do? Combined with cultural anthropology and other social sciences, it could also go far in explaining why people do what they do? Sociobiology has caused ethologists to pay more attention to the intraspecific variation of behaviour and to individual behaviour patterns. Beyond that it has offered biological explanations for those behavioural characteristics that had not previously been explained by the theory of natural selection, such as the existence of altruistic behaviour (sacrificing behaviour).

Two other fields that border ethology are BIOACOUSTICS and the study of BIOLOGICAL RHYTHMS. The goal of bioacoustics is the investigation of sound production with the help of high quality recording equipment and tape recorders. The ability to produce sound spectrograms resulted in an objective and reproducible presentation of animal sounds which discontinued the use of old and subjective description by words or musical notes. More generally, bioacoustics include the investigation of vocal and instrumental acoustics, auditory sense organs and the sound-producing organs like vocal cords, stridulating organs, and instruments like feathers, wings, legs (modified to produce sounds), etc. In all, it includes the study of production and perception of sounds, their mechanical and physiological processes. It also includes the relationships between the vocalizations of the animal and its habitat. Bioacoustics have contributed important knowledge to ethology in the area of the ontogeny of behaviour. The study of Biological rhythms is concerned with recurring, rhythmic events of living organisms and their underlying processes. Since such periodicity is so prominently expressed in the behaviour of an animal, biorhythms form an integral part of ethology.

Behaviour is studied by many people throughout the world and its fundamental principles are taught in almost all courses of biology and psychology in western countries, it is a recently introduced subject in our country. **Ethologists** are formally trained in **biology** and approach behaviour from the view point of its relation with **nature** and **ecology**. They study a **wide variety of behavioural repertoire** in an equally **wide variety of free living animals**. By contrast, most **psychologists** are formally trained in **psychology** or **medical science** and are mainly interested in the **behaviour of people** and for that reason, may carry out research on animals. Their studies are generally carried out on **dogs, cats, rats, pigeons** and **chimpanzees**

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in **laboratory conditions**, they concentrate most on **learning** feats of which animals are capable, **aggression, reproduction**, and **maternal behaviours**. The ethologists prefer to remain behind a hide looking out at the freely moving animal, while the psychologists move about freely around his laboratory collecting results from an animal enclosed in a cage. Initially, after World War II, there were **two main schools of animal behaviour**, the **first** consisted largely of **Europeans** and they called themselves **ethologists**. The **other group** was mainly of **American psychologists**. World renowned **ethologists** are **K. Lorenz, Karl V. Frisch** and **Niko Tinbergen**. Their work is mentioned later in this chapter. Among **psychologists, B. Frederic Skinner** became the founder of "**behaviourism**" a branch of psychology founded early in this century in USA, which regards learning as of the supreme importance, Skinner studied learning by "reward" and his work has given rise to the school of "**Skinnerian psychology**". This method has general laws of learning through the study of animals, usually rats, trained to do tasks such as to press a lever which is arranged to deliver them a pellet of food. In this "**Operant conditioning**" the amount of a particular behaviour pattern, like pressing of lever known as the operant, in upward or downward direction, is associated with reward or punishment. Skinner believed that the principles emerging from such experiments could be generally applicable to other animals and even to human beings. **Harry F. Harlow**, one time Director of University of Wisconsin's Primate Laboratory, observed the intricate relationship between **mother and infant** and **effect of deprivation** of maternal care on **growing infants** in rhesus *(Macaco mulatta)*. His work has got him world wide recognition. He has proved that if the infants are kept in isolation, they show abnormal behaviour even in their adult life i.e. **early childhood experiences have profound effect on remaining life**. **I.P. Pavlov** was a psychologist, born in Ryazan in Russia. He is best known for his studies on **conditioned reflexes** that has formed the basis of much subsequent work on learning. In his best known experiment, he studied the **salivation of dogs** when they were presented with food and showed that, if a **bell is rung** everytime the food appeared, the dogs will ultimately come to salivate to the sound of the bell alone. He was of the view that the building up of such associations is an important part of learning. Besides this, other well known psychologists, like **Hess, Hinde, Thorndike, Sherrington** also greatly contributed in exploring animal behaviour.

Few basic differences between the ethologists and psychologists could be summerized as follows :

It is interesting to note that at first, ethologists and psychologists took little notice of each other's findings, but when they did, cross fire began and the best thing was that both sides scored good points and their dispute generated more light than heat and they were more enlightened than annoyed.

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Ethologists	Psychologists
1. They work in forests, in national parks and in reserves using camera, binocular and stop watch.	1. They work in laboratory using specially designed boxes, mazes and other instruments.
2 Watch animals in their natural habitat	2 Watch animals in captivity.
3. Study wide variety of animals from ants to elephants, from weevil to whales and from protozoa to primate.	3 Study few selected animals viz rats, cats, pigeons and chimpanzees.
4. Deal with visible actions which includes innumerable types of behavioural acts.	4. Deal with feelings and emotions, also concentrate on learning processes.
5. Correlate behaviour with environment or vice-versa. Persons specializing in it are called ecoethologists.	5. Correlate behaviour with body physiology specially nervous system, persons specializing in it are called neurobehaviourists.
6. Let their animals roam around freely in natural habitat, they rarely kill animals	6 Let their animals remain in cages and may kill them for experimental use.

History

The history of ethology is as old as prehistoric man because at that time human beings were hunters and they had to be careful students of behaviour, a fact revealed in the paintings on the walls of excavated caves of that time. It was actually the great Greek philosopher **Aristotle** (372 BC) who for the first time wrote excellent descriptions of animal behaviour in his book- *Historia Animalium* meaning "the history of animals". He collected a great deal of information on animals and wrote that animals also possessed insight, and love for families. **William Harvey**, a scientist of seventeenth century, studied breeding, nesting and incubating behaviour of many birds. **Gallen** (1840) carried out extensive observations on life of animals and wrote complete theory in details in a book consisting of two large volumes. Scientific study of animal behaviour has its origin in the works of eighteenth century naturalists such as **Gilbert White** (1720- 1793), of England he made meticulous observations of many aspects of behaviour of swallows. But **Charles Darwin** (1809-1882) must be regarded as the first one to make scientific study of animal behaviour due to three reasons (i) his theory of natural selection gave background to understand animal behaviour in evolutionary terms (ii) his views on instincts formed firm basis for other theories to develop (iii) and his observations on behaviour and their compilation in his book *"The expression of the Emotions in Man and the Animals"* (1872) gave a detailed and vivid description of animal behaviour, this book is still considered a classic book because of its contribution in understanding the emotional expression and their development in animals and human beings. He wrote in his book on **origin of species by natural selection** in 1859 that phylogeny of behavioural development would be subjected to the same laws as that of

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morphological changes and perhaps all instinctive motor sequences have emerged gradually, developing from many small and useful modification. Darwin could not live to see his theories being appreciated and accepted. Later, Darwin's assumptions got support from **Mendel's Laws of Inheritance**. In 1882, the year Darwin died, **John Romanes**, a student and friend of Darwin wrote an excellent book on *"Animal Intelligence"* which is also considered a classic book on animal behaviour. **Charls O. Whitman** (1908) a Zoologist at the university of Chicago, USA studied the behaviour of pigeons and doves. He wrote some of his observations in his book entitled *"Animal Behaviour"*. After his death, his student **O. Riddle** published his remaining work. Earlier people started their work by studying pets, domestic and farmhouse animals. Fundamental turning point came in the works of a German Zoologist **Oskar Heinroth** (1871-1945), he devoted his life studying waterfowls and wrote a book *"Ethology of Anatidae"*, his findings and dedication fascinated many of his colleagues and students. One of his most devoted students was **Konrad Lorenz.** Ethology reached its peak of popularity in the works of three great workers Konrad Lorenz, an animal psychologist in Vienna, **Niko Tinbergen**, a Zoologist in Holland and **Karl Von Frisch** from Germany. These three shared a **Nobel Prize** in 1972-73 for their remarkable contribution in the field of Animal Behaviour. They also got the credit of introducing an absolutely new branch of science to Zoology and making it popular among common people.

Konrad Lorenz (1903-1989; Fig. 1) is regarded as the founder father of ethology, he was a Lecturer in Animal Psychology at the University of Vienna, Austria. He got initial inspiration from his teacher Oskar Heinroth, his close interaction with this great teacher proved to be extremely useful in building up firm basis for future studies. Lorenz used to live in a farm house, where he had many pets (his wife had to keep their son into the cage!). He observed shrews, frogs, monkeys, dogs, jackdaws and mainly greylag geese on which he carried out extensive studies and developed a theory of **imprinting** (Pragung in German) or **childhood learning** during the **critical period** (Refer chapter 2). He wrote popular books like *"King Solomon's Ring"* (1952), *"Man Meets Dog"* (1954), and *"On Aggression"* (1962). All these books showed his deep understanding of animals, and hence received wide attention. He is rightly known as **founder father of ethology** because his work created enthusiasm in many others for the study of behaviour. Although between Darwin and his time several others carried out studies on this subject but his contribution was more wide ranging.

Another major force in behavioural studies was **Karl Von Frisch** (1886-1982; Fig. 2) who was born in Vienna but spent his life in Germany. He also had the opportunity of living in a house surrounded by a big farm, with many trees, flowers and pet animals, his main interest was in bees. With great patience he conducted most tideous experiments on this tireless social

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Fig. 1. Konrad Lorenz.

Fig. 3. Niko Tinbergen

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Fig. 2. Karl Von Frisch.

insect, by carrying out a series of experiments with coloured cards. He observed that bees perceive colours, that they can locate the sun even during a heavy overcast because they can perceive ultraviolet rays, his most significant discovery was that bees have an extensive communication systems, bees have two types of dances-waggle and circle to communicate to their conspecifics, the exact position of sun from the hive, flowers from the hive, and the type of flowers. He also studied behaviour of bees during total solar eclipse. His marvelous work on bees got him the laurel of Nobel prize. He also carried out work on the hearing and colour vision of fishes.

The third most important name in forming the history of ethology is **Niko Tinbergen** (1907; Fig. 3) he was born in Holland, but lived in England. He devoted many years observing and teaching behaviour; he was a Zoologist by profession. He studied variety of animals from butterflies and digger wasps to three spined sticklebacks and gulls in their natural habitat. He is an author of many books; his book on "*Animal Behaviour*" a LIFE/TIME Publications has helped many young readers to get acquainted with the subject. His other books *"The Study of Instincts"* (1951), *"The Animal in its World"* (1972) and *"Social Behaviour in Animals"* (1965) have been milestones in ethology. ***Niko Tinbergen's*** contribution on the details of sign stimuli which are needed to elicit a specific instinctive behaviour (refer to chapter-2) is still appreciated. He found out that, in addition to colours and light-dark contract relationship, the size and position of sign stimulus also plays an important role.

Study of Animal behaviour has its roots in European countries, **Lorenz** (1970), **Frisch** (1970), **Tinbergen** (1972), **Hess** (1957), **Thorpe** (1958),

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Ramsay (1954) and many students of **Lorenz** contributed significantly for ethology, this new branch in Science grew and took an advanced, developed shape in USA. Pioneer American workers in Animal Behaviour and Psychology are **Beach** (1967), **Scott** (1970), **Griffin** (1971), **Wilson** (1973), **Eiesenberg** (1976), **Harlow** (1951), **Skinner** (1967) and **Carpenter** (1940). Presently, extensive research on Animal Behaviour has been undergoing in USA, Europe, Africa, South America, Australia and India.

Significance of Study of Animal Behaviour

As the years are passing by, **Ethology** is growing from its nascent phase to maturity, it has formed an important **bridge** between the **molecular** and **physiological** aspects of **biology** and **ecology**; it has become a **link** between **organisms** and **environment** and between the **nervous system** and the **ecosystem**. Behaviour is recognized as one of the most important function of animal life; it plays a **critical role** in **animal adaptations** and **evolution**, through behaviour an organism interacts with its environment.

Animal behaviour has gained much popularity in past few years which is obviously evident by the time that television devotes to animal films and the amount of money that people spend on nature trails and books. There is much more public interest in animal behaviour than previous years.

Study of animal behaviour has become an important scientific field on its own. This science has made important contributions to other disciplines like **anthropology**, **sociology**, **psychology**, **environmental biology** and **sociobiology**. Ethology today has applications to **human behaviour**, to **neurosciences**, to the study of **animal welfare** and to the **education of future generations**.

Animal Behaviour and the Environment

The behaviour of animals often provides the first clues of environmental degradation. Changes in sexual behaviour occur much sooner in animals affecting their population size due to environmental disruption. Declining animal populations allows us to take measures to save the environment. Studies of natural behaviour in the field are vital to provide baseline data for environmental monitoring. For example, the Environmental Protection Agency uses changes in **swimming behaviour** of **minnows** as an **index** of possible **pesticide pollution**.

Basic research on how salmon migrate back to their home waters started by **Arthur Hasler** (1969) that has taught us much more about the mechanisms of migration. This information has also been valuable in preserving the **salmon industry** in the Pacific Northwest and applications of Hasler's results has led to the development of a **salmon fishing industry** in the Great Lakes in USA. Therefore, basic animal behaviour research has important economic implications.

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Animal behaviourists have understood insect reproduction and host plant protection leading to the discovery of **non-toxic pheromones** for insect pest control that avoid the need for **toxic pesticides**. Understanding of **predator prey relationship** has led to the knowledge of maintaining proper **food web** in a given **ecosystem**. Knowledge of **honeybee foraging behaviour** is applied to mechanisms of **pollination** which in turn is important for **plant breeding** and **propagation**. Bees have also helped us developing helicopters, planes and buildings.

An understanding of **foraging behaviour** in animals has led to an understanding of **forest regeneration**. Many animals serve as **seed dispersers** and are thus essential for the **propagation of tree species** and essential for **habitat preservation**.

The conservation of **endangered species** requires that we know enough about their **natural behaviour** (migratory patterns, home range size, interactions with other groups, foraging, reproductive behaviour, communication, etc.) in order to **develop effective reserves** and effective protection measures. **Relocation** or reintroduction of animals (such as the **Peer Davis** deer of **China** and **Golden lion tamarin** of **Brazil**) was not possible without detailed knowledge of a species' natural history. With the increasing importance of environmental programs dealing with populations of rare species, both in captivity and in the natural habitat, animal behaviour research has become increasingly important. Many of the world's leading conservationists have a background in animal behaviour or behavioural ecology.

Basic behavioural studies on reproductive behaviour have led to improved captive breeding methods for near extinction species like whooping cranes, **golden lion tamarins**, **cotton-top tamarins**, and many other such species.

Animal Behaviour and Cell Biology

Sir Charles Sherrington, (1954) a **Nobel Prize winner**, developed a **model** for the **structure and function of the nervous system** based on close behavioural observation on animals. Seventy years of subsequent neurobiological research on human has completely supported the inferences Sherrington made on animals.

Neuroethology, the mixing of animal behaviour and the neurosciences, provides important framework for explaining neural mechanisms. Careful behavioural data gathered on animals allow neurobiologists to focus their studies for the benefit for human. Behavioural studies of **poisonous** and **venemous** animals, then subsequent **extraction** of **neurotoxic chemicals** and their use in various **medicines** has benefit mankind.

Recent work in animal behaviour has demonstrated its impact on physiological and **cellular research**. Variations in social environment can inhibit or stimulate ovulation, produce menstrual synchrony, induce

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miscarriages. Other animal studies show that the quality of the social and behavioural environment have a direct effect on **immune system functioning**. **"Behaviour of cells"** is a common term in the research field of cancer, Aids and hepatitis.

Animals have helped in making important brain atlases and understanding our own brain and behaviour.

Animal Behaviour and Animal Welfare

Animal welfare without the knowledge of animal's behaviour is impossible. The society has placed increased emphasis on the welfare of **domestic, pet** and **research animals**. The animals are protected by Law. There are punishments against **animal cruelty**. The psychological well-being of research animals specially nonhuman primates in labs has to be ensured. It's the duty of an ethologist to look at the behaviour and well-being of animals in lab and field. Animal behaviour studies have provided expert suggestions to bring about reasonable and effective standards for the care and well-being of research animals.

Further developments in animal welfare still require input from animal behaviour specialists. Improved conditions for **farm animals**, breeding of **endangered species**, proper training and care of **companion animals** for **blinds** and **disables** all require a strong behaviour data base.

Animal Behaviour and Science Education

Many in our society are still scientifically illiterate, because of lack of interest that people have in studies of animal science. Students are still far away from wildlife and their behaviour. Courses in **animal behaviour** and **behavioural ecology** have been recently introduced in Indian Universities. Departments of Anthropology, Psychology, Zoology and Wildlife teach very little about animal behaviour. Its disheartening that most students are not familiar with commonly found birds and animals around their own residence leave aside national parks, sanctuary and reserves. In the recent curriculum, there is much emphasis on cell and molecular biology and very little on Wildlife and animal behaviour. There is a possibility that a student will recognize the DNA of **Hangul deer** but will not be able to recognize the animal! Time has come when Wildlife Biology, Conservation, Management, Animal Behaviour, Animal husbandry and Welfare studies must be provided sufficient importance in school, college and university education

Animal Behaviour and Human Society

Many problems in human society are related to the interaction of **environment** and **behaviour** or **genetics** and **behaviour**. The fields of **socioecology** and

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animal behaviour deal with the issue of environment- behaviour interactions both at an **evolutionary (ultimate)** level and at **proximate (immediate)** level. Increasingly social scientists are turning to animal behaviour for a framework in which to interpret human society and to understand possible causes of problems of our societies e.g. there are books on human behaviour taking analysis from animal research, many studies on **child abuse** and **infanticide** in human find bearing from observations on animals. Its been documented that human societies have slowly and gradually evolved from animal societies, by understanding animal's behaviour we help unfolding the mysteries of our own social organizations. **Desmond Morris** has written many books explaining human behaviour using knowledge from animal behaviour.

Research by **de Waal** (1971) on chimpanzees and monkeys has illustrated the importance of **cooperation** and **reconciliation** in **social groups**. This work provides new perspectives to understand **aggressive behaviour** of human beings.

The methodology applied to study animal behaviour has had a tremendous impact in psychology. **Social scientists** and some renowned **psychologists** had started their careers studying animal behaviour. **Jean Piaget** (1968) began his career with the study of **snails**, and he extended the use of careful behavioural observations and descriptions to his landmark studies on **human cognitive development**. **J. B. Watson** (1973) began his study of behaviour by observing **gulls**. Aspects of his experimental design, observation techniques, and attention to **nonverbal communication signals** were developed in animal behaviour studies before their application to studies of human behaviour. The behavioural study of humans would have been much less today without the influence of animal research.

Charles Darwin's work (1885) on **emotional expression in animals** has had an important influence on many psychologists, such as **Paul Ekman**, (1930), who studied emotional behaviour of human.

Prof. Harlow's (1960) work on **social development** in rhesus monkeys has been of major importance to theories of **child development** and to **psychiatry**. The work of **Overmier, Maier and Seligman** (1967) on learned helplessness has had a similar effect on child development and psychiatry.

The comparative study of behaviour over a wide range of species can provide insights into influence affecting human behaviour. For example, the **woolly spider monkeys** in **Brazil** displays no overt aggressive behaviour among group members. We might learn how to **minimize human aggression** if we understood how this species of monkey avoids aggression.

Study of **parental care** by males in **California mouse, marmosets, tamarins** and some, birds can give us insight, understanding and significance of fathers involvement in child care.

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Studies of various models of the **ontogeny of communication** in birds and mammals have had direct influence on the development of theories and the research directions in the study of child language.

Understanding the differences in **adaptability between species** that can live in a variety of habitats versus those that are restricted to limited habitats can lead to an understanding of how we might improve **human adaptability** as our environments change.

Research by animal behaviourists on **animal sensory systems** has led to practical applications for extending **human sensory systems. Griffin's** demonstrations (1963) on how bats use sonar to locate objects has led directly to the use of **sonar techniques** in a wide array of applications from the **military** to **foetal diagnostics** through **sonography.**

Studies of **chimpanzees** using **language analogues** have led to new technology (**computer keyboards using arbitrary symbols**) that have been applied successfully to teaching language to disabled or **physically challenged** human populations.

Basic research on **circadian** and other **endogenous rhythms** in animals has led to research relevant to human factors and productivity in areas such as coping with **jet-lag** or changing from one shift to another in an industry. Research on animal behaviour has developed many of the important tests relating to identify stress and **psychological disorders.** Basic research on **pheromones** and **hormones** on animals has led to **perfume industry** and towards greater understanding about reproductive and maternal behaviours in human beings.

IMPORTANT QUESTIONS

➤➤ *Short answer type questions*

1. Write very brifly :
(i) Branches of Ethology, (ii) History of Ethology, (iii) Konrad Lorenz, (iv) Niko Tinbergen, (v) Karl Von Frish, (vi) Animal Behaviour and Environment, (vii) Animal Behaviour and Cell Biology, (viii) Animal Behaviour and Science Educaiton, (ix) Animal Behaviour and Human Society, (x) Differentiate Between Ethologist and Psychologist.

➤➤ *True and false*

1 Konrad Lorenz worked with graylag geese
2. Karl Von Frish worked with graylag geese.
3 Konrad Lorenz worked with honey bees.
4. Karl Von Frish worked with honey bees
5. Konrad Lorenz, Niko Tinbergen and Karl Von Frisch shared the noble prize in 1973
6. Konrad Lorenz, Niko Tinbergen and Karl Von Frisch shared the noble prize in 1983

Answers

1. True, 2. False, 3. False, 4 True, 5 True, 6. False

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➤➤ ***Fill in the blanks***

1. The term ethology was introduced by.....
2. Attribution of human emotions to explain animal behaviour is..... ..way.
3. E. O. Wilson in 1975 wrote a book on.....
4. Book Historia Animalium was written by.....
5. Book-expression of emotions in man and animals was written by.....

Answers

1. Niko Tinbergen, 2. Anthropomorphic, 3. Sociobiology, 4. Aristotle, 5. Darwin.

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2

Concepts and Patterns

Introduction

The study of animal behaviour is still in its infancy, nevertheless, considerable research has been done in laboratory and in wild. The major works come from European and American scientists. The classical ethology has its root in Europe and modern ethology found bearing in USA. Efforts of **Konrad Lorenz** and **Niko Tinbergen, Skinner, Harlow, Dawkins, Wilson, Trivers, Hinde, Hamilton** and many other scientists have brought forward some basic concepts and patterns of behaviour. It is a prerequisite for a student of Ethology to get familiar with them. The dictionary meanings of **Pattern** is **"a series of actions of events that together show how things normally happen or are done"** and definition of concept is **"an idea of something new"**. If the patterns and concepts of ethology are put together it will mean. **"An idea of series of new actions that together show how behaviour takes place."** Both are important to understand for a student of behaviour. **Patterns and concepts** form two sides of a coin. They collectively constitute Motivation, Fixed action patterns, Sign stimulus, Innate releasing mechanism, Action specific energy, Physiological basis, Learning, Imprinting, Behavioural genetics, Evolution of behaviour, Sociobiology. **Patterns** has a vast meaning, it includes **aggression, territoriality, courtship, communication, feedings, drinking, grooming, parental care, learning** and **social behaviour.**

Motivation

A hypothetical state of the individual organism that arouses a goal directed activity is motivation. **Mood** (as called by **Oskar Heinroth**), **drive, urge or readiness of an animal to perform a certain behaviour, is motivation.**

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Each instinctive behaviour has a certain motivational level at all times. This value declines when the act is performed, then rises again. At different times the animals respond in different ways to the same stimulus, for example : a hungry dog would get up, sniff here and there, look around for food, at this time motivational level or the urge for eating food is at the **highest level.** When it finds **goal** i.e. food it starts eating and after eating a full meal, the motivational level goes down to its **minimum level.** This dog will not eat for next few hours. By this time, the motivational level rises gradually and once again after a lapse of few hours when the level rises to its maximum, the dog would start looking for the goal i.e. food once again and all these steps would be repeated (Fig. 1). Thus, dog would respond to food differently when he is hungry or full. This is true not just with food, but almost all instinctive behaviours (determined by genes) are regulated by motivation. There seems to be an **urge** or **internal drive** to elicit a particular behaviour at particular time. Motivation to perform a particular behaviour is deduced from the strength and frequency of the behaviour itself, which is called **motivational analysis.** The majority of behaviour patterns can be assigned to four larger motivational systems: feeding, reproduction, fight, and flee (escape). Within the large motivational systems there are many subunits of behaviour that are more or less connected with each other. For example, subunits of reproduction include not only sexual behaviour but also nest building and care of young and these behaviour patterns have their own drive mechanisms.

The psychologists have divided a drive into three phases.

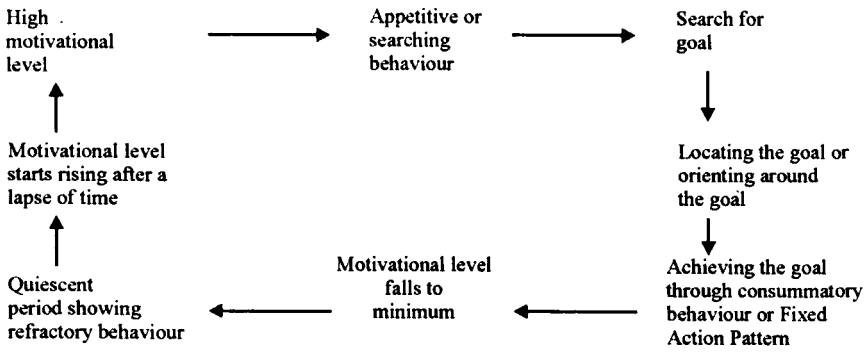

Fig. 1 Schematic explanation of motivation.

(1) Search for goal (appetitive or searching behaviour)
(2) Orientation around the goal and achieving the goal (consummately behaviour).
(3) Quiescent period (refractory behaviour). (Fig. 1)

The biological significance of drive mechanism or motivation is to remind the animal about when a behaviour should occur and to prepare an animal to perform a particular behaviour.

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In an experiment, rats were trained to run for water through a maze (a zig zag path), it was observed that they ran through the maze much faster and drank more when they were kept thirsty as compared to those rats which had water ad-libitum (i.e. available whenever they wanted).

Fixed Action Patterns (FAP) or Instinctive Behaviour

The behavioural patterns, which are basically determined by **genes** and exhibited automatically by any animal without having seen or learnt from, conspecifics or performance of a behaviour even when the animal has been raised in isolation, is known as **FAP.** When a wasp supplies its young with caterpillars or a pregnant mouse builds a nest, they are not guided by conspecifics. Among animals there are many instances of elaborate behaviour which are found throughout a species and are not acquired through previous experience or learning. These acts are Fixed Action Patterns and are, also known as **consummatory action, innate, instinctive, inborn or inherent behaviour**. The behaviour of each animal is adapted to its surroundings and is perfectly attuned to the requirements of its living and non-living environment, the information to adjust to this can enter an organism in two different ways: by means of the genes which can be stored in the **genome**, this represents a "**species memory**" that is passed on from one generation to another generation. The other information is acquired by an organism and is not transferred through the genes. If it is derived from the genes, the behaviour is referred to as **inborn** or **innate**; if it is based on individual experience, it is called **acquired** or **learned**. The terms **inherited adaptations** and **acquired adaptations** are sometimes used to emphasize the source. By definition instinctive patterns is species specific, stereotype sequence of co-ordinated motor actions. The animals can perform them without having previous experience and without having seen another species member (conspecifics) do it.

There are innumerable number of behavioural patterns in the entire animal kingdom that are transferred through genes, these acts are already prewired or preprogrammed in the central nervous system through the genetic material. The elaborate **courtship displays** in most of the animals (Fig. 2) **mating, feeding patterns, nest building, parental care, vocalization; songs of crickets, birds and whales; wing cleaning in insects** and **birds, territoriality** and **aggression** in sticklebacks and Europian robin males, **lek formation** in sage grouse, **construction of web** by **spider** and of **pendulum nest by weaver bird** (Fig. 3) all fall into this category. The most common example which comes across is of **dancing peacock**. The peacocks start dancing as they see peahens during the breeding season, they do not learn dancing by watching conspecifics. Similarly, it is worth noting that weaver bird never learns to construct the nest, it just knows, and the bees do not learn to build their hive, this property is acquired genetically. A tailor bird (Fig. 3) would bring

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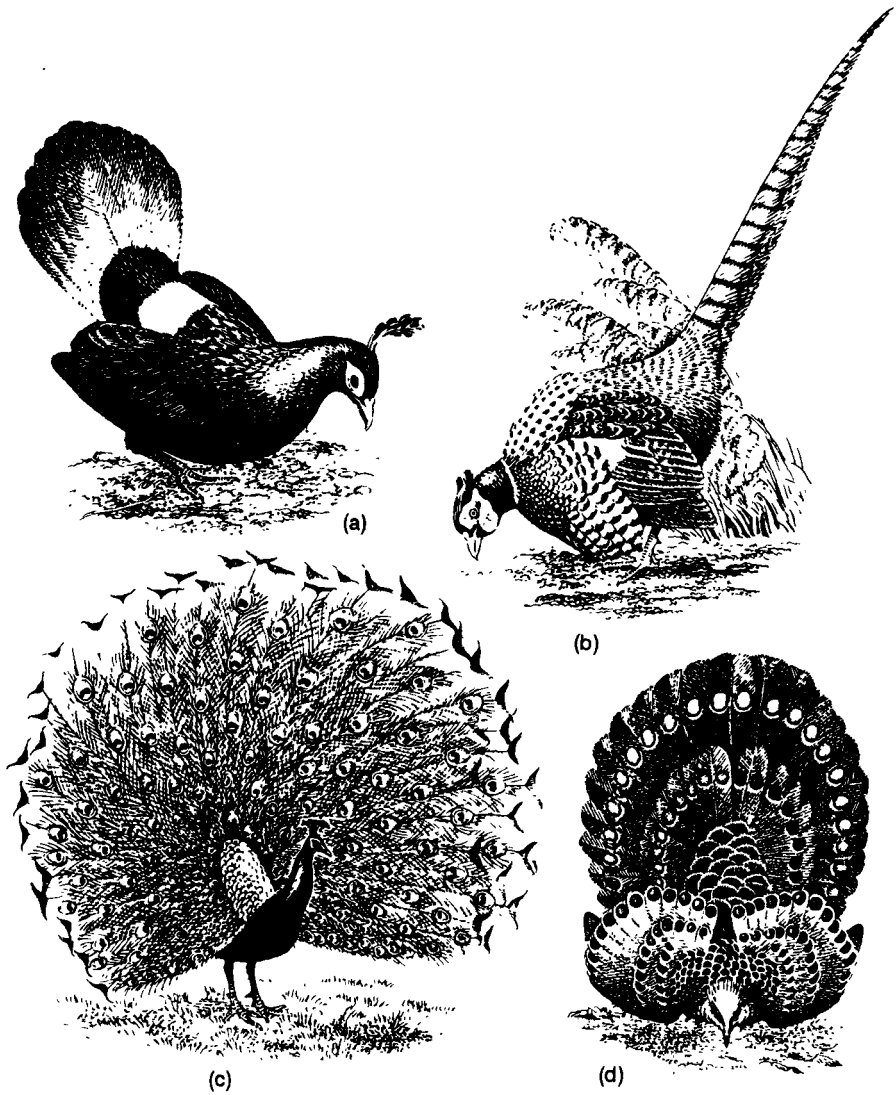

Fig. 2. Courtship display in birds (Collins, 1986), (a) Himalayan monal, (c) Common peacock, (b) Ring necked pheasant, (d) Burmese peacock.

two leaves together and literally stitch them with the help of long, flexible grass, then cushion it with soft grass and lay her eggs; these birds when kept separately from their conspecifics could still perform this behaviour although they were given no opportunity to watch their older conspecifics to learn it, this vital information was passed on to them through their genes. In human

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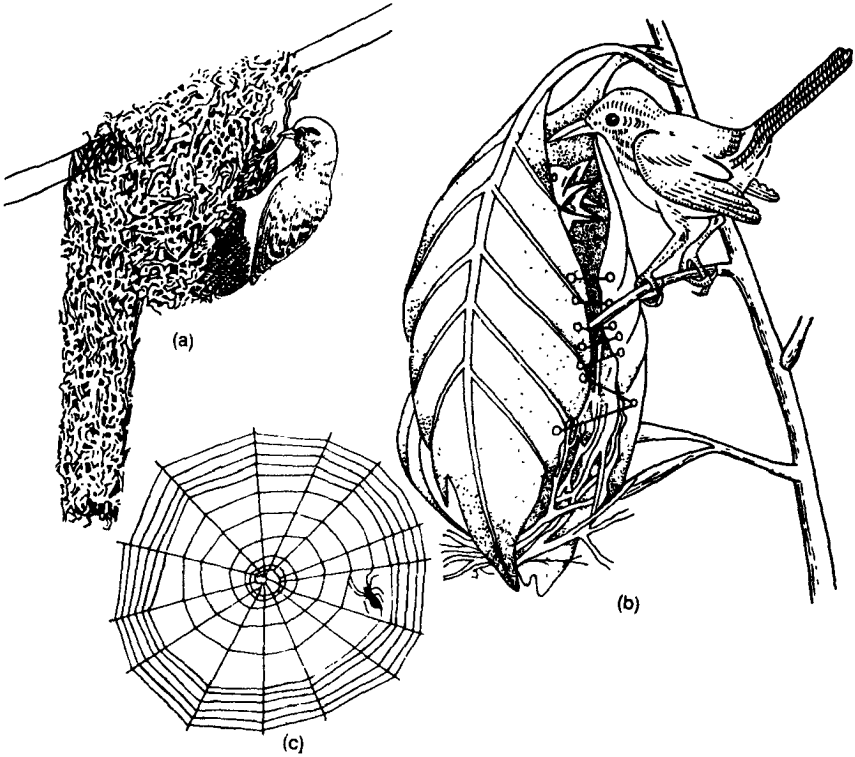

Fig. 3. Construction of nest by weaver bird (a), tailor bird (b) and formation of web by spider (c).

beings **crawling, smiling, crying** are not learned, they are the examples of instincts and Fixed Action Pattern.

Instinctive behaviour has evolved gradually along with the other morphological features through natural selection, to enable the animal to fit steadily and gradually in the environment in the best way. Instincts such as **hunger, sex, fight, fear** and even **pleasure** have been wired into brain circuits to ensure survival of the species.

To distinguish between **innate and learned** behaviour, experiments are conducted on animals reared in isolation by keeping them individually, away from others, from as early an age as possible, when they mature, their responses to a variety of stimuli are tested and compared with animals reared normally. Many fishes and birds perform normal feeding, sexual and aggressive behavioural patterns even when reared in isolation. The **chaffinche** develops its complete song during its first 12-13 months; if it is reared in a sound proof room until the expiry of 13 months, it can not sing normally. The song of this bird, is of about the right length, and has the right number of notes but the melody is not recognizable, because for that it has to live with its

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conspecifics, indicating that length and notes of songs are instinctive but melody is learnt. In human beings also vocalization i.e. production of sound is inherent but we have to learn the language.

Experimentally isolated animals never have any experience with the particular situation but they will still perform certain behavioural pattern in appropriate situations; some **squirrels** were reared in **isolation** and were never given nuts (one of their favourite foods) to handle or to eat, but when such squirrels were given plenty of nuts they ate them and attempted to bury extra nuts in the ground, typically like all other squirrels. Therefore, this behaviour of squirrel is a Fixed Action Pattern and is instinctively controlled, animals that are grown under the conditions of isolation for the study purposes are called **Kaspar Hausers**. The instinctive behaviour show following properties :

[I] Constancy or stereotype

Instincts are inherited and are similar in all individuals of a species i.e. all digger wasps and weaver birds build their nests in the same way, roosters of same species court their females in generally the same way. Instincts involve **complex**, and often **highly rigid** patterns of behaviour, in which numerous muscles, muscle groups, organs and systems function in an extremely coordinated fashion.

FAP are found to be the same in all members of a species (**stereotype**) and can not be influenced in performance by external stimuli. A classic example of FAP is provided in the study of egg rolling in greylag geese (plural). These birds build shallow nests in the ground, the greylag goose (singular) uses a stereotype set of behaviour to bring back eggs that roll out of the nest.

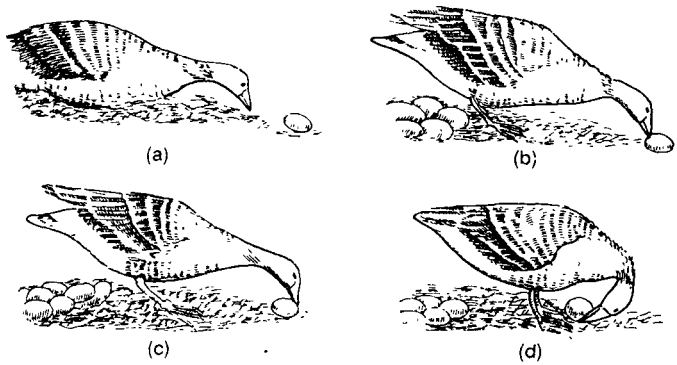

Fig 4 Egg rolling in greylag goose

(a) Looks at the egg which has rolled out (b) Rises and tries to touch it with the bill tip (c) Places the underside of its beak on top of the egg (d) Bends the neck and swings it laterally in a rhythmic movement to pull the egg back to the nest

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The movements shown in Fig. 4 are typical of this species, no matter in which environment or circumstances it may live. It need not watch conspecifics doing it, this action is performed automatically. Sight of an egg outside the nest acts as stimulus (which is known as **sign or key stimulus**) and that elicits egg rolling behaviour.

[II] Resistant to phylogenetic changes

FAP (instincts) are extremely **conservative** in evolution of a species. It has been assumed that once they have appeared in a species, they are **resistant** to phylogenetic changes occurring through evolution. It can be studied by comparing the behaviour of long tailed and short tailed monkeys. When a long tailed monkey runs along a branch, its tail moves from side to side thus achieving balance, which is a FAP. Short tailed monkeys stopped using their tail as a structure for balancing yet perform similar type of movements of tail. Probably short tailed monkeys evolved from long tailed monkeys, where tail had an important function of balancing and FAP, once evolved, persisted even though the relevant morphological structure had disappeared.

[III] Need sign stimulus for release

A characteristic feature of instinct (FAP) is that they are elicited by **simple** but **specific stimuli**, which are known as sign **stimuli**.

Innate complex behaviour patterns can as a rule show two components that are clearly distinguishable; one is stereotyped i.e. **consummatory action** (as explained earlier to you as FAP) while the other is made up of a longer, more variable sequence of movements that lead to the consummatory action; this second component is called **appetitive** (as named by Wallace Craig) or **searching behaviour** (Fig. 1). By definition, it is a behaviour for a situation that contains a stimulus that could release the consummatory behaviour. **Eckhard Hess** (1962) pointed out that appetitive behaviour may be characterized in two ways : (i) a motor pattern (usually locomotion) (ii) an orientation towards the goal or stimuli to which the animal is receptive i.e. smell or sight of food, water and mate. Most of the instincts (consummatory action) are initiated by searching or appetitive behaviour. Instinct are **invariant** whereas, appetitive behaviour is **variable**, i.e. appetitive behaviour is terminated by the appearance of food and then starts FAP (stereotype eating pattern). A dog may spend hours in search of a mate during mating season, which shall cease after copulation. Here the act of mating is an example of instinct, and searching for goal i.e. (mate) is appetitive behaviour.

Both the actions are dependent on the level of motivation for that particular behaviour (Fig. 1). When a dog is hungry, the motivational level/urge/drive increases for eating i.e. it starts showing searching behaviour, after locating the food, it starts indulging in a consummatory action (eats food), by this

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time the motivational level of hunger starts going down and when the animal has eaten its full meal, the motivational level for that particular behaviour gets to almost zero and that stops both consummatory and appetitive behaviours.

Transfer of behaviour through genes has great significance in the survival of species. Firstly, there are behavioural acts like feeding, drinking, mating which form essential part in an organism's life; they save time and energy if such vital traits are transferred through genes. Secondly, some organisms have a short life span, and they never get enough time and opportunity to watch conspecifics, in such an eventuality, their life processes depend only on inherited traits.

Animals are born with certain behaviours pre wired in their nervous system as part of its inherited structure. Honey bees inherit the ability to form wings and wing muscles for flight towards flowers to seek nectar and pollen. Such responses are called-**instinctive**. The classical Instinct pattern can be explained by the following example : A young weaver - bird " Bayaa" manages to acquire a mate and is in the process of building its nest. The bird first finds nesting material (long grass) then proceeds to weave them together in a most complex fashion. It manages to tie knot in each piece of grass and pulls it tight so that the grass blades form a spacious nest. It then searches the area for twigs and soft grass to make the floor of the nest, and on this cushion, it deposits its eggs. The **weaver bird** has not witnessed nest building by older birds and it has no previous experience in such a task. But on its first try, it builds a nest (Fig 3a); the logical explanation is, that this behaviour is transmitted through genes from parents.

Among animals there are many such instances of elaborate behaviour that are found throughout a species and are not acquired through previous experience or learning.

How in fact can we recognize an instinctive pattern ? When a bird such as **white throat** or a **garden warbler** is hand reared from the egg in a sound proof room (acoustic isolation), in due course of time it will produce the perfect elaborate song of its own species, then we can say quite definitely that there were no chances of learning and the behaviour pattern was innate (instinctive) in the sense that it was coded genetically to work through central nervous system at the appropriate time by appropriate stimulus.

Characteristics of Instincts

(1) **Instincts** are innate and **inherited** and are similar in all individuals of a species, e.g. all **digger wasps** of the same species build their nests in the same way; all the **cocks** use the same series of movements when courting hens, all **tailor birds** stitch their nests in the same way, birds of one species sing a common sing.

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(2) **Instincts** involve **complex and highly rigid pattern** of behaviour, in which numerous muscles, muscle groups and whole organs and organ systems are perfectly co-coordinated.

(3) **Instinctive action** are characteristically evoked by **complex stimuli** such as visual or auditory which are known as **sign stimuli.**

Difference Between Instinctive and Learned Behaviour

Instinctive behaviour evolves gradually as the structural features and natural selection modifies it to fit in the environment in the best way. If forms a kind of **species memory** passed on from each generation to its offspring. It is controlled genetically.

Alternatively, an animal may have no inherited responsiveness with regard to a situation but instead, have the ability to modify its behaviour in the light of experience. It learns which responses give the best results and changes its behaviour accordingly. It is not passed on to the next generation. This is known as **learned behaviour.**

Instinct and **learning** both ensure **adaptive behaviour**, the former by selection operating during the **history of a species**, the latter during the **history of an individual**. Instinct can equip an animal with a series of adaptive responses which appear readymade at their first performance. This is clearly advantageous for animals with short life-span and little or no parental care e.g. a female digger wasp emerges from her underground nest in spring. Her parents died the previous summer. She has to mate with a male wasp and then perform a whole series of complex pattern connected with digging out a nest hole, constructing cells within it, hunting and killing prey such as laying eggs and finally sealing up the cells. All this must be completed within a few weeks, after which the wasp dies. It is quite inconceivable that she could achieve this tight schedule if she had to learn every thing from scratch by watching conspecifics doing it.

In contrast to the digger wasp's situation, is that of a **wolf cub**. Born helpless it is protected and fed by its group members until it can move around. It is slowly taught to eat solid food. It has constant opportunities to watch and learn from its parents and other group members. The digger wasp must rely on pre-set instinctive behaviour and the wolf can learn in leisure represent two extremes on the behavioural scale. It is not that the digger wasp has everything instinctive. It must learn many other things during its brief life e.g. the exact locality of the nest, so that it can return to it after its hunting trip (Fig 12). Similarly, a wolf possess many behavioural patterns that are instinctive e.g. running, growling and mating.

One advantage of learning over instinct is its greater potential for changing behaviour to adjust to changing circumstances. Such a consideration is obviously more important to a long-lived animal than to an insect that lives only a few weeks. To make any critical distinction between instinctive

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behaviour and learnt behaviour, it must be based upon their **development** within the individual. The processes which are **learnt** take **longer** and show variation but **instinctive** behaviour are elicited **early** and are rigid, show little variation (therefore also called Fixed Action patterns or consummator acts). Further more, **learning takes long** time, if we put a hungry rat into a box with a lever it may take hours to push that lever. But if receptive female rat is put with a male rat, they acquire the acceptance posture for mating after very little experience with each other i.e. the **instinctive behaviours** are **elicited quickly** at the arrival of stimulus.

Instincts such as hunger, sex, anger, fear, aggression and even pleasure have been pre-wired into brain during the course of **evolution** to ensure **physical** and **psychological** well being of the **species**. A great deal of work on a variety of animals, birds and mammals has shown how responsive the animals are instinctively to events even when they are very young.

We have a basis for development criteria of instinctive behaviour and the commonest way of testing them has been called "**isolation experiments**". Animals are kept individually out of contact with others from as early an age as possible. When mature, their responses to a variety of stimuli are tested and compared with those animals that were reared normally. **Eidl- Eibesteldt** (1970) reared young **pole cats** in isolation and never gave them any opportunity to catch live prey. These cats showed varying degrees of interest when first presented with a live rat. There was no hint of attack unless the rat ran away from them, the rats who sat quietly were not noticed. If rats moved, cats instantly seized them in their month, usually shaking it rapidly in a characteristics way. Their bites were at first badly oriented, but after a few trials they were seizing prey by the nape of the neck and killing with a single bite. Clearly there were **inherited component** to the **killing patterns** which were perfected by practice or learning. Many fish and birds have been shown to perform various feeding, sexual and aggressive patterns of behaviour quite normally after being reared in isolation. These experiments are not very easily accepted, because isolation causes severe abnormalities in other behaviours.

Expression of instinctive behaviour is linked to the **development** of animal's **nervous** and **muscular system** e.g. young **birds** can often be seen making vigorous **flapping movements** with their wings while still in the nest and it is commonly supposed that they are practicing flying. **Human parents** are often seen supporting young babies on their legs and encourage them to practice walking. **Spalding** (1973) showed that young **swallows** reared in small cages where they could not stretch their wings, flew just as well as normally reared birds when released, this indicates that for certain Fixed Action Patterns it is the **maturation** of the **central nervous system** and its **co-ordination** with **muscular development** that matters. The bird will fly and human baby will walk only after-CNS maturation and proper muscle

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development, both activities are essential for execution of above mentioned instinctive behaviours.

The development of an animal's behaviour must obviously be linked to its normal growth process, e.g. the development of sexual behaviour in most vertebrates is linked with the growth of gonads. The sexual behaviour is instinctive but it is only released when there is a certain level of sex hormone in the blood.

The performance of behaviour gets better with practice (learning). The development of **pecking** in newly hatched **chicks** provides an example of interaction between instinctive and learned behaviour. Young chicks have inborn (instinct) tendency to peck at objects, they peck indiscriminately but after many trials and committing errors chicks gradually improve with practice or the instincts are improved by learning. These two processes are inseparable. The conclusion is instinctive behaviour is fed in by genes during the development of the nervous system, the instincts are perfected or polished for finer adjustments by learning, that development and proper performance of instinctive behavioural patterns depend on the proper maturation of nerves, endocrine glands and muscles.

According to Lorenz, when animals perform FAP it seems that as if the animals were **releasing** some kind of **tension**, eg. a ground squirrel in captivity when presented with excess of food may retire to a corner of its cage and go through the motions **pretending** to bury the food on the iron floor apparently **satisfied** by the act, even though the food remains in full view. Similarly, a hen canary in breeding season, **deprived** of nesting material, has been seen to fly repeatedly from one part of the cage to the nest site, holding one of her own feathers hi her beak and on reaching the nest site, it goes through the movements of weaving the material into the nest, even though the feathers were still attached to her body. A female rat deprived of nesting material has been seen repeatedly carrying her own tail from one corner of the cage to the nest site, going through the process of buiding the nest; such a release of FAP is called **in Vacuo**.

Sign or Key Stimulus or Releasers

In general, **releasers** are those parts of the surrounding that **trigger instinctive acts**. Isolated characteristics of an object, such as colour or shape, that evoke FAP or the **simple and specific stimuli** that cause release of FAP are termed as sign stimulus (SS). It was **Konard Lorenz** who first realized that specific stimuli (which he called as key stimulus) are needed to release the FAP. He said that a stimulus acts as a key which unlocks and opens a particular fixed action pattern. **Sticklebacks** are small fresh water fishes; in the breeding season, the males develop a **red colouration** on the underside of their bodies and become highly territorial. They select a site, form a tubular nest and defend it actively by fighting and chasing an intruder male (Fig. 5). **Niko**

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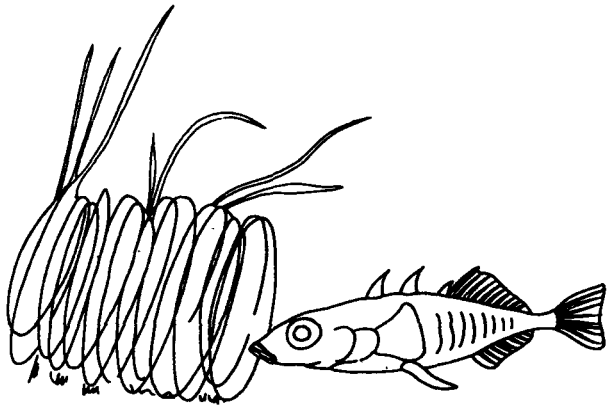

Fig. 5. Male stickleback with his nest

Tinbergen in 1952 performed some classical experiments to understand the intriguing mechanism behind sign stimulus. He used some models to study the specificity of sign stimulus (Fig. 6).

Model A (Fig. 6) was very realistic but did not have a red coloured underside, whereas, models B and C were of odd shapes but with red bellies. Models with red undersides acted as sign stimuli for releasing attack behaviour in other male sticklebacks. Therefore, red belly is the **critical** or specific sign stimulus responsible for releasing **territorial defence** in male sticklebacks. Similarly, the exposure of **red breasted feathers** of the male **european robin** in the territory of another male robin is a sign stimulus for aggressive patterns of behaviour. Significance and specificity of sign stimulus is reflected in many other examples : A **herring gull's chick** pecks instinctively at a **red spot** on its parents bill and that acts as a sign stimulus that induces the parent to regurgitate food (Fig. 7) called crop milk. The chicks of **song birds** that are born blind and helpless **respond to the jerk** on their nest. In nature, when the parents arrive on the nest it creates movements, which acts as a sign stimulus for the chicks, they turn their neck in the direction of movement

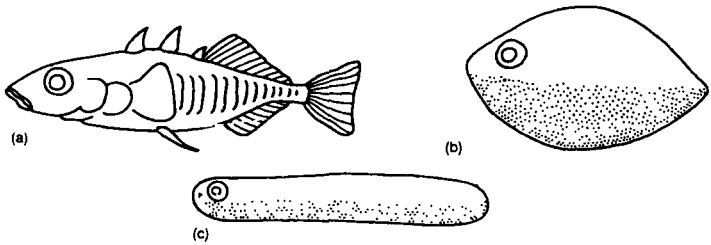

Fig. 6. Use of stickleback models to study the specificity of sign stimulus (Tinbergen, 1951) (a) Realistic model except for red belly, (b) and (c) Unrealistic models with red bellies.

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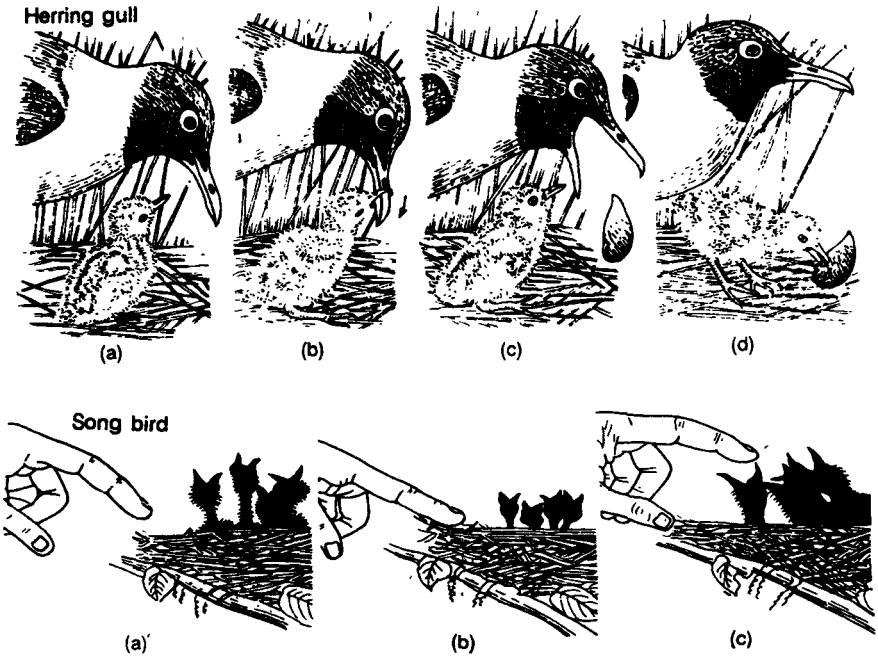

Fig. 7. Response of herring gull and song bird chicks towards the red spot and jerk on the nest. Herring gull. (a) The parent arrives, the chick looks at the parent's bill, (b) Chick pecks at the red spot (c) Parent regurgitates the food (d) Chick eats the food Song bird : (a) Blind helpless chicks open their beaks, but do not know the direction.
(b) The experimenter gives a slight jerk on the nest, as if the parent bird has arrived.
(c) All the chicks turn towards the hand of the experimenter. (Life/Time publ)

and open up their mouths (Fig. 7) the colouration inside or just the sight of gape acts as sign stimulus for the parents to regurgitate food.

A **hen** does not **rescue** a chick that it can see struggling under a glass cover (Fig. 8). She will come to rescue chicks only if she hears the **distress cries** of the chick, that means, only such calls can release the rescuing behavioural pattern in mother and not the sight of helpless chicks. Similarly, **Turkey hens** render parental care only after hearing the calls, but not to the appearance and movement of chicks, even an unnatural model will be brooded by the hen if chick calls can be heard from a small loudspeaker mounted within.

Male flicker has a **black patch** under its beak resembling a moustache. If a moustache is printed on female, on her return to nest the male attacks her as though she was a rival male. Therefore, the black spot is a sign stimulus for the release of attacking behaviour pattern among flickers. **Cuban finches** react aggressively during breeding season towards any model having a **yellow mark** that imitates the neck band of a male. An interesting experiment

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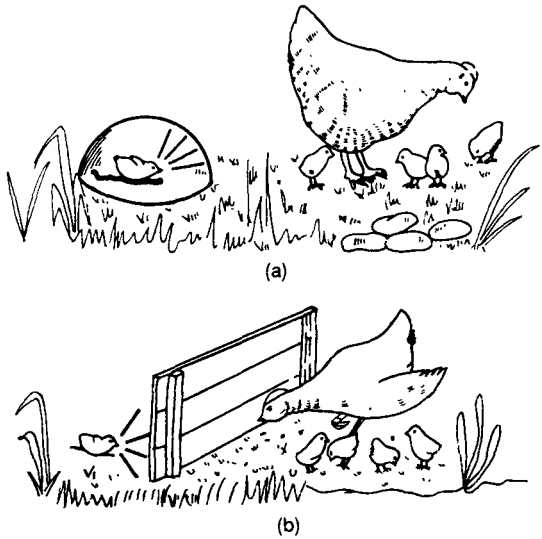

Fig. 8 Release of rescue behaviour in hen. (a) Turkey hen could see the chicks but could not hear, did not rescue (d) Turkey hen could hear the chicks but could not see, rescue

was done using a **card board** model to study the specificity of a stimulus, this model (Fig. 9) was flown over young **gallinaveous** birds like **pheasants, partridges, turkey** and **domestic fowl**. In one direction the model resembled a hawk or a **predatory bird** and it elicited an escape response in birds, whereas, in the opposite direction, it resembled a **duck or a crane** and hence did not receive an escape response.

Organisms use a variety of stimuli to release different behaviour patterns. Impressive results have been obtained in experiments with the **grayling butterfly**. During the breeding season the male of this species performs a

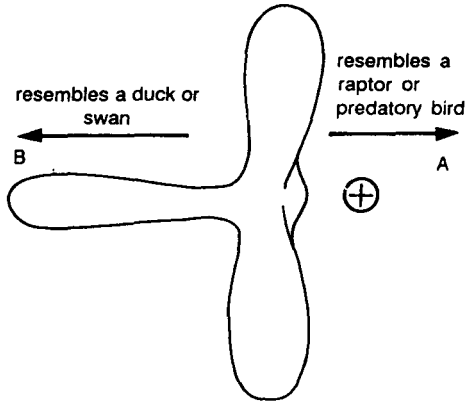

Fig. 9. Release of escape response in gallinaveous chicks. Flown in direction (A) released escape response but when flown in direction (B) did not release escape response. *(Z–37/Ani. Beh.)*

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pursuit flight or courtship flight that invites passing female to land near him, after a short courtship ritual they copulate. By the use of models that varied in colour, form, brightness, movement and contrast with background it was determined that the first three cues were almost completely ineffective, and the important stimuli were movement and contrast.

Sometimes, the **sign stimulus** is not just one but **a combination of many**. In **gulls**, begging behaviour in hatchlings is stimulated by (i) the shape of the bill (long, pointed objects were preferred over short and stubby), (ii) the colour of the patch (red preferred over all other colours), (iii) the contrast of the patch with its background (more the better) (iv) a moving beak model attracted many more pecks than stationary one and (v) a beak that pointed down was more effective than one oriented in another direction.

Fighting behavioural patterns in the **male cichlid fish** is elicited by five stimuli

(1) Silvery blueness of body
(2) Dark margins
(3) Broadness of animal
(4) Parallel orientation to opponent and
(5) Tail beating.

Any one of these stimuli was capable of eliciting hostile behavioural patterns and that any two would produce about twice the reaction of one. Therefore, in many instances response to releasers appears to be **additive**, and is called **law of heterogeneous summation.**

These stimuli have been compared to a key which unlocks a behaviour pattern in the animal's neural system. The ethologists have developed a concept that assumes the existence of an inborn neural mechanism that responds in a specific way to the releasers.

Each organism, at any moment, is confronted by a wealth of information from the environment but only a small fraction is biologically significant for the animal. One of the most important task for the organism is the selection of those stimuli that should be followed by a reaction. Two organ systems are available for this sorting out or **filtering** of information - the sense organs and central nervous system, these are called peripheral and central stimulus filtering respectively and both are helpful in selecting relevant stimuli.

Ethologists have constructed models that are more effective in releasing FAP than the original stimuli. **Exaggerated form** of stimulus which releases a particular behaviour pattern more effectively than the appropriate natural stimulus is called **super normal stimulus.** This phenomenon was first discovered in laboratory conditions, eg. a bird, **oyster catcher** (Fig. 10) prefers eggs larger than normal and will try to sit on eggs too large to incubate.

Other ground nesting birds eg. **killdear, herring gulls** or **greylag geese** when presented with eggs or egg models that are more conspicuous or larger

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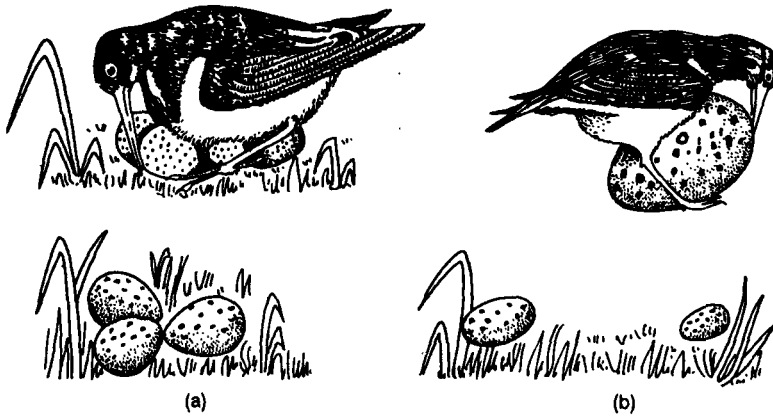

Fig. 10. Super normal stimulus : (a) an oyster catcher incubates a supernormal clutch of five eggs, which is preferred over the usual three (b) the same bird prefers the giant egg over the eggs of small size (Tinbergen, 1948, 1951).

than their own eggs, retrieve those exaggerated forms into the nest and incubate in preference to their own eggs.

The existence of supernormal stimuli shows very clearly how strong the **selection pressures** are to make stimuli even more important and conspicuous. There are some supernormal stimuli that occur in the natural situation. Some birds eg. cuckoos lay their eggs in someone else's nest. This is known as **brood parasitism.** The nestlings of **cuckoo** possess a gape marking in their mouth that is more prominently coloured than the gape marking of the host species' young. The stimulus of gape marking of cuckoo is so effective that the response of the foster parents is more towards them and hence they feed them more.

In our day to day life, the TV advertisements or other marketing strategies are taking advantage of many different kinds of supernormalizing devices/ stimuli. For every product a supernormal end product is predicted to entice the customer, be it a toothpaste, soap, shampoo or cooking oil.

Innate Releasing Mechanism (IRM)

The special **neurosensory mechanism** that releases the behaviour in response to specific sign stimuli is called the **Innate Releasing Mechanism**, in other words there exists an inborn neural centre called IRM that responds to a sign stimulus. The term and concept were proposed by **Niko Tinbergen** (1951), it was called Angeborener Auslosemechanismus (AAM) by **Konard Lorenz** IRM or AAM are essential for the perception and processing of relevant sign stimulus. IRM is situated at the **hypothesized locus** in central nervous system (CNS) on which sign stimulus acts to release FAP. A specific sign stimulus acts on a specific locus; a lock and key analogy is often used to clarify the

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relationship of the sign stimulus and IRM. For each FAP there is separate IRM, which is like a gate to a reservoir of energy used to bring about FAP.

Action Specific Energy (ASE)

It is also known as Specific Action Potential (SAP) or Action Specific Potential (ASP). **Lorenz** in 1950, advanced the concept of ASE- that could not gain wide acceptance, probably due to lack of neurological evidence to support it. Lorenz postulated that ASE, or energy for a specific action is **constantly** being **produced** in the animal's **central nervous system.** The ASE is that energy which is required for carrying out a particular FAP. It is being produced continuously in an animal's CNS, but it is held in check by some **inhibitory mechanism** until the appropriate sign stimulus releases this energy and subsequently FAP; each FAP is thought to have its own ASE. The concepts mentioned so far, function in an organised sequence: i.e. appropriate sign stimulus is received through sense organs and sent to the hypothesized locus IRM in central nervous system, which releases ASE to elicit FAP. Lorenz in (1950) proposed a model known as **"Psycho-hydraulic model"** or **"Flush toilet model"** (Fig. 11) to explain the coi relation between SS, IRM, ASE and FAP (instinct).

Sign stimulus (weight) acts on IRM (spring and valve) which in turn allows ASE to flow from reservoir to carry out FAP; gradually increasing pressure of ASE as well as sign stimulus act in the same direction to release the FAP.

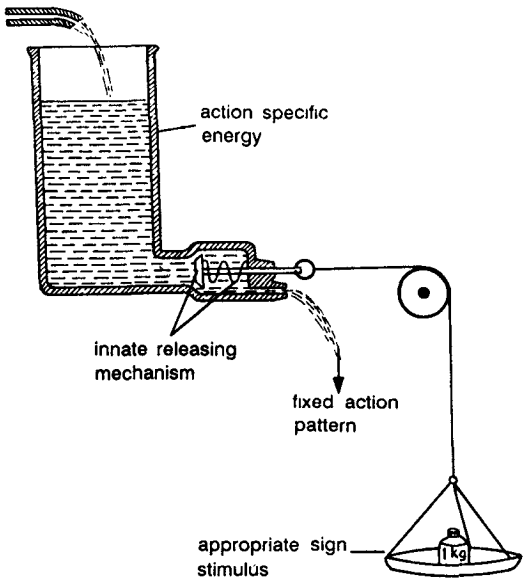

Fig. 11. Psycho-hydraulic model of K. Lorenz (1950).

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The higher the ASE levels the smaller the weights (stimulus) required. In the absence of sign stimulus, ASE is accumulated and eventually its own pressure may push open the valve to release an instinct, this kind of release is known as "in-vaccuo" release, which has already been mentioned earlier in this chapter. Once the reservoir is empty, the behaviour can no longer be elicited for some time, no matter how strong the stimulus is, but gradually the ASE would get accumulated again and would be ready to elicit behaviour.

Physiological Basis

After Lorenz, ethology began to expand into the **neurophysiological** field. **Von Holsta, Hass, Hinde, Pavlov, Harlow, Skinner** are the prominent names in this field. **Neuroethology** and **ethoendocrinology** are specialized branches of ethology. For a long time, an animal's behaviour was seen exclusively as a reaction i.e. as a response to external or internal sensory stimulation. The simplest form of reactive behaviour is the **reflex**. Initially it was considered that many behaviour patterns are brought about by long and complex chain of reflexes. Not until the middle of 1930s did **Erich Von Holst** (1932) and **Konard Lorenz** (1935) independently discovered, on the basis of experiments and observations, that behaviour is not just a reaction to external stimuli but is also based on internal physiological conditions and spontaneous reactions controlled by **central nervous, hormonal** and **muscular systems**. This discovery made it possible to separate innate and learned behaviour patterns, conceptually from reflexes. There is one basic difference between reflex and innate behaviour, in a reflex the response to a stimulus is generally identical from one presentation to the next, i.e. under the same conditions and the same stimulus the response always occurs in exactly the same way, whereas in an innate behaviour pattern it can vary. Classification of behaviours is based on the assumption that the complexity of behaviour increases with the complexity of the underlying neural mechanism. The major phyla of animals differ in the complexity of their nervous systems, correspondingly, these groups differ in their ability to carry out elaborate and difficult tasks, to solve complicated problems and to cope up with the changes in environment. Behaviour is actually a result of **co-ordinated muscle activity** and it is very well known to you that muscles do not contract unless stimulated by nerves. It has been rightly said that **"behaviour is the symphony of muscle contractions, guided by messages from the central nervous and hormonal systems."**

Behaviour and physiology are inseparable, the animal senses its external world through sense organs, which in turn send nerve impulses to brain, where it is interpreted and message is sent to respective muscles to behave accordingly. The **internal urges** are also sensed by special structures eg. long hours of **hunger and low level of glucose** in the blood - causes excitation of feeding centre in hypothalamus, this causes hunger, animal shows appetitive

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behaviour, after finding the food the consummatory actions are performed. It is only the last part which can be seen and designated as behaviour, but it is whole lot of body physiology responsible to make these movements possible.

All the sense organs form an integral part of animal's behaviour, because it is through these organs that the organisms receive external stimuli from environment and keep adjusting to changes accordingly. The brain perhaps plays the most important role in bringing out a behaviour.

Learning or Experience

"It is the process by which an activity originates or is changed through reacting to an encountered situation" or **"any change in behaviour as a consequence of experience"** is learning. All animal forms from protozoans to primates learn. You have already known that some behavioural acts are inborn, that is, the animals perform them automatically without having any previous experience and are called FAP. The other is learned behaviour, which the animals can perform only after **seeing the conspecifics** performing it. That makes two major categories of behaviour- innate and learned and there is an adaptive significance attached to both these categories. Certain behaviours are essential for survival viz feeding, drinking, sex, maternal, aggression and escape, etc. hence their basic components are transferred genetically. The other major advantage of having innate behaviour is for those animals who either live solitary or have a short span of life, the first ones do not want to see conspecifics and the second ones do not get enough chance to see the conspecifics. A female digger wasp emerges from her underground nest in spring, her parents are already dead, she finds a male and mates, then digs a hole on the ground and forms a complex nest of many cells by performing complicated behavioural patterns; then she goes out for hunting, kills caterpillars, brings them to the nest, lays eggs and seals the opening of nest, this is completed in few weeks time, the female leaves and dies. The wasp has a short life span, where she does not get the time to see her parents; if she had to learn every act by watching others she could probably never achieve this tight schedule. For such organisms genetically programmed behaviours are most important.

All the complicated behavioural patterns are genetically controlled, and this does not mean that they do not learn anything at all, they do. Because if all the behavioural patterns were innate which are stereotype, repetitive, rigid and invariant, how would an animal adjust to day to day variations it has to face, in the habitat it lives in or adjust to the ever changing environment ? Therefore, it is very necessary to have the ability to modify its behaviour through experience or learning according to factors like habitat, geography and climate. In contrast to digger wasps situation, the **tiger cubs** do not have the pressure of short life span. Born quite helpless, the cub is sheltered and fed by its mother until it can move around, the cub is gradually

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introduced to hunting and solid food. The cub has constant opportunities to watch and learn from its parents and other members of the group. The digger wasp, which must predominantly rely on preprogrammed inborn behaviour and tiger cub, that can learn in leisure, represent two different categories of behaviour. Instinct and learning both have adaptive significance, the former operats during the history of a species, the latter during the history of an individual. Snapping at food is a routine in **toads** or it's a FAP, when they are mature enough they snap up flies, mealworms and other moving creatures. If a **millipede** is placed in toad's enclosure, the toad will snap at it automatically, as a consequence of FAP. The millipede gives out nauseating substance, whereupon the toad will spit out the prey from its mouth. Later, this toad will always refuse to ingest a millipede species even though if it is hungry, showing that its behaviour has changed, the animal has learnt to avoid obnoxious prey, it has learnt to discriminate between edible and inedible. Similary, **chicks** peck indiscriminately on all objects which they see on the ground as a FAP but as they grow, they learn by experience to peck at useful food items only and ignore the rest.

Though most of the **insects** live by their instincts yet they are capable of rapid learning. In a classical experiment, **Niko Tinbergen** studied learning in digger wasp *Philanthus triangulum.* He found out that a female digger wasp can learn the appearance of her nest entrance by encircling just one flight above it. Tinbergen kept few pine cones in a circle surrounding the nest of wasp as physical cues (clues). When wasp came out, it took a circling flight, and went away. Just after that Niko Tinbergen displaced those pine cones. On return wasp searched the nest in the centre of the displaced ring. The wasp had learnt the position of its nest by taking a flight around the pine cones (Fig. 12).

In another experiment, observations were made on adult **songthrust**, a bird that feeds on snails, it picks up a snail, carries it to a rock, where it holds it by its feet and smashes it against the rock by means of rhythmic sideways swinging motion of the head. This is achieved by a long period of learning in the young birds by seeing their adults doing it. If a song-thrust is reared in isolation, it will not be able to perform the above mentioned behaviour.

It is almost impossible to differentiate between innate and learned behaviours in an adult animal without performing experiments in isolation. Probably the most spectacular instance of learning has been found among island populations of the **Japanese macaques** *(Macaco fuscata).* On one particular island a two year old female, Imo, started washing sweet potatoes-by holding them in the water with one hand and cleaning sand away with the other. Within few years, 90% members of her group except the very young and very old, had learnt this habit. Something more interesting soon followed, within three years of her first learned task, the same female -Imo invented an interesting method for separating wheat grains from sand. She collected the

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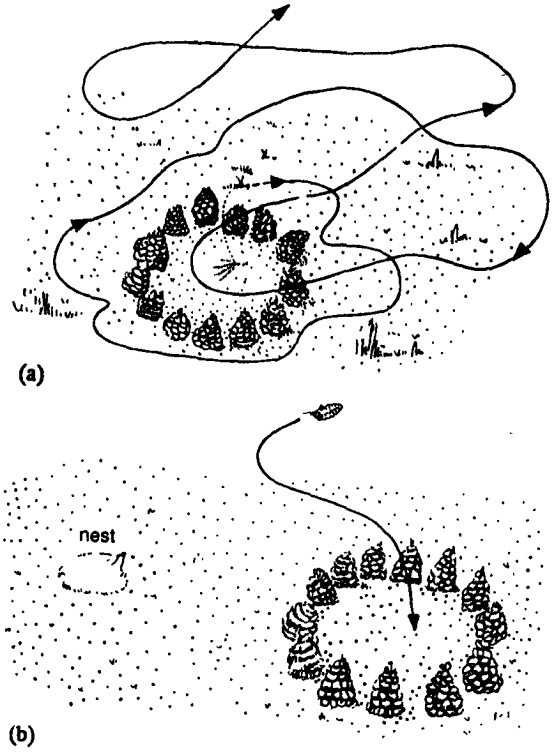

Fig. 12. Learning in digger wasp (Tinbergen, 1951) (a) Digger wasp takes a circling flight over pine cones and comes back to the nest opening (undisplaced pine cones) (b) Digger wasp takes a circling flight over pine cones and searches for nest opening on return in the centre of circle formed by pine cones (displaced pine cones).

mixture of sand and grains in her palms and carried it to the sea, threw it into the water, let the sand sink, and strained off the floating grains. This pattern spread through the group as well.

Learning in animals can be of two types :

1. **Flexible.** Which includes **habituation, trial and error, classical,** and **instrumental.** As the name suggests this kind of learning is flexible to further changes and experiences.

2. **Restricted.** This includes a very special type of learning called **imprinting,** once it is esablished, it is comparatively resistant to further changes. It plays an important role in the development of many behaviours in almost all higher animals.

Imprinting

The animals learn through their own experience, through observation and imitation throughout their lives, but there are some phases in an animal's life

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when it is likely to be sensitive to some typical learning processes. Many animals and even human beings pass through such a period when certain learning experiences are far more significant than at other times. This means that if an individual encounters the same kind of experience outside this period, perhaps it may not learn it at all. **K. Lorenz** (1935) was the first one to notice this type of learning and he coined the term - **"imprinting"** for such a process. Lorenz has mentioned many interesting incidents in his book **"King Solomon's ring"**. He was a great lover of animals, and had many animals as pets in his farm house. He was especially fond of greylag geese (duck); with which he conducted classical experiments of imprinting for which he is world renowned. **K. Lorenz** had unique ways of studying animal's behaviour. There is an interesting incident - while he was studying **jackdaws** (crow like); he used to take them out from their nests to mark them with aluminium rings. After few days, jackdaws started making wild noises just at the sight of **Prof. Lorenz**. He got rather worried and thought how to stop birds from developing a permanent shyness for him, so he disguised himself. He used to wear a Devil's costume while closely observing or handling jackdaws, which was a gorgeous black furry dress with a mask covering the whole head, complete with horns and tongue and a long devil's tail. He picked up a newly hatched jackdaw from the nest and hand reared it, it got imprinted on **Konrad Lorenz,** as the breeding time approached, it courted **Konrad Lorenz**, pecked at his teeth and fed him with minced worms mixed with jackdaw saliva, in normal course the jackdaw would do this with a mate.

In early life of many animals a period starts as soon as they are hatched or born. This period varies from days, weeks, months or years depending upon the species. During this time, also known as the **critical period**, they learn to identify or recognize their parents by following them, according to **Schultz** it is known as **filial imprinting**, if following is carried out uninterrupted, this knowledge is utilized by the animals later in their adult life to recognize mates known as **sexual imprinting**. Imprinting has profound influence on animal's social behaviour. Though it sounds strange that how a thing which is learnt so early in the life can influence adult behaviour? But it is true, that there is a critical period in early childhood when an individual can learn certain things, once this period is over, those particular behavioural patterns cannot be learnt. **Konrad Lorenz** observed that newly hatched **precocial** birds (which start walking immediately after hatching eg. chicks and ducklings) follow the first moving object they encounter, - usually they are their parents but with incubator reared birds it is likely to be a human being. If ducklings begin their walk by following a man, they will continue to follow a man in preference to adult ducks throughout their life. Moreover, they behave as if man belongs to the same species. These birds may even court a man taking him as a mate.

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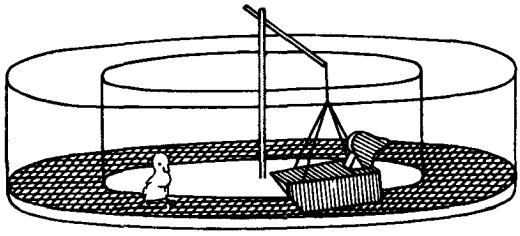

Fig. 13. Circular runway used in experiments on imprinting.

As mentioned earlier, that in wild or in nature the new borns see their parents, and learn to follow them or learn to recognize their mates through them. Sometimes if the parents leave or die, the newly borns have been seen following individuals of other species which they saw around during the critical time. **Mallard ducks** raised by parents of another species followed their surrogate mothers. **Calves of buffaloes** and **bisons** have been observed following **horses**, and **zebras** followed a car. As adults these animals preferred courting them also. Five year old **turkey** raised by hand, preferred courting human beings even though they had been placed with members of their own species. Zoo authorities know that hand reared animals preferred courting their **caretakers** and such animals had poor reproduction when they were allowed to remain with their conspecifics. In lab condition, the animals got imprinted to match boxes, balloons, wooden blocks, toys and many other unnatural objects. The experiments are carried out in a circular runway (Fig. 13) which has a long rotating arm to which are attached different models which move slowly along the circular path.

The birds can recognize the shape, size and colour of the model. If they are imprinted with a wooden block they will not follow a toy duck. Further, according to **E. Hess** (1964) the more difficulty a duckling 'has in following a model, the stronger it will imprint on that model. Also a **moving** and **noisy model** is more effective. Socialization and an animal's ability to become a part of a social group are largely determined by early experiences. Human children may become shy loners if between 2 to 6 years they are not part of some social group i.e. a school. **H.F. Harlow** described "**Deprived Syndrome**" in young rhesus infants. The syndrome is expressed by general restlessness, aggressive reaction, extensive apathy and lack of exploratory behaviour, as adults most of these animals were unable to mount and copulate. According to **Lorenz** imprinting is a unique form of learning because of the following factors :

(1) It takes place only during a brief sensitive period early in the life.
(2) It has great stability, often lasting for the rest of the animal's life.
(3) It influences the animal's adult social and sexual behaviour.

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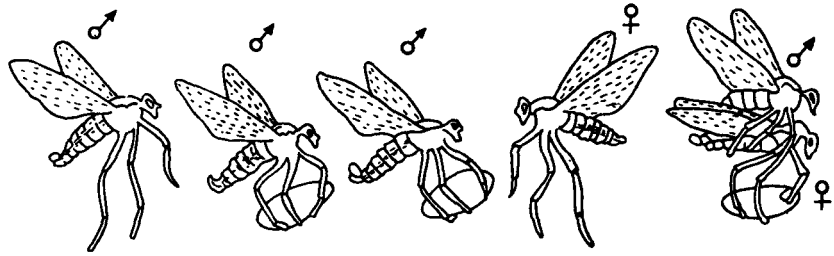

Fig. 14. Presentation of prey by male cupid fly to female.

Behavioural Genetics

Let us now look at some of the evidences which suggest that patterns of **behaviour** can be **transmitted** from parents to offspring via **genes**. Actually it should have been a part of FAP, but since it now makes a separate and specialized field in ethology and explains issues based on experimental evidences therefore, it needs a special mention. In those species in which parent upbringing is absent, any sort of complex behaviour that is spontaneously expressed is very likely to be genetic. A male **cupid fly** will catch a prey, form a cocoon around it and present it to female before copulation, female cupid fly will open up the cocoon and eat the prey, in the meantime male will copulate (Fig. 14). All this has to be done within the few weeks of its adult life. Such complex behaviours would hardly be accomplished by learning, it is assumed that the entire sequence of behavioural steps followed by cupid flies is coded in the fly's genes.

The example of the hygienic **honeybee** is a particularly dramatic instance of the genetic control of behaviour.

Certain honeybee strains are "**hygienic**", if their larva or pupa dies inside a cell in the hive, the workers uncap the seal and remove the dead animal, whereas in "**unhygienic**" strains this behaviour does not occur. Among themselves, both these strains breed true to their type. If they are mated experimentally, hybrids between hygienic and unhygienic strains are all unhygienic. If these hybrids are mated to hygienic bees, four types of progeny result (Table 1).

The fascinating point is that what seems on first site to be a complex behavioural pattern can be understood on the basis of action of just two genes.

An interesting cross breeding experiment between two species of **love birds** was conducted by **William C. Dilger** (1962) of Cornell university. One of these species had the peculiar habit of cutting up strips of leaf or bark for its nest and then tucking them in the feathers of its rump, and in that way carrying them to the nest site. The other species used to carry its nesting material in its bill (Fig. 15). The hybrids between these two species carried

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Table 1. **Cross between hygienic and unhygienic strains of honeybees.**

UU = Do not uncap the cell
RR = Do not remove the dead larvae — Unhygienic UURR
uu = Uncap the cell
r r = Remove the dead larvae — Hygienic uurr

UURR × uu rr
‖
UuRr
×
uu rr

Gametes	UR	Ur	uR	ur
ur	UuRr	Uurr	uuRr	uurr
	(1)	(2)	(3)	(4)

(1) Those which neither uncap nor remove the dead body i.e. unhygienic.
(2) Those which do not uncap, but if the experimenter does so, remove the dead body.
(3) Those which uncap cells containing dead larvae, but do not remove the dead body.
(4) Those which uncap and also remove the dead body i.e. hygienic.

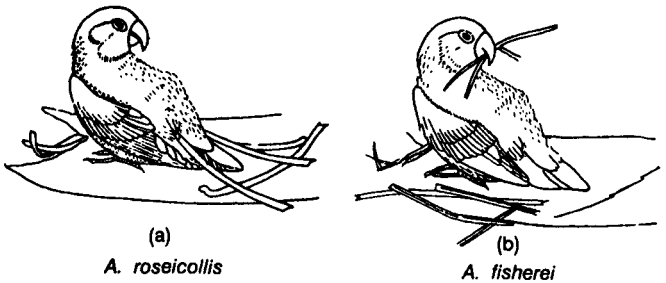

Fig. 15. Transportation of nesting material in lovebirds of genus Agapornis.

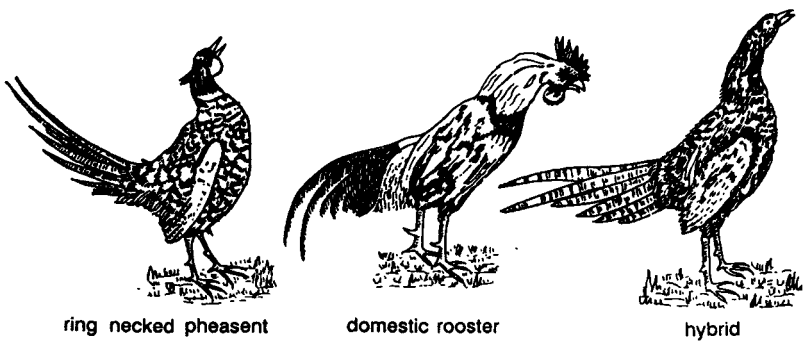

Fig. 16. Crowing in roosters (Stadie, 1968).

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material both ways. They started off by carrying most of the nesting material tucked in the rump feathers, but this was less efficient than transportation by bill, it kept falling out, and they subsequently learned to use their bills more and more. The **roosters** of different species crow in different postures, ring necked pheasant crows by stretching its neck and pointing upward, domestic rooster looks down and a hybrid of both (Fig. 16) species assumes intermediate position. Variability in species and populations is as large for behaviour characters also as it is for structural characters.

Evolution of Behaviour

Has behaviour evolved? It most certainly has, unfortunately, **fossils do not behave**, and so we have no direct knowledge of the course that behavioural evolution has followed in the past. Yet there is a great deal of **indirect evidence** which allows us to say something about the way behaviour has evolved. As in any other evolutionary process, we can assume that new behavioural developments did not take place by sudden leaps and bounds, but through small changes and stages of adaptations. In animals today, we see the combination of structural adaptation and behavioural patterns developed through many generations, which enables every individual to survive. For example, certain animals, like the **screech owl** and **sphinx moth** have developed behavioural traits that provide each of these with two distinct lines of defence against predator. Both these species are nocturnal and rely primarily on **camouflage** to protect them while roosting during the day. They stay **motionless** and if at all detected by a predator, the screech owl bluffs by swelling, snapping and flapping, trying to scare away the predator. Sphinx moth has a more subtle second line of defence, it flicks open its wings to **expose eyes like spots** (Fig. 17) which often **startle attackers**, allowing the moth to escape. This simple act is a forceful example of behaviour developing in step with the evolution of body markings. **Caterpillars**, on which eye spots have evolved as part of their defence, have also developed behavioural displays that show their markings to best advantage. Many larvae have eye spots concealed in the folds of their skin and only reveal them when threatened. Some other animals have them underneath and display them by turning their bodies.

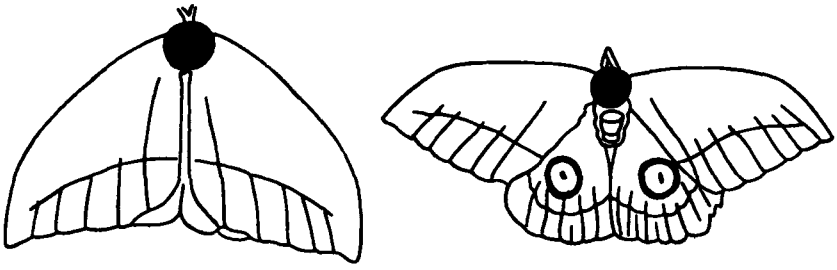

Fig. 17. Startling behaviour of sphinx.

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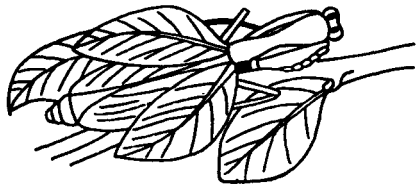

Fig. 18. Out line disruption in camouflaged mantis.

Many animals gain protection by imitating physical structure and behaviour similar to objects regarded as inedible by predators. A **twig caterpillar** has evolved the physical dimensions and markings of a real twig, unless it remains as still as a part of the tree, a predator will not be fooled and the insect will be eaten, **candid fish** in the Amazon basin, resemble dead, dry leaves and can float motionless for hours to escape the notice of larger fishes and predatory birds, similarly some **grass hoppers** resemble fresh grass, Camouflaged mantis *(Derpplatys* sp; Fig. 18) have their wings like plant leaves.

Studies of evolution often involve comparisons between closely related species. It is not easy to comprehend how something as complicated as the **social life of honey bees** may have evolved ? By studying the behaviour of many species of bees **Karl Von Frish** was able to suggest a likely course of evolution from solitary ancestor, through various intermediates, to the social structure of hive. There is one species of bees whose individuals live solitary, each bee makes a burrow, constructs few cells in a tree trunk, lays eggs singly and puts honey in each cell, seals all the cells and leaves. In another species, the young hatch while their mother is still laying eggs, some will help the mother before she leaves. In bumble bees, the young ones which hatch to help mother remain small and less fertile and finally comes the species where mother lays eggs, young come out that remain sterile and all of them live together with mother to form a complex social group.

It is widely accepted that all behavioural patterns that are learned or preprogrammed are for the individual's benefit, in other words, any behaviour performed by a particular animal must be directly useful to it. In terms of evolution all individuals behave to increase their own "**genetic fitness**". It is measured in the currency of offspring and is given in terms of the number of its offspring expected to survive to the reproductive age. In other words, it is a measure of the number of **copies of genes an animal contributes** towards the hereditary composition of the generation. The animal behaves to increase its own fitness irrespective of other individuals of the same group or clan. Here **"fitness"** does not mean the **physical fitness**, an animal could be physically very fit, but if it does not reproduce and leave its genes through progeny in the population it will remain an **evolutionary flop**. That means an individual should behave in such a way so as to **maximize its reproductive**

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success. That way all individuals should be **selfish**, they should be concerned about themselves only. Then why should animals live in social groups? What is the process by which they form bonds between members of a family, leading to **mutual support** and **cooperation**? Could we not argue that each individual according to the rules governing evolutionary process, should be concerned primarily with its own reproduction. Why things like **Altruism** (sacrifice) and **cooperation evolved** in social animals?

Altruism is, when an animal facilitates the reproductive chance of a conspecific at the expense of its own, altruism may include anything from sharing food when food is scarce to defending others at the risk of the animal's own life.

Why some of the bees give their lives in a suicide attack while proctecing sister bees of the hive? **Squirrels, deer,** and **some monkeys** do risk their lives by drawing attention of the hawk and big predatory cats while giving out alarm calls to others. There must, therefore, be circumstances under which alruistic behaviour can be advantageous. The clue to the origin of most of altruistic behaviour in the animal kingdom lies in such behaviour which are being directed toward one's blood relatives. Aunts of **elephant calves** and **lion cubs** protect and nurse them. The animals often tend to be altruistic towards other animals which share in common, a large fraction of their hereditary units or genes by virtue of common ancestry. For example, a person might be willing to throw away his own life to save the lives of two full brothers but he may not be willing to do so to save the lives of three strange persons. Altruistic behaviour, could be explained on the basis of "**kin-selection**" in which any individual would sacrifice its own reproductive success for the sake of its kins or relatives who share some proportion of its genes. In other words, the same genes must be passed on or propagated, either through individual or through a kin.

The help is not rendered to related animals alone. In the troops of the **African olive baboon**, quite unrelated males may get together to help each other when predators attack. Baboon males are big in size and often when they get together they may kill a leopard. This kind of cooperation held at the time of need it is like "you help me this time and I will help you whenever you need me", therefore, safe guarding their own genes.

Organisms without any social tendencies are very rare. We know of few animals that avoid all contact with others of their species, yet they have to come together in order to breed. **Oyster bank, swarm of grasshopper, schools of herrings**, flocks of starlings, the brood colonies of gulls, pack of wolves, herds of antelopes, pride of lion, and group of monkeys are few examples of social tendencies. The non-social behaviours may have just provided roots for the growth of higher social life. Above mentioned behaviours are part of newly emerging branch of ethology called sociobiology.

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Sociobiology

Sociobiology has provided a whole new way of looking at behaviour. It is a relatively new branch of ethology. It deals with the application of **evolutionary biology** to **social behaviour**. Sociobiology provides a better understanding of human behaviour. Old concepts and patterns of behaviour are getting a new fresh look and this branch has provided more innovative approach to animal and human social behaviour than ever before (**Barash** 1979). Sociology is defined as "**Systematic study of the evolutionary basis of all forms of social behaviour in all kinds of organisms**". Study of sociobiology takes help of evolution to interpret the basic patterns of social behaviour and provides two ways of interpreting behaviour :

(1) Proximate
(2) Ultimate

All students of animal behaviour ask the question "why does an animal perform a particular behaviour?" There are different ways of answering it. If there is a question "Why do birds migrate?" The **proximate answer** to it would be, because (i) birds undergo hormonal changes due to change in temperature, day length, rainfall or humidity (ii) accumulation of body fat is responsible for migratory restlessness and consequently birds migrate (iii) as the day length increases it stimulates the receptors in hypothalamus, that in turn influences bird's physiology to prepare for migration. A sociobiologist will explain it using **ultimate interpretation**. According to them (i) scarcity of food causes birds to explore other areas with more food, if they get sufficient food, their survival is better, if this is so, then they can leave more progeny (ii) birds must escape harsh climate to survive and breed for perpetuation of species, therefore, migration becomes important from the point of view of evolution.

The sociobiologist looks into questions like "What is the evolutionary history of a behaviour?" "What is the adaptive significance of the behaviour?" Are animals behaving in a way that maximizes their fitness?" "**The proximate answers are tools and form basis for ultimate answers**. The explanation of any behaviour is more satisfying when it is explained both ways.

According to Darwin every individual is concerned about its own survival. Sociobiologists feel that the concern of survival does not stop there but grows up to the level of population. **Success of survival** is measured in term of fitness. **Fitness** is a measure of **evolutionary success** that applies to reproduction and leaving of fertile progeny. He/she who **leaves maximum progeny** (that gets mature and reproduces) is considered the **fittest in terms of evolution**. Darwin knew that each individual behaves to maximize only its own fitness. The sociobiologists have taken this idea further ahead, according to them "yes, all animals behave to maximize their own fitness, but they also behave to increase the fitness of a relative." *(Z–37/Ani. Beh.)*

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According to modern theory, there are different levels of fitness. If it relates to one individual it is called **Individual** or **Personal fitness**, if it relates to own offspring's also it is called **Inclusive fitness**. If it relates to own relatives then it is known as **kin selection** and finally if it relates to own group which may have unrelated or distantly related members it is called **group selection**.

Sociobiologists concentrate on social behaviour patterns viz. **altruism, eusociality, cooperation, reciprocation, selfishness and spite in animals.** All these behaviours in a social group depend on the "**degree of relatedness**" denoted by "r". Higher the r value between two individual the more genes in common. For example, between parents and offspring the degree of relatedness is 1/2th, between brother and sister is also 1/2th, between first cousins it falls to 1/4th, between distant cousins it will be 1/8th the sociality falls accordingly.

Altruism

"**Behaviour that reduces the Darwinian fitness of performing individual while increasing that of the recipient**". Darwin had imagined that individuals behave for their benefit alone. **Lewontin** in 1970 observed in rabbits in Australia that related rabbits helped each other. Sometimes one rabbit sacrificed food or shelter for another related rabbit. After this example, if you read the definition again it gets a meaning. Reduction of personal reproduction in order to favour the reproduction of other related animals is called altruism.

Eusociality

"**When one sacrifices its own reproductive privileges to promote reproduction in another related individual it is called eusociality**". It is considered the height of sociality. The presence of non reproductive casts in bees, termites and wasps is eusociality. In a bee hive female workers remain sterile to help their queen to reproduce.

Cooperation

Related animals help each other at the time of need. **Cooperative brood care** is seen in birds and monkeys. **Cooperative hunting** is common in wolves, wild dogs, crocodiles, seals, walruses and many such predatory animals. **Cooperative defense** is also common among related animals. Birds of the same flock mob the snake, moneys of the same group face the predator collectively. Cooperation is done together and benefit in drawn simultaneously by individuals. Both gain at the same time.

Reciprocation

"You scratch my back today, I will scratch your" Its been known in animals to reciprocate help rendered. Reciprocation can be done at some other time. *(Z–37/Ani. Beh.)*

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Dolphins help the sick to come to the surface to breath. Next time when the helping dolphin gets sick it will get the same help from other group members. Baboons, langurs, zebras, birds look after babies of related individual of their groups. Both gain but at the different time. Preening in birds grooming in monkeys are based on reciprocation.

Selfish and spite

Surprising but true, that animals can be selfish or can take a revenge. In selfish behaviour the initiator gains and recipient loses. In langur groups, after a take over, the new male who becomes the over lord of the harem kills the babies who are feeding on mother's milk. By killing the infant the female stops lactating and starts ovulating and the male can sire his babies. This is one good example of selfish behaviour.

An animal who gains nothing or even reduces its own fitness in order to reduce fitness of another is committing spite. It is not very common among animals. The fighting males can belong to this category.

Aggressive Behaviour Patterns

Aggression is a part of **agonistic** behaviour, it comprises of everything that leads to resolution of conflict between individuals, this means aggression as well as escape. Aggression is used to adjust inter and intra specific conflicts. Agonistic behaviour comprises of all that which leads to solving a **conflict** between individuals. Conflicts arise when two or more individuals **compete** for same object like food, water, space (**territory**) for burrows and holes, egg laying sites, tree branches, for nesting or resting and for mates.

Aggression is **expressed** depending upon its **intensity** from mild to medium to most pronounced e.g. facial expression, chasing, grabbing, pulling, pushing, banging, fighting and biting. These expressions vary from species to species. Aggression includes many forms of behaviours varying from species to species. But their function is similar.

Aggressive behaviour is formed of four **components** (i) agonistic (**threat**) (ii) conflict (**fight**) (iii) appeasement (**submission**) and (iii) escape (**flee**). Aggression is formed of complex responses of the animal's nervous and endocrine systems, **programmed** to be used at the time of **stress**. Conflicts between conspecifics without dangerous weapons is not fatal. The opponents go on fighting until one of them is exhausted. But animals with weapons can kill each other. Aggression is genetically controlled, it has high degree of heritability, therefore, has adaptive value, it is influencd by environment.

Types and Causes of Aggression

Aggression is influenced by internal and external stimuli, hunger, thirst, pain, breeding and other social circumstances, genetic factors, learning processes, and frustrating memories.

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[I] Xenophobia or aggression towards strangers

The strongest evoker of aggressive response in animals is the **sight** of a **stranger**, specially a territorial intruder. This **Xenophobic principle** has been documented in every group of animals displaying higher forms of social organization. Almost all the animal species chase away a stranger trying to come inside their territories.

[II] Crowding or proximate aggression

Close proximity and crowding causes **more encounters more aggression**, this rule is applicable to all animals. Increased crowding causes decrease in the space availability per animal consequently, the encounters increase. Crowding in captivity causes more aggressive interactions in rhesus than free ranging (**Southwick 1969**). Crowding in captive rats lead to behavioural pathologies like fierce fights and infanticide (**Calhoun 1962**). The introduction of a strange individual generates a substantial increase of aggression among residents because they add to crowding. Both human and nonhuman animals tend to act most ferociously towards strangers. In a mice colony, a stranger can not gain entry (**Selander 1970**). Knots live in dense flocks while ringed plovers don't, because of crowding knots are more aggressive. During egg laying period female iguanas fight for the sandy spaces between the rocks, where they bury their eggs.

[III] Space or territorial aggression

Signaling by a male to an intruder (generally male) to keep away from his area is very commonly seen in animal kingdom. These territorial males are tolerant towards females, the females entering the male territory assume appeasement posture e.g. **three spined sticklebacks** during their courtship mating. The most common reason for aggressive response is the sight of a stranger, specially towards the territorial intruder. Strange ants in a colony of ants is enough to raise alarm through pheromones, within no time the soldiers come and gather around the stranger. **Monkeys** show signs of aggression when strange monkey tries to come closer to their social group. Male **lions**, normally move slowly and quietly, but adults of a pride become attentive and start roaring when strange males come into sight.. East African **baboons** fight for **sleeping trees**, desert dwelling hamadrya baboons fight for **water**. **Fur seals** breed on rocky islands in north pacific, the males compete aggressively for a piece of **rocky area**.

[IV] Seasonal changes or breeding/sexual aggression

Males threaten or attack rival males and sometimes also threaten, bite mating females. Male **hamadraya baboons** recruit young females for breeding into their harem by threatening them.

(Z–37/Ani. Beh.)

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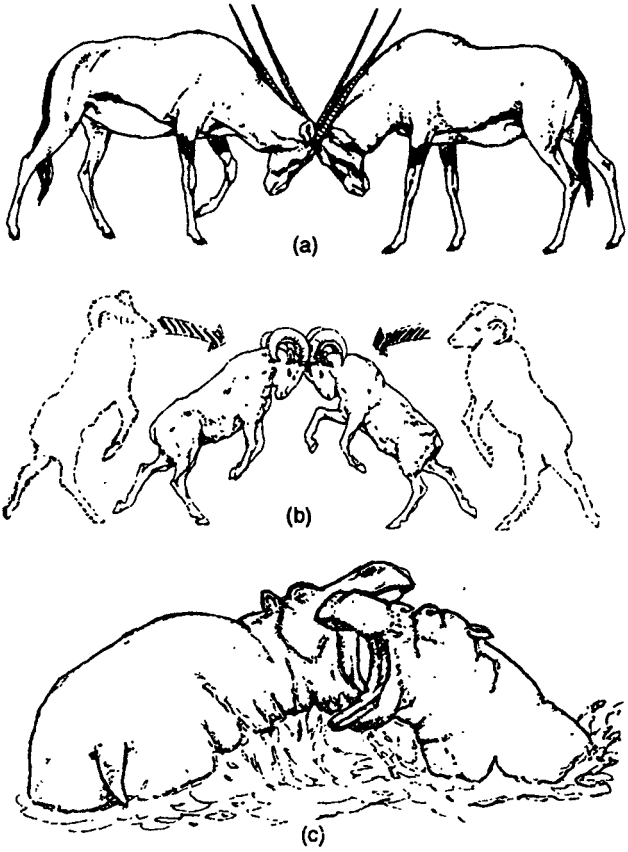

Fig. 19 (a). Gemsbock males bang heads, (b) Male bighorn rams fight during rut, (c) Male Hippos fighting for territory.

The aggressive interactions in most species peak in the **breeding season.** Fighting in **tigers** is restricted to contest for estrous females. The **sifaka** a lemur is peaceful through most of the year but erupts in fighting during breeding season. Animals, specially females become more aggressive just after giving birth. Female **reindeer** is a passive animal, most of her life but just before and after giving birth she becomes aggressive. The bulls of **seals. walrus, sea elephants, hippos, elephants,** stags of **deer** and **antelope** (Fig. 19) and most of the males in non human primates get extremely aggressive during breeding or rutting season. Mates are an important resource and are cause of aggression. Sexual aggression is highly seasonal. The correlation of breeding and aggressiveness is seen among ungulates. Head to head banging in ungulates is commonly seen during the rutting season.

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[V] Previous experience or pain and aggression

Animals behave aggressively in **response to pain (Ulrich** 1966). Two rats caged together begin to fight if they receive an electric shock. Aggression in both human and non human animals has been attributed to frustration. Offer a hungry rat access of food at the end of a runway, then put a glass barrier just before he reaches it, the rat will behave aggressively, it will scratch, bite.

A variety of experiences in the life of an animal influence the form and intensity of aggression. When two **rats** are given painful stimuli e.g electric shock, they attack each other. You keep the **puppy** of domestic dog in isolation, beat or scold him, chain him, he will grow into a ferocious dog. The past painful experiences make him more aggressive.

[VI] Social status or dominance aggression

Displays by dominant animals towards subdominant group members such as the strutting walk of **lemmings**, tail up by **rhesus** and facial expression and tail carriage in **wolves** prevents unnecessary fights among the conspecifics. Establishment of dominance hierarchy helps conserving time and energy among the members of a social group. Once the dominance is established, may be by fighting, but later it is followed by just showing off the strength by exposing canines, or horns and antlers. Subordinates respond by appeasement signals.

As animals move up in rank, their **readiness** to **attack increases**, particularly towards rivals who have been defeated previously. Although the phenomenon of dominance hierarchy is more pronounced in vertebrates, it also occurs in **bumblebees** and **cricket (Free** 1961).

Male **mice** *Mus musculus* reared in isolation after weaning were less aggressive than those reared in social groups. The dominant males in **rhesus** are more aggressive than subdominants. In a pride of **lions**, the dominant animals eat first. In a flock of **birds** there is a peck order. Birds higher in order are more aggressive. Animal hostility is precipitated by break down of social system, fighting increased in a social group of **walrus** when the leader was removed.

[VII] Food or feeding aggression

The relation of aggressive behaviour to the food supply and distribution can be seen among a group of animals feeding. Animals of a group show more aggression if the food is clumped or is in less amount.

Food is a common cause for aggression.If there are ten hungry **hyenas** attempting to feed from a single **zebra** that offers enough meat for only five, then the hyenas get aggressive and fight for the food; likewise **shortage of food** can cause fights among other animals also. **Baboons** in Africa and

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rhesus in India can be seen fighting for food. If the food is **clumped** rather than **homogeneously distributed** the fights are more. **Oceanic birds** such as **puffins, auks, murres, cormorants** and **gulls** fight over clumped food. Aggressive resource competition occurs when the resource is limited in quantity and therefore worth fighting for. Aggressive competition may be strongly seasonal, if the resource itself is seasonal. For example there are frequent fights at the **bonanza of fruits** and **oasis of water**.

[VIII] Nest or parental aggression

It can be of two types (i) towards nestlings (ii) towards intruders. Parents of many birds and mammals direct mild forms of aggression at their offspring (i) to keep them close, (ii) or urge them to move, (iii) to break up fighting, (iv) to terminate suckling, and (v) at the time of weaning.

All most all females in the entire animal kingdom become aggressive towards intruders when they become mothers. A mother **rhesus** or **langur** can bite at the slightest provocation. The **crocodile** female makes a nest for her eggs and then guards them ferociously. This is an adaptive behaviour with evolutionary significance, because the female invests heavily in terms of time and energy to bring a baby to this world, she has to be aggressively protective.

[IX] Instinct or genetic aggression

Is aggression innate or learned? It has both answers yes and no. It is partially determined by hereditary as evident from the example given below.

According to **Lorenz**, individuals reared in a non frustrating environment will still be aggressive. Out of the two strains of **mice** he studied, **strain A** was aggressive and **strain B** was not. The puppies of both strains were cross fostered. B puppies were kept with aggressive mothers of A and puppies of strain A were kept with less aggressive mothers of strain B. That means their environments were changed. They were given enough shelter, food and water. It was found out that puppies of aggressive strain remained aggressive in spite of peaceful non aggressive environment around them. Lorenz said that animals have innate need to behave aggressively. **Hermit crabs** were kept in isolation away from group, these animals showed aggression. Such individuals that had never been provoked or frustrated by members of their own or other species fought aggressively. On the other hand, this does not mean that social experiences, and early child hood frustrations and traumas have no influence on aggression.

Aggressive behaviour is not pathological or abnormal it is very much part of the normal behavioural patterns of almost all animal species. Darwin explained that stronger and healthier animals are selected for reproduction to produce better progeny. The animals are favoured for aggression.

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Aggressive behaviour is essential for animal's survival. Aggression can take numerous forms it can be **accidental** (a frustrated pet dog can growl at an owner who stretches the arm to pet; a person annoyed with some one at office can shout at home at the wife) or **intended** (a hungry feeding pet dog can snap at owners approaching hand; a father can be angry with indisciplined child) **and physical** (through chase, bits, slap) or **mental** (it relates to feelings only e.g. a person could be smiling but may be feeling angry).

Aggression in two strains of male mice (**BALB/c and CD-1**) was studied. Aggressive behaviour was estimated by **wound counts**, and level of **testosterone** in blood. Physiological responses to aggression were investigated through urinary **corticosterone** and **adrenal tyrosine-hydroxylase** measurements. Marked differences were found between the two strains. **CD-1 mice were more aggressive**, had higher testosterone levels but lower corticosterone levels, and had fewer wounds than BALB/c mice. It seems that housing mice in small, socially stable groups or keeping social disturbances to a minimum, considerably regulates aggression in caged male mice. Mice of both strains housed in cages with adequate quantity of nesting material had lower urinary corticosterone levels, lower aggression than standard-housed mice. For scientists working with captive mice, it is advisable, that animals are provided with sufficient amount of nesting material this may enhance the welfare of laboratory mice.

Communication Patterns

Chirping of crickets, roaring of tigers, singing of birds, monkey calls, barking of dogs, distinctive smell of urine of cats and **dogs, coloured feathers of birds** and **beautiful wings** and **fins of butterflies** and **fish** are used by animals for communication. Communication has been defined as :

(1) Biological communication is defined as action on the part of one organism that alters pattern of behaviour in another organism.

(2) Communication is a fundamental property of all social systems. It occurs at several levels between individuals, among members of groups and societies and among societies that live in the adjoining territories.

(3) Communication-according to **Scheflen** (1964) includes "all behaviours by which a group forms, sustains, mediates, corrects and integrates its relationship."

(4) Communication is transfer of information from one individual (producer or signaller) to another (receiver) that influences the listener's behaviour.

(5) Communication involves an action on the part of one animal that alters the behaviour of another (**Wilson** 1975). After receiving the signal, the second animal modifies its own behaviour accordingly.

(6) Communication is mutually beneficial transfer of information between signaller and the receiver when they have the same interests.

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(7) Communication occurs when signals are given out by one animal which are used by another to predict the behaviour either of the first animal or of something else in their environment, after perceiving the signal, the second animal modifies its own behaviour accordingly.

The essence of communication is the relationship between **signaller** and **receiver**; a **bird** gives an alarm call towards an approaching **cat**, and all the other birds fly away, the bird that had spotted the cat passed on the information to the other birds.

Animals use communication to attract mates, ward off predators, mark territory, and to identify conspecifics. Communication helps animals survive, therefore, it is adaptive.

Advantages of Communications

(1) It helps in recognition of species, individuals, neighbours, castes (social insects), kin, and demes.
(2) It facilitates courtship and mating between males and females of same species through acceptance or rejection.
(3) It prevents agonistic interactions and promotes the establishment of social status between conspecifics.
(4) It facilitates social animals to herd at dusk or at the time of danger.
(5) It accelerates coordination among hunting animals.
(6) It plays crucial role during parental care.
(7) It alerts kins in a social group through alarm calls

Types of Communication

[I] Auditory communication

Sound is the most used form of communication in animals. Proper vocalization in vertebrates and noises made by invertebrates using special structures are included in this category.

Crickets, birds, amphibians, bats, whales, primates all have extensive use of **sound (Acoustics)**. The **deer** give **alarm calls** for approaching tiger; male **frogs** call to attract females; **bats** use **echolocation** as a form of communication as well as for hunting. **Bird song** serve both territorial and courtship functions. Other animals use sounds to communicate danger, reproductive readiness, and species recognition.

Animals make different sounds to communicate. From the spine chilling **roar of a lion** to well composed **whale songs** to **chirpy songs** of birds. Sounds are waves of alternating pressure changes that pass through a medium; air, water or solid.The intensity or volume of sound is measured in decibels (dB).

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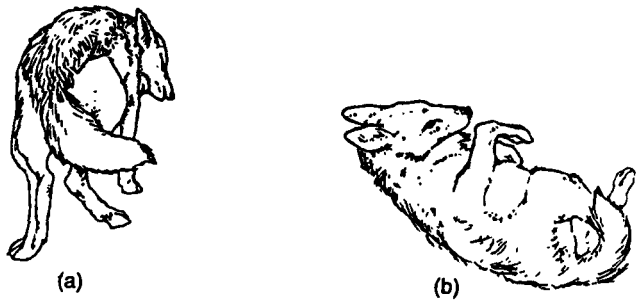

Fig. 20. Submission in Dogs.

[II] Visual communication

Light signals detected by the eyes come into this category- like gestures, postures, and facial expressions, courtship and aggressive displays in many birds, fish, amphibians and mammals,raising of hair and colour change are some of the good examples of visual communication.

There are two types of visual communication.

1. Badges. Includes the colour and shape of the animal. This involves, morphology. They are **structural adaptations.**

2. Displays. These are the things or acts animals do to communicate. They are **behavioral adaptations.** Visual communication is most used during agnostic behaviour and in courtship. **Wolves and dogs** (Fig 20) use visual behaviours such as lowering their tails and lying on their backs to show submission. To show dominance they stare at each other, raise their fur, and bare their teeth. Male **stickleback fish change colours dramatically during breeding season.**

Understanding vision and visual systems involves an understanding of the properties of light. While humans can see light from **sun** in a visible spectrum, many animals can see **infrared** and **ultraviolet** light invisible to human. Some animals have exceptional **colour vision**, others have poor colour vision. Some have exquisite **night vision**, others have poor night vision.

Visual communication is most important to monkey and apes and certainly the best described and understood. Primate eyes have exceptionally good capability of perceiving very small movements and small differences in shapes.

Visual signals in non human primates include.

(1) Postures
(2) Gestures (including facial expressions)
(3) Movement of tail
(4) Pile-erection

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[III] Chemical communication

Substances that can be picked up by the sense of taste or smell are **pheromones**. They are produced by special ducted glands and are proteinaceous in nature. Found widely in **insects** and **mammals**.

Chemical signals are the primitive form of communication among animals This form of communication has been well studied and documented. Chemical signals sent and received by individuals of the same species are called pheromones. Pheromones are powerful, a few pheromone molecules released into the air or water through urine, sweat, or other bodily secretions are enough to influence another animal's behaviour. Unlike visual, sound, or tactile signals, pheromones can persist in the environment for a long time. This is important for many **cat species**, for instance, because females release pheromones signalling fertility without knowing when the males will receive them. Because of their long duration, scent has the great advantage that it can be left to transmit information while the animal that made the signal goes away and does something else. It is, however, a relatively slow form of communication.

[IV] Tactile communication

Communication resulting from actual physical contact are through tactile signals. They are used extensively in social bonding, infant care, grooming, and mating.The type of signal most frequently used by a particular species is directly correlated to the sensitivity of their receptors. Hence an animal with keen eye sight will use visual signals, whereas, one with poor eye sight, but a keen sense of hearing will use acoustic signals. Tactile Communication is when animals use touch in one or the other ways to communicate something to each other. In our day-to-day life we see a cat rubbing its body against ours or our pet dog offers us its paw this way they are communicating their affection towards us. Preening, grooming are the consequence of this form of communication.

Patterns of Parental Care

A unique social relationship in the animal kingdom is that between parents and offspring. No matter how non- social an animal may be, at least twice in life it has to socially inter act with conspecifics – mating and parental care (**PC**). It is defined as-form of parental behavior that increases the fitness of a offspring . And the Parental Investment (**PI**) is a form of parental behavior that increases an individual offspring's fitness at the cost of the parent's ability to invest in future offspring (**Trivers**, 1972).

Most species that provide little to no care are **insects**, **reptiles**, and **fish** that produce many young. In stable environments when both parents have an equal probability of associating with their offspring then, both mother and

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father provide care; in predictably fluctuating environments when one sex has a higher probability of associating with the young than the other, then that sex provides more care; in fish, this is typically males who defend a nesting territory; in birds, this is typically females except under unusual conditions where females abandon their broods in the care of the fathers and start new broods with additional mates; in mammals, lactation predisposes females to care the most.

(1) PC starts before the baby is conceived in the form of gamete production. Eggs are large and rich in nourishment.
(2) Birds provide warmth (incubation) to the egg for the chick to develop and hatch properly.
(3) The construction of nest takes much time and energy of both parents. A pig walks 5-10 kms to look for a safe place to construct a nest and it takes about 10 hours to construct it (**Jensen** 1993).

Types of Parental Care

1. Neither parent is involved in care of young. Promiscuity is associated with no parental care, the mating system that typifies **reptiles**. Most solitary **insects**, 100 **teleost fish** species with external fertilization, some **amphibians** and reptiles, birds showing brood parasitism (e.g. cavity-nesting ducks, cuckoos, cowbird), there is no example from mammals under this category.

2. Both parents involved in care of young. Monogamy is associated with bi-parental care No insects, reptiles or amphibians reported in this, a few fish species (e.g. mouth brooding cichlids), many bird species (e.g. willow ptarmigan; most song-birds; tri-colour blackbirds), and few monogamous species show this trait. (e.g. gibbons, tamarins, marmosets).

3. Mostly Females are involved in care of young. Wasps, dung beetle, and social bees provision brood cells and defend/protect their larvae, females of about 14 species of teleost fishes with internal fertilization and 24 with external fertilization show parental care, in alligators and crocodiles its generally the female alone that guards the eggs and babies, bird species in which the male has less investment than the female during brood care are red-winged blackbirds and wrens. This is most widely used in animals kingdom. Why females provide so much care ? **According to the investment hypothesis** : The female invests so much energy, it would be risk for her to abandon her offspring without providing care, since offspring may not survive. **The paternity uncertainty hypothesis says because** female is more likely to be parent of offspring than male. Lastly, there is **association hypothesis**, according to this, the females are more likely to be the parent around during egg laying or birth many a times, due to **internal fertilization**– this situation allows males to leave, females have to care for her eggs. Males physically get separated from progeny. Polygamous mammal species in which only females feed and look after offspring without the help of

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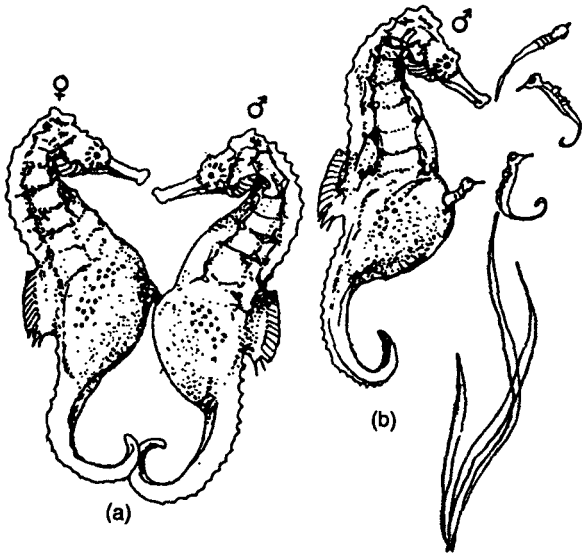

Fig. 21. Sea Horse male.

a male are marsupials, rodents, ungulates, felids, some solitary primates e.g. orangutan.

4. Mostly Male are involved in care of young. The examples are few in this category, male **water bug** carries fertilized eggs, in fishes the male usually cares for offspring. Parental care occurs in 28% of fish families and among 61% of these the male takes care of the offspring. In about 63 species of teleost fishes, mostly males defend a nesting territory eg **three spined stickle backs**, in **pipe-fish** and **sea horse** female places fertilized eggs in male's pouch (Fig. 21), birds living in flooded marshes e.g. jacana, tinamous and moorhens or migratory birds e.g. sandpipers and phalaropes and ground nesting ostrich, however, very few mammals belong to this category. Males of golden lion tamarin of Brazil are world's finest fathers. The female generally gives birth to twins, her job is only to feed babies, the rest is done by father alone. He carries them on his back day and night, protects them from heat, rain and predators.

5. Relatives are involved in care of young / alloparenting : Eusocial insects where sisters (full and partial) care for eggs laid by their mother (e.g. bees, termites), no fish, amphibians or reptiles reported, among birds **helpers-at-the-nest are found in** eg **florida scrub jay, green wood hoopoes, white-fronted bee-eaters, babblers, and Mexican Scrub Jay. In elephants, wolves, dwarf mongoose, monkeys, lions** the related females, called **aunts** help in feeding the baby, related elephants help each other in acts like while mother drinks at a water hole, the aunt guards the young (Fig. 22). White-footed

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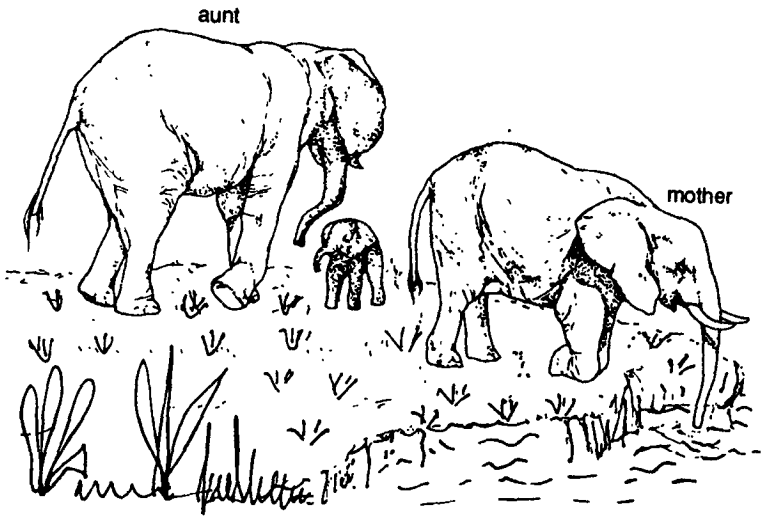

Fig. 22. Elephant aunt guarding.

deer mouse, prairie dogs, banded mongoose, spotted hyena show communal denning, related females help making a den and can also look after the babies in the den, thief or sneaked suckling is reported in elephant seals.

Courtship Patterns

Species survival is dependent on two most important things :

(1) Eat and avoid being eaten.

(2) Mate and reproduce to pass genes to the next generation.

Courting birds and fish have always fascinated people with their apparent graceful movements and the beauty of their body parts and eye catching colourful display. Scientists define the term "display" as "behaviour patterns which exposes special structures and colours". German ethologists have coined the word ***Ausdruksbewegungen*** **(expressive movements)** because they express moods and interaction between individuals. The general understanding is that **courtship refers to all expressive movements involved in pair-formation and copulation.**

Everyone has been fascinated by this behaviour, perhaps through direct observation of animals, and also through books and films. One very common example is the courtship of peacocks, which can be seen easily and is an extremely attractive sight. Important function of courtship is to synchronize the reactions of male and female so that copulation can take place.

A courtship situation does not always have to be very noticeable, nor do we necessarily perceive it as either beautiful or bizarre. Even certain single celled animals display a complex pre conjugation behaviour, such as

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Paramecium they swim around each other for up to half an hour, roughly on the same spot by constantly changing direction. They can lose each other, find each other again or continue this ritual with a new partner. Once two paramecia have met the preliminary ritual enters a new phase. The partners no longer swim around each other but remain side by side, separated by a distance equal to the length of their cilia, their anterior ends pointing in the same direction, swimming back and forth on the same spot for about a quarter of an hour. During the final minutes they come closer and closer, then suddenly jerk and cling together and exchange nuclear material. Undoubtedly this can be called as beginning of courtship. The courtship can be seen in animals having either external or internal fertilization. In animal kingdom there are two types of fertilizations.

The courtship behaviour has following important characteristics :

(1) It is performed in species specific sequence, it is genetically controlled therefore is instinctive (fixed action pattern).

(2) The male and female of same species must synchronize their courtship sequence ensuring fertilization.

Most animals court and breed only at certain times of year. Breeding in individuals of the same species is synchronized. This is influenced by environment when the food is in rich supply at the time of mating as well as when the babies are born. Day length, temperature also play key role in triggering the courtship.

Courtship is found almost in entire animal kingdom from simple following as seen in Paramecium to extremely complex rituals or displays or dances of birds and mammals. The onset of courtship behaviour is closely regulated by biological clock, its influenced by day length and temperature via the endocrine system. It's most pronounced in **arthropods, molluscs, fish, birds** and **mammals**. Other conditions are also necessary for successful mating in peacocks. Although free-living peacocks in India court virtually all year round, the hens do not allow copulation until the monsoon rains starts. This is the greenest time in north India. This is important because the young can be safely reared during the rainy season when plants grow, blossom, and bear fruit. Uninterrupted courtship requires the cock to defend a territory and to drive away all rivals.

Courtship patterns in three spined stickleback fish

Fish vary greatly in their courting behaviours. Some are territorial, some are not, some prepare nests, some don't, some change colour, others don't, some are social, and others are not. Their mating habits vary too. Most are polygamous, each male fertilizes the eggs of many females. But some are monogamous- a pair of male and female true to each other, some have internal fertilization and are viviparous, but most have oviparous having external fertilization. Parental behaviour ranges from the guarding of eggs

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and young by one or both parents to leaving of eggs in carefully prepared nests, to simply leaving the eggs anywhere in the sea.

The three spined stickleback *Gasterosteus aculeatus* is the best studied fish for its courtship behaviour. They are small fresh water fish about 50 mm to 2 inches long. Out of the breeding season they are undistinguished grayish-green fish living in schools. The courtship of the sticklebacks has been described mainly by **Tinbergen** and his students (1937, 1951 & 1954). Outside the breeding season, this fish tends to live in school, that means a peaceful group which has no leader and in which there is no fighting. The most striking feature of a school is that all the individuals in it usually perform the same activity at the same time for example - they swim around and take turns together or feed together.

The longer day length of spring produces increased secretion of sex hormones and also causes migration from deep fresh water to shallow freshwater spawning grounds. Here, stimulated by temperature changes the male undergoes dramatic changes in both appearance and behaviour, which is said to be there courtship condition.

The glowing red makes the belly and sides of the male glossy and transparent, the iridescent blue- green of its back whose colour and brilliance can only be compared with the illuminating neon light the eyes become emerald green. No other animal becomes so completely transformed when in love; no one glows in such a literal sense, with passion as stickleback. While the female is distinguished by her silvery colour and by her enlarged belly she does not change colour.

After developing this colour the males leave the school and set up territories in an area of sandy bottom containing water plants where they build a nest. The nest is made up of plant material such as algae and weeds. This nest is made in the same pit which was dug in the sandy bottom. The territory extends outwards and upwards from this nest. Male secretes a sticky kidney fluid over the loose pile of algae and weeds. This material functions as glue and the nest is given a tunnel shape as the male always swims through it to complete it. Therefore, the male thinks of making love only when the cradle for the expected babies is ready.

The territory is defended against other males in one common thereat posture, the male adopts a vertical position with head down, near his nest, thus exposing the red belly to the intruder. After completion of the nest the male goes through another colour change, the upper portion of his body bluish. This colour pattern attracts females towards him. The egg filled belly of a female stimulates the male to display a peculiar type of movement - popularly known as zigzag dance.

A made begins to advertise for females by swimming close to the surface in a curious jerky fashion. Ripe female are bold intruders, females do not go away even when butted and bitten, instead they adopt the so called

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'**appeasement posture**' i.e. hanging obliquely upward in the water. This posture is also adopted by male rivals, defecated in a fight. It always inhibits attack, and offers a chance of escape for males and a chance to court for females. This posture displays belly. In females, this is silvery and swollen with eggs.

The most conspicuous feature of courtship is the Zigzag dance which is formed of many steps :

(1) a male swims **jerkily.**
(2) alternates **leaping** towards the female.
(3) with a side ways **jump** away from her.
(4) he may **circle** around her. The side way jumps are always roughly in the direction of the nest.
(5) from time to time the male makes a dash towards the nest, which is known as **leading.**
(6) comes back and again performs the **zig zag dance.** Courtship can proceed no further unless.
(7) the female follows at the nest.
(8) he shows his nest entrance by lying on his side and **thrusting** his snout into it. The female responds by **pushing** her way inside the nest if she does not then.
(9) the male immediately starts **quiering (gentle tapping)** with his head against her tail (Fig. 23). Then,
(10) she enters the nest and **spawns** and then swims out from the other side.
(11) the male follows her through the nest and **fertilizes** the eggs.
(12) the male repairs his nest and invites other females. One male can bring in many females.

A female who is not quite ripe will fail to respond at some point, and although the male may continue to court her for a while, he will eventually chase her away. Alternatively, an unready male, particularly one whose nest is not complete is likely to be too aggressive and will frighten females away. The male tries to mate with as many females as possible. Occasionally, when he has just persuaded a female to come to his nest, he may notice another female at the edge of his territory. He may rush to invite the second female to his nest even before he has had a chance to fertilize the eggs laid by the first female. But, **Desmond Morris** a famous anthropologist and behaviourist discovered that the second female only looks like and acts as a female, the fish infect is a sneaking male in disguise, lacking the red belly. While pretending to lay eggs the pseudofemale fish fertilizes the eggs of the first female. After the sneaker leaves, the proud though foolish owner of the territory attempts to the fertilize the already fertilized eggs often unaware of the trick that has been played on him.

After mating with about 4-5 females the male begins his parental duties and resumes his protective colouration. He aerates the eggs by fanning water

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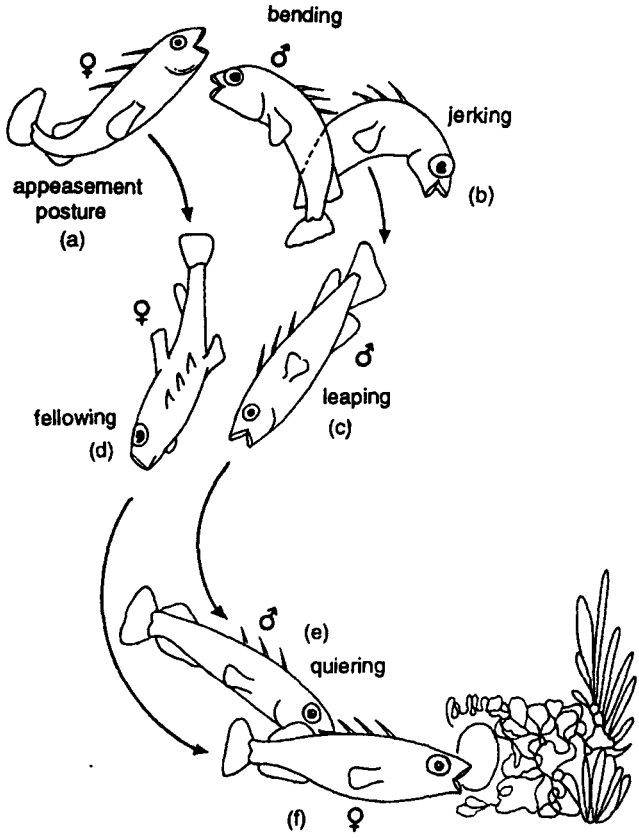

Fig. 23. Courtship in sticklebacks

over them. When the brood hatches about a week after fertilization, the male guards the young. If one strays too far from the nest, the male takes the hatchling into his mouth and spits it back into the nest.

IMPORTANT QUESTIONS

➤➤ ***Long answer type questions***

1 Name all the concepts and patterns . Describe any four concepts with suitable examples.
2. Derive correlation between sign stimulus, innate releasing mechanism, action specific energy and fixed action pattern.
3. Write on patterns of aggression and communication
4 Write on patterns of courtship and parental care.

(Z-37/Ani. Beh.)

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➤➤ *Short answer type questions*

1. Write a short note on— (i) Any one concept or pattern, (ii) Flush toilet model.
2. Define the Following
   (i) Concept, (ii) Pattern, (iii) FAP, (iv) IRM, (v) ASE, (vi) Learning, (vii) Imprinting, (viii) Motivation
3. Write very briefly :
   (i) FAP, IRM, (ii) ASE, (iii) Learning, (iv) Imprinting, (v) Motivation, (vi) Aggression, (vii) Courtship, (viii) Communication, (ix) Parental care.

➤➤ *Fill in the blanks*

1. Study of animals behaviour is called ... .
2. Study of evolution of social behaviour is called . . ..
3. Concepts were formulated by .... and ..... .
4. Searching for goal is known as .... Behaviour
5. Urge to perform a behaviour in governed by. ....
6. Three phases in motivation are.... ...., ... and . .. .
7. Full form of FAP is ....
8. Full form of IRM is . ...
9. Full form of ASE is ....
10. Four components of aggressive behaviour are ....and ..
11. Aggression towards strangers is called ....
12. Level of aggression in strain CD-1 is . . ..

➤➤ *True or false*

1. Study of animals behaviour is called Ichthyology..... . . .
2. Study of evolution of social behaviour is called sociology.. .....
3. Concepts were formulated by Lorenz and Tinbergen.... ... .
4. Searching for goal is known as appetitive behaviour... .
5. Urge to perform a behaviour in governed by motivation ....
6. Aggression towards strangers is called xenophobia ....
7. Level of aggression in strain CD-1 is high. .....
8. Instincts are acquired.. .....
9. Instincts are genetically prewired ....
10. Flush toilet model was proposed by Tinbergen.....
11. Flush toilet model was proposed by Lorenz.....
12. Instincts are complex and rigid.....
13. FAP are invariant and appetitive behaviour is variable.... .....
14. In the absence of proper sign stimulus FAP can never be released. . . .
15. Law of heterogenous summation is related to sign stimulus .. .
16. Aggression is totally genetic.....
17. Males invest equally in rearing up a baby in monogamous species.. .. .
18 Communication by pheromones is a primitive form..... ..

Answers

1. False, 2. False, 3. True, 4. True, 5. True, 6. True, 7. True, 8. False, 9. True, 10. False, 11. True, 12 True, 13 True, 14. False, 15 True, 16. False, 17. True, 18. True.

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➤➤ ***Matching type questions***

1. Konrad Lorenz	(a) Waggle dance
2. Niko Tinbergen	(b) Imprinting
3. Karl Von Frisch	(c) Sign Stimulus
4. Nest building	(d) Instinct and learned
5. Bird song	(e) Instictive
6. Motivation	(f) Internal drive
7. Instinct	(g) Genes
8. Sign stimulus	(g) Specificity

➤➤ ***Multiple choice questions***

1. Study of animal behaviour is called :
   (a) Ichthyology (b) Ethology (c) Etiology
2. Sociobiology deals with :
   (a) Sociology and biology (b) Biology and ecology
   (c) Social behaviour and evolution
3. Motivation is a :
   (a) Physiological state (b) Mental state
   (c) Both
4. Instinct is :
   (a) Flexible and learned (b) Rigid and unlearned (c) Both
5. IRM is a :
   (a) Hypothesized mechanism (b) Established mechanism
   (c) None
6. ASE is an :
   (a) Establishes energy (b) Imaginary energy (c) Both
7. Sequence in courtship of Stickleback is :
   (a) Jerky swim, leaping, jumping, circling, leading, thrusting, quiering.
   (b) Circling, leading, thrusting, quiering, jerky swim, leaping, jumping.
   (c) Thrusting, quiering, circling, leading, jerky swim, leaping, jumping.
8. Length of Stickleback is about :
   (a) 2-4 inches (b) 4-6 inches (c) 50mm to 2 inches
9. Aunts are found in :
   (a) Zebras, kangaroos and koalas (b) Elephants, lion and monkeys
   (c) All the above
10. Scrub jays are known for :
    (a) Nets building (b) Helpers at the nest
    (c) Nest raiders
11. Male parental investment is seen in :
    (a) Sticklebacks (b) Sea horse (c) Both
12. Gesture involves :
    (a) Body position (b) Facial expressions (c) Both
13. Pilo erection deals with :
    (a) Erection of penis (b) Erection of hair (c) Erection of pinna

Answers

1. (b), 2. (c), 3. (a), 4. (b), 5. (a), 6. (b), 7. (a) 8. (c), 9. (b), 10. (b), 11. (c) 12. (b), 13. (b).

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3

Approach and Methods

Introduction

Not all behavioural studies take place in well equipped laboratories or in forest, casual observations on pet, domestic or familiar animals also contribute vital information on animal behaviour, therefore, ethology begins from home; it is also a fact that many people watch animals but, few really observe them. Careful or keen observations are different than casual watching. You already know from earlier chapters that acclaimed ethologists Karl Von Frisch, Niko Tinbergen and Konrad Lorenz devoted their lives and accumulated important information on behaviour by staying with animals in their natural habitat or by keeping them at their farm houses. Some other names have become completely associated with the animals they studied e.g. **Jane Van Lawick Goodall** has spent more than 40 years in the jungles of Tanzania in Gombe National Park to study **chimpanzees**. **Dian Fossy** devoted her life studying **gorillas** in Africa, she used to spend so much time with the gorillas that she was virtually accepted as one of them by the gorilla group. Fossy's extra concern and protectiveness about gorilla population led to her murder by the poachers (the persons involved in illegal hunting). Similarly, **George B. Schaller** studied **tigers** and Himalayan fauna, and wrote excellent books. **Irwin DeVore** carried out exhaustive observations on baboons. Name of **John F. Eisenberg** is inseparable from the eco-behavioural studies of most of the **mammals. Salim Ali** from India has been known all over the world for his most remarkable contribution in **Ornithology**. Like them not many of us would sit all day in jungles or in front of a cage and spend our entire life studying animal's behaviour. The hazards of encountering carnivores, snakes, insects, and poisonous plants, camping, bad weather, variable food supply in

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the forests and monotony would be discouraging. Although we all have watched animals around us, inside the Zoological Gardens and Sanctuaries for recreation but scientific observation requires specialized training and procedures. Animal behaviour is a very vast subject, it includes innumerable types of behaviour viz feeding, drinking, fighting fleeing, territoriality, dominance hierarchy, mating, nest building, parental care, social organization, daily or seasonal activity, orientation, migration, mother-infant relationship, inter and intra specific and prey- predator relationships. The short, specific and scientific methods for studying animal behaviour have been introduced recently. Earlier, people studied animals in a naturilistic way in their farm houses, backyards, and nearby jungles. As mentioned earlier, the great ethologists of earlier times devoted their entire lives studying different animals, though this is the best and most authentic way of studying behaviour but then, one needs a great deal of patience to spend entire life with animals. Not all who have been interested in behaviour get this opportunity. Therefore, quick and reliable methods were formulated by different workers.

Before starting data collection on behaviour the aims, objectives and subject are ascertained. Study of behaviour can be expanded from body physiology, to individual, to groups, population and species. The first and foremost thing is to decide the behavioural processes of interest. For example, a study may be carried out to know how an animal obtains food and water and which food does it select; another study may focus on how females wean their young ones in monkeys and apes or how adult males take possession of a harem and decide dominance hierarchy in a deer group. One may be interested in knowing how do animals budget their time daily, monthly, seasonally and yearly? When animal behaviour is broken down into such segments of study, observations are easier to make and this makes the study systematic and scientific, easy to quantify and interpret otherwise, ethology is nearly a limitless discipline. This subject can be studied in lab under highly controlled conditions and in field under natural conditions.

Study of Animal Behaviour Can Take Place

1. In lab. Behavioural experiments are carried on small to medium sized animals such as invertebrates, frogs, fish, pigeons, doves and on small mammals (rat, mice, hamster, guinea pigs, cats, dogs and apes). These animals can be operated, or animals are subjected to psychological tests like maze, jumping box, Thorndike box, Skinner box in which they are tested over grids, wheels etc. The animals are used for the study of brain and behaviour by surgical, chemical and electrical methods.

2. In zoo. There is no restriction on the type of animal. It can be from rat to rhino, from eel to elephant. Any animal that can survive in captivity can be studied in zoo for its behaviour. In zoo, the recording of behaviour

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is purely by ocular observations i.e. by looking at the animal. No surgery or handling of animals is done.

3. In wild. There is again no restriction on the type and size of animal. Amphibians to mammals can be observed, if the terrain and climate permit. Animals are studied in their natural environment. Animals are allowed to roam around freely. Animals are handled only when they have to be radio collard or for the measurement of their vital statistics.

Psychology and Ethology both relate to behaviour. The complete understanding of behaviour and its neural mechanism is gained through several methods. The psychologists carry out research mostly in the laboratories on animals like cats, rats, pigeons, and chimpanzees. They keep the animals in confinement, try surgical procedures like removing parts of brain, or pass mild electric current through various regions of the brain or introduce small amounts of chemicals to evoke behaviour. Whereas, ethologists study behaviour of animals in the wild, by allowing them to move freely in their natural habitat, they conduct studies on a wide variety of animals, from weevils to whales.

The study of behaviour can have two different approaches :

(1) With relation to brain and physiology. These studies are carried out in **laboratory** by utilizing following methods : (i) Neuroanatomical, (ii) Neurophysiological, (iii) Neurochemical.

(2) Study of behaviour in **wild** or in natural habitat in relation to environment and ecology by using following methods : (i) Ad libitum, (ii) Focal animal sampling technique, (iii) Scan sampling technique, (iv) All occurrence, (v) One zero.

Physiological research is rarely carried out on large sized animals but small sized animals can be used in both instances.

Studies in Laboratory

The first major goal of brain researchers or psychologists was the localization of brain functions, to know which areas or structures of the brain were involved in controlling particular behaviour.

[I] Neuroanatomical or lesion or ablation technique

This is the oldest and also most crude method in neuroethological research for studying the relationship between particular neural structure and behaviour. For this purpose, certain regions of the brain are destroyed and their function is deduced from the abnormal behaviour it causes in the animal. The larger **ablation** (removal of tissue) or **lesion** (pathological changes in tissue) may be carried out free hand by means of knife cuts; whereas, the localized and small lesions are produced by passing electric current through platinum, iridium electrode to cauterize the area, small lesions can also be created by neurotoxic

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kainic acid. Lesion methods are different from stimulation method, in the latter case neurons are activated while in the former they are inhibited or destroyed. This technique helped many workers to form brain atlases or brain maps, which are known as **Stereotaxic atlases** that are presently available for many mammalian species viz. rat (**De Groot**, 1959), cat (**Jasper** and **Marsan**, 1954) and dog (**Lin** and **Coworkers**, 1961). The lesions were produced by careful surgery, this particular technique was first practiced by medical doctors, who used to examine patients of head injury, these doctors observed that patients showed peculiar behavioural changes due to injury in head, it was rightly correlated by them that behaviour is controlled by brain. While performing the operations, or post-mortem autopsies the destructed areas of brain were identified, and impairment in behaviour was correlated with it, indicating direct influence of brain over behaviour.

Broca (1861) was a doctor who came across a patient with head injury whose speech was defective, this correlation fascinated him and he started observing different patients with similar injuries. After few years, he concluded that there is a definite area in the cortex which is responsible for speech. Later using the same technique another scientist-**Wernick** (1880) established another area in the brain responsible for speech, these two areas are known as **Broca's** and **Wernick's areas** (Fig. 1) respectively. Broca's area controls the infrastructure for speaking a word, this means it has control over neck muscles and larynx, and Wernick's area is word retriever or dictionary. A lesion in Broca's area causes slurring in speech and there is difficulty in understanding the words spoken by such a person though the person would

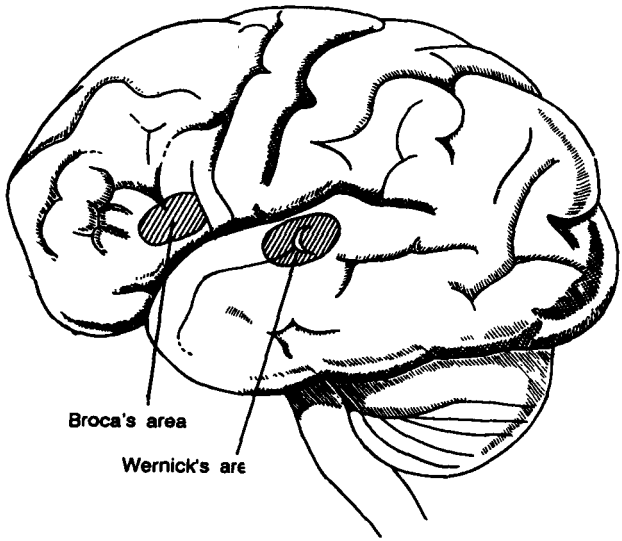

Fig. 1. Human brain showing Broca's and Wernick's areas for speech.

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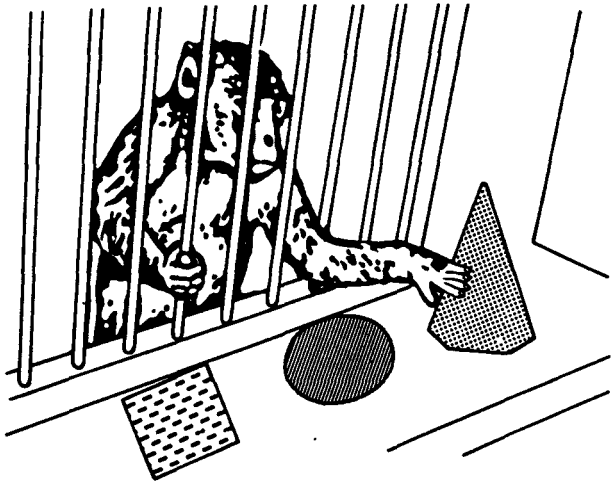

Fig. 2. Monkey offered blocks of different shapes.

talk sensibly. Opposite to it, if there is a lesion in Wernick's area then the person can talk clearly but the speech will not be articulated or coherent.

Toads have been the major objects for ablation techniques; the experimental finding that there are zones in different areas of the toad brain responsible for the triggering of prey catching (**optic tectum**) and avoidance behaviour (**TP-region**) is supported by ablation experiments.

Today many areas in the brain responsible to carry out particular behavioural types have been identified using neuroanatomical techniques. In an experiment, rhesus monkeys were subjected to choose between objects of varying shapes and were rewarded by banana for picking up the triangular one (Fig. 2). Monkeys with their visual cortex removed could no longer perform this test, thereby indicating that visual cortex is the part involved in learning to discriminate between various shapes.

The first indications of brain structures that influence aggressive behaviour were obtained by lesion experiments which suggested that **amygdala**, the **medial hypothalamus** and **periaqueductal grey** of the midbrain are responsible for the control of **aggression** and **defence** in cats. Classic experiments were done by **Lashley** (1938) using ablation technique. His experiments proved to be very important in understanding the neural mechanism of learning. Deficits produced by different brain lesions on standard learning tests such as maze learning, object discrimination, avoidance learning and lever pressing have been proved to be very useful one of his famous experiments was performed on rats. The rats were trained to run in a maze, after they learnt it, he removed a small part of cortex and assessed the impairment in learning ability, he kept removing cortex bit by bit and after the completion of experiment he proposed that the impairment in learning

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was directly proportionate to the amount of cortex removed. According to him the majority of learned tasks are equally distributed and stored by cortex. On the basis of this experiment he proposed **"the law of equipotentiality"**.

Discovery of different nuclei of hypothalamus and their role in controlling vital activities like feeding, drinking, mating, aggression and parental behaviour (which have already been described in chapter 2) were made using neuroanatomical techniques.

Perhaps the most quoted lesion experiment deals with eating behaviour. Lesions in hypothalamus can lead to adipsia, hyperdipsia, aphagia and hyperphagia, it can make an animal extremely overweight or under weight. In most of the animals lesion in **ventromedial hypothalamus** increases their hunger to such a great degree that they may eat themselves to death, indicating that the destroyed area had **satiety centre**. On the other hand, a lesion in the **lateral hypothalamus** can cause the rat to stop eating forever so that it eventually starves to death because the destroyed part contained the **feeding centre.** Experiments conducted using brain lesion technique helped identifying gratification centres of basic needs. This technique has also contributed in locating sensory and motor regions in the cortex. Tedious experimentation has brought to the knowledge that removal of tissue from frontal lobes of brain caused paralysis or inactivity in muscles, and removal of parts from parietal lobe proved to affect sensory activities. These regions of brain were identified as motor and sensory cortex respectively.

In one experiment, bilateral ablation or lesion in amygdala (part of limbic system), enhanced the sexual behaviour of a male cat to such a degree that it tried to mount and copulate with inappropriate mates like dogs and monkeys. This **hypersexuality** was reduced by forming a **lesion** in the **anterior** and **ventromedial nuclei** of the hypothalamus (Fig. 3) indicating that there are specific areas in the brain which start and stop the sexual behaviour.

In earlier years, neuroanatomical techniques made sufficient contribution to understand the mysteries of the mind but between 1870-1900 ablation technique was dropped by most of the neurologists and was considered crude, because when a particular part of the brain was removed surgically, a portion of surrounding brain tissue was also damaged, it became difficult to rule out whether the impairment in behaviour was due to the specific part removed or due to the damaged surrounding tissue. When critically evaluating lesion experiments, it must also be noted that an animal with a brain lesion is possibly no longer the same animal in many respects apart from the obvious lack of this brain region. The brain represents a complex feed back system, when a component is absent, the whole system is modified. For example, lesion in ventromedial hypothalamus (Fig. 3) also destroys noradrenergic bundle, lesion in lateral hypothalamus (Fig. 3) usually damages the nigrostriatal bundle containing dopaminergic fibers, these fibers are involved in mediating sensory and motor functions.

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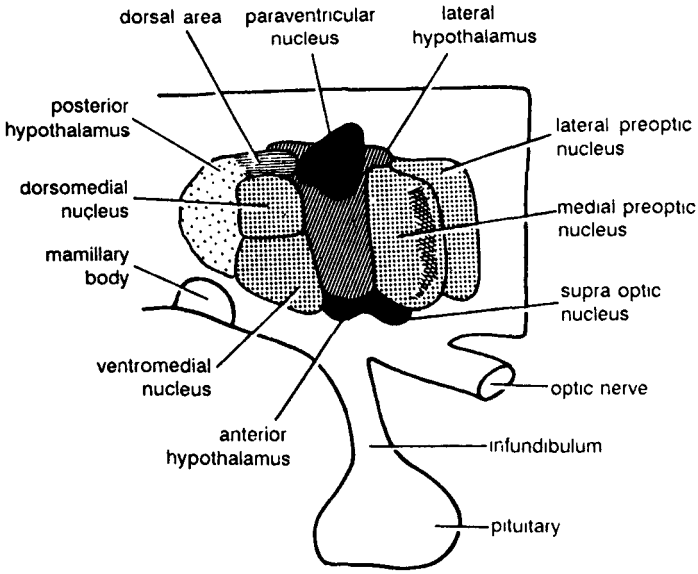

Fig. 3. Nuclei of hypothalamus.

Later, different finer and more efficient ways of removing small portions of brain came into practice. Lesions were made by **aspiration** (suction of small part with a machine) in which thin hollow needles are inserted through the skull and small part of the brain is sucked out, lesions are also made by freezing small portions with **cryoprobes.** Lately, lesions are being created by **laser beams** (a device that transfers light of various frequencies into an extremely intense, small and non-divergent beam; capable of mobilizing immense heat and power when focussed at close range) also.

[II] Neurophysiological technique

The discovery of **bioelectricity** came by chance. The Italian scientist **Galvani** (1786) hung some frog legs on his balcony railing one day and noticed that the legs twitched when they touched the metal fence. Galvani at first misinterpreted this phenomenon attributing it to muscles alone. By 1793 Galvani discovered that twitches occurred in the nerve muscle preparations even without any metal; the nerve and muscle were producing electricity by themselves. This finding laid the foundation for **electrophysiology.**

The discovery that the messages in nervous tissue travel in the form of electric current led to a less destructive and more precise neurophysiological method to study behaviour.

This method involves two ways

(1) Recording of electrical activities from brain while animal is behaving.
(2) Stimulating the brain region and eliciting behaviour.

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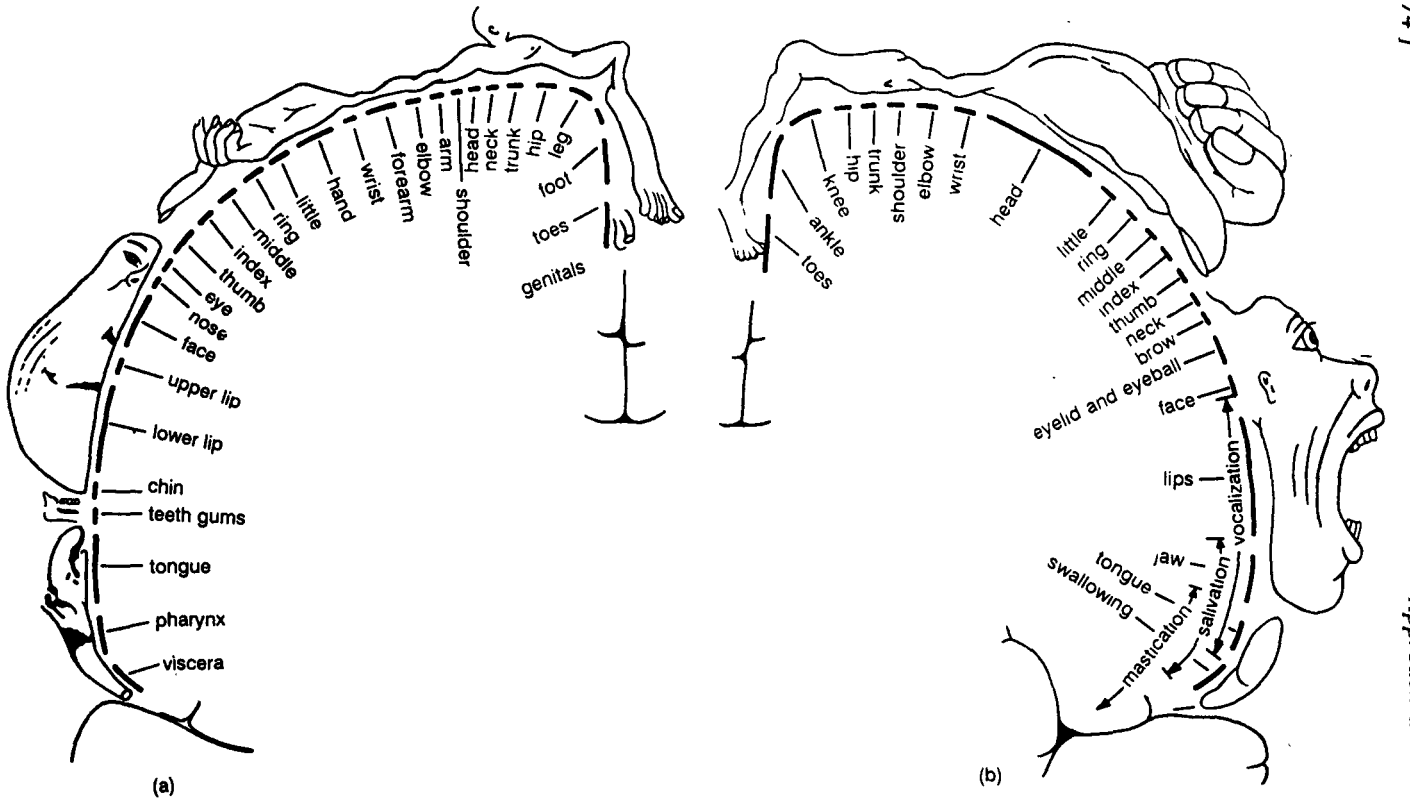

Fig. 4. Schematic diagram showing correlation between the body parts and size of cortex controlling its function sensory (a) and motor (b)

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During the German-French war of 1870-71, **Edvard Hitzig** electrically stimulated the exposed brain of a wounded, unconscious soldier, with the result that the soldier moved his eyes. Previously **Fritsch** and **Hitzing** (1870) had used same technique on dogs and observed that stimulation of different regions of the cerebral cortex produced contractions in different muscle groups of the body. **David Ferrier** (1873) performed similar studies on monkeys and **Bartholow** (1874) on man. Both scientists found that particular motor patterns of movement could be released by stimulation of defined regions of the cerebral cortex and they charted such sites on brain maps. At the end of the 19th century, Ferrier was able to roughly localize in the cerebral cortex the sensory centres for vision, auditory, gustatory and olfactory sensations; with the advent of new technologies and scientific knowledge sensory and motor cortex have been mapped with astonishing precision (Fig. 4).

It became technically possible to **record** the **elctrical potential** of active nerves with the aid of implanted **electrodes** and to amplify this activity by a highly sensitive instrument, where it could be detected and measured. Early in the 19th century scientists knew that nerve tissue responds to electric stimulation; at this time neurophysiological methods came into use for the purpose of evoking behaviour artificially. Electrical brain stimulation for deriving the correlation between structures eliciting behaviour was first performed by **R. W. Hess** (1931) in freely moving cats. This technique has now become a routine tool of neurophysiologists and neuroethologists. The procedure involves cutting the scalp in anesthetized animal, removing portion of the skull by means of special drill, exposing part of the brain surface by cutting dura-mater. Two or more electrodes, each insulated except at the tip are then lowered into the brain region to be examined and fixed to the skull with a quick hardening substance. However, in large animals, a head holder with adjustable electrodes is used (Fig. 5). In electrical brain stimulation

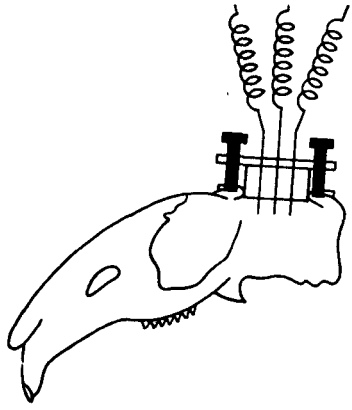

Fig. 5. Rabbit skull with electrodes and holder.

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experiments the threshold current plays an important role. It is presently accepted that different behaviour patterns are often characterized by varying levels of response thresholds in central nervous system e.g. in an experiment conducted on toads the electrical threshold for release of **escape behaviour** from optic tectum is lower than that for prey catching from caudal thalamic pretactal region. Further more, within a single mode of behaviour, such as the prey catching behaviour, the sequence of the different behavioural components-orienting, snapping, swallowing is assured by different and graded threshold at the same point in the brain.

Invention of the stereotaxic machine made it possible to study the electrical activity in different parts of brain. This machine consists of a head holder into which, the skull of the animal is placed. The head holder has tiny electrodes made up of steel or tungsten. With the help of stereotaxic atlases (brain maps), these electrodes are inserted deep into particular areas of brain and the precise location of their tips can later be ascertained by taking X- ray pictures. The experimental animals do not experience pain throughout this procedure as no pain receptors are located in the brain, and the surgical wounds in the skull are small and heal quickly. The electrodes are connected with an electric impulse generator. The first successful recording of brain waves from the skull of man was accomplished by **Berger** in 1929; who named this technique as **EEC- Electro Encephalogram.** Today, the results of brain stimulation experiments are available from a large number of vertebrates, primarily birds and mammals, and from several invertebrates, especially insects, crabs, and crayfish.

A real break in the field came in 1930 with the work of **R.W. Hess** in Switzerland for his work on cats. His research was honoured in 1945 with the Nobel prize. Generally, the neurophysiological 'experiments can be carried out in two different ways. The first one involves recording of the normal electrical impulses in brain and correlating them with behaviour. Basically four types of electrical brain waves have been recorded in human beings : **Alpha waves** from parietal and occipital lobes when the person is at rest with eyes closed; at this time brain is alert but unoccupied. These waves are also produced when we are awake, but in a peaceful, relaxed mind. **Beta waves** are produced from frontal lobe when brain is stimulated by sensory input or mental activity, these waves occur at the times of concentration and thought, and in normal daily alertness. **Theta waves** are generated from temporal and occipital lobe under emotional stress or when brain receives unpleasant stimuli; theta waves are associated with earliest stages of sleep, hallucination and creativity; and lastly **Delta waves** are the result of deep sleep. (Fig. 6).

The second method is the study of behavioural patterns that are initiated as the result of electrical stimulation delivered to a specific brain region by implanted electrodes. For example, by stimulating a particular locus in the

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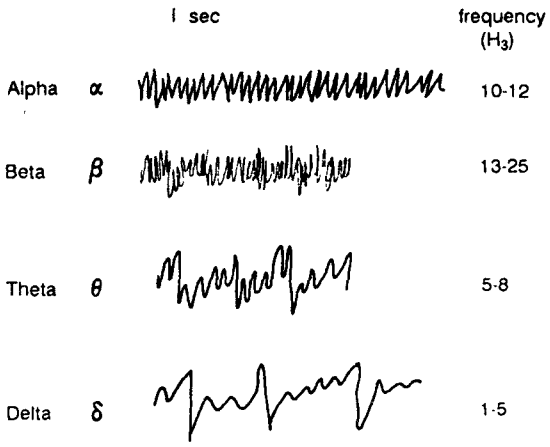

Fig. 6. Types of electrical activities in the human brain.

diencephalon of a cat, J. Flynn (1929) elicited **prey catching** behaviour. A. **Zukerman** (1965) was able to release behaviours like fleeing, courtship and threat by elctrically stimulating different regions of a pigeon's brain. **E. Von Hoist and Von Saint Paul** (1960) were able to elicit sleeping behaviour by stimulation with an electrode placed into the brain stem of a cock. Similarly, **T. D. Delius** (1958) located two areas in the brain of a cat for two different behaviours; one was motor cortex and the other was medial thalamus. Hoist and Saint Paul in an experiment observed that when an area in diencephalon is stimulated electrically in chickens by implanting elctrodes, the chicken assumed a fighting posture against a toy cat (Fig. 7a), threatened or attacked it (Fig. 7b) and when the electrical stimulation was stopped, the chicken

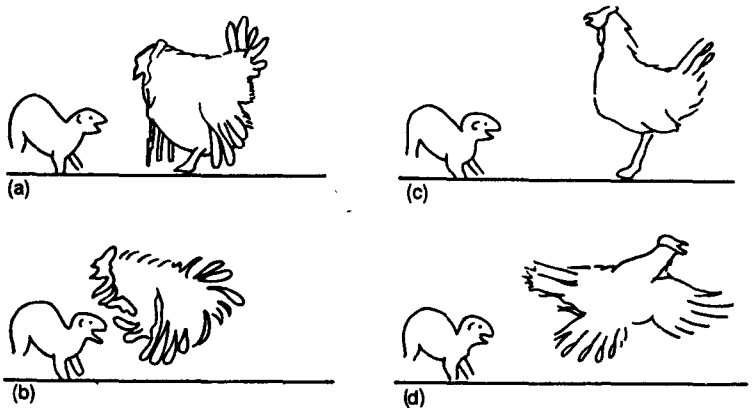

Fig. 7. Electrical stimulation of an area in diencephalon in chicken (Holst and Paul, 1960), indicating four situations (a—d).

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stopped all these activities (Fig. 7c); on the other hand, if the stimulation continued the chicken flew away (Fig. 7d).

Another interesting finding made by Von Hoist and Von Saint Paul (1960) was that when two separate areas of the brain responsible for different behavioural patterns are stimulated simultaneously, very different responses take place, e.g. suppose two areas in brain X and Y are stimulated simultaneously, the following variation might occur : superposition of both patterns (X+Y), average (X + Y/2), alternate (Y,X,Y or X,X,X), disappearance (X+Y=0), change to another pattern (X +Y=Z) or suppression of one of the patterns (X or Y). The changed behavioural pattern was shown by **T. Brown** and his associates (1967) in an experiment with cats, they identified two separate loci in a cat's brain that induced growl and flee, simultaneous stimulation of these two loci produced attack behaviour.

Using the same techinque of electrical stimulation by electrodes certain brain areas are identified in human brain, as **pleasure centres.** During clinical tests **C-Sem Jacobson** (1967) found that patients sometimes experienced a stimulation through an electrode as pleasant. Some of these patients reported sexual pleasure and some described it as general feeling of well being. Unfortunately, our hopes of treating depression by administering this kind of brain stimulation remain futile, because certain undesirable side effects like addiction cannot be eliminated. But the diseases can be controlled using this technique. Since childhood, Ray a boy in USA had suffered from several attacks of epilepsy. During these attacks he used to become violent and unreasonable, even homicidal. Drug treatments were tried and found to be ineffective. Later, a small electrode was surgically implanted in Ray's brain and attached to a stimulation device which he carried with him, the device had a remote control his instructions were to press the button of his brain stimulator whenever he felt an attack coming on. Ray never got a complete attack after the operation. He was able to eliminate his violent obsessions by simply pressing a button and sending electrical impulse to the part of the brain which inhibited the attack of epilepsy.

Though precise single cell recordings by microelectrodes are possible, still the neurophysiological techniques have problems regarding their application in stimulating specific areas, for example, in rat's hypothalamus electrical stimulation at one point elicits both eating and drinking behaviours though not at the same time. Initially it appeared that the two behaviour patterns were controlled by the same network of neural connections but later it was found that eating and drinking were controlled by two different and independent neural circuits which are very closely set to each other, and therefore the stimulus current can activate both circuits at the same time. Fisher in 1964 found out that chemical stimulation activates only those circuits, for which that particular chemical stimulus is specific. **S. Grossman** (1966) discovered a method for activating eating and drinking circuits separately. He used a

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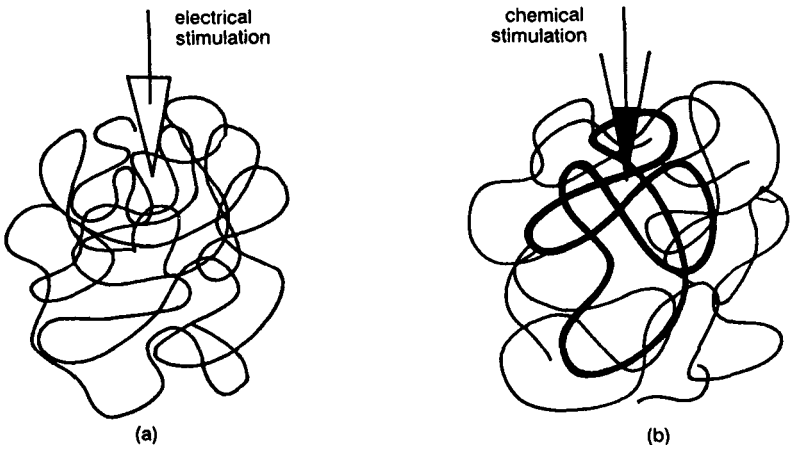

Fig. 8. Schematic representation showing (a) several neural circuits excited simultaneously after electrical stimulation and (b) selectivity of chemical stimulation.

particular canula to inject noradrenaline at one particular point and could evoke only eating behaviour. The nearby circuit for drinking behaviour did not get excited by the introduction of noradrenaline; this confirmed that there are two different centres for eating and drinking which are very closely set, electrical stimulation can cause excitation of both centres, but if activity of one of the circuits is inhibited by using neuro-inbibitors, it is possible to excite only one behaviour. Electric stimulation frequently activates several neuronal circuits (**thin lines**, Fig. 8a), simultaneously releasing various behavioural responses resulting in overlapping effects. Chemical stimulation, on the other hand, activates mainly the circuit (**thick line**; Fig. 8b), for which the chemical stimulus is specific (Fisher, 1964). After such discoveries use of drugs came to practice and opened a new field of research.

[III] Neurochemical technique

The electrical brain stimulation method by itself has only a limited significance for studying the behaviour. As discussed earlier, electrical stimulation does not unequivocally show whether the stimulated area takes part directly or indirectly in the activation of a behaviour pattern. Therefore, the search for a possible chemical coding of behaviour led to the development of "**chemical brain stimulation techniques**". In these methods, neurons are affected more selectively in their activity by local application of **drugs, neuro-transmitters, blocking agents** and **hormones**.

The use of certain substances such as alcohol, opium, hashish to abolish pain, to induce euphoria (sense of well being), relaxation and sleep has long been practiced by men. Addictive use of "bhang" *(Cannibis)* in India has been age

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old and festivity, fun, frolic are attached to it. Addictive use of drugs and alcohol has led many to criminal path. For the Yanomamo Indians of northern Brazil and Venezuela, drugs sometimes cause so intense alteration in behaviour that they become violent.

Introduction of certain chemicals and drugs orally or through blood or muscles or directly on brain parts produces behaviour. For example, when people drink alcohol or take opium they develop a feeling of well being and derive much pleasure. These drugs are absorbed and sent to blood, through which the drugs reach brain and when they reach specific target areas in the brain euphoric feeling is developed. To locate the exact centre in the brain the drugs are directly poured or introduced into different places of brain and when the person describes a feeling of well being it is ascertained by the experimenter that this particular part is the centre for pleasure. After the discovery of such centres in the brain and their stimulation, studies brought forward many drugs which helped solving problems like insomnia (sleeplessness), depression etc. The clinical and experimental use of **psychoactive drugs** viz. tranquilizers, sedatives to fight insomnia and depression is of recent origin. There are other drugs which stimulate mental state, give a feeling of hallucination and are very addicting e.g. lysergic acid (LSD). Such drugs are called **psychomimetic drugs.**

Drugs can be **administered** via many routes **intraperitonially, intramuscularly, subcutaneously** or **orally**. Accurate method of studying behaviour with the help of drugs is the introduction of chemicals directly into specific brain sites. For example **Fisher** in 1956 showed that sexual and maternal behaviour can be induced by the injection of minute quantities of **sex hormones** into the regions of **hypothalamus.** Transmission across synapses is carried out by means of chemicals or neuro-transmitters. There are certain drugs which can block their activities. A portion of brain which is responsible for the release of aggressive behaviour if treated with antineuro-transmitter or neuro-inhibitor will immediately block the aggressive behaviour because of blockage in synaptic conduction.

In order to learn about the glucose sensitivity of the neurons, blood sugar was replaced by goldthoiglucose, (GTG), the organism is unable to distinguish this substance from glucose. As soon as GTG is taken up by cells with glucose receptors it destroys them, it was discovered that cells in ventromedial hypothalamus were glucose receptor and formed a part of satiety centre, after they were destroyed, the animal showed hyperphagia. In another experiment, minute amount of acetylcholine in rat's hypothalamus produced drinking behaviour. **Acetylcholine** excited or **stimulated the drinking centre** and the animal started drinking. **R.P. Mitchell** (1968) administered estrogen with a small canula into the brain of female cats when they were not in heat, still the cats responded immediately by inviting tomcats for mating. Estrogen was introduced in anterior hypothalamus, if it was put in any other area of brain,

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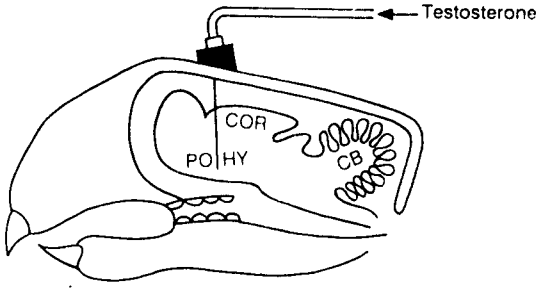

Fig 9 Introduction of testosterone with canula into the hypothalamus (Hy) in rabbit Cor = Cortex, CB = Cerebellum, Po = preoptic nucleus.

it did not produce this behaviour. Radioactive estrogen injected into blood stream was absorbed only by anterior hypothalamus.

Testosterone is a male sex hormone, if in a male or female rat it is injected into the central area of the preoptic region-located in front of the hypothalamus, using a fine injecting instrument and a thin canula (Fig. 9), the rats of both sexes elicit maternal behaviour, they start building nests. If testostrerone is injected slightly lateral to the central area of the same general brain region, males as well as females start exhibiting male sexual behaviour.

The chemicals can affect behaviour in different ways. Depending upon their nature, chemicals and drugs have been classified as :

1. Physiological agents. Adrenalin, histamine, serotonin, lutamic acid are known as physiological agents. They are present normally in the body but they are considered drugs when administered in concentrated dose.

2. Foreign agents. Reserpine, barbiturates, lysergic acid fall under this category. They are not normally present in the body. According to another classification neuro-active drugs could be identified as :

Tranquilizers, energizers and hypnotizers. Tranquilizers reduce agitation, excitement and emotion; energizers or stimulants include caffeine, amphetamine etc, they tend to produce hyperexcitability and also facilitate sensory and motor performance, they also act as anti-depressants. Whereas, hypnotizers such as barbiturates are the drugs that produce sensory and motor depression and deep sleep. In large doses, they cause unconciousness and even death.

Most recently the brain is being explored for its various functions using **tomographic techniques** (any method that produces images of cross section of the body reconstructed by a computer programme, most widely used technique with reference to behaviour is the PET-Positron Emission Tomography). There are millions of unanswered questions regarding brain and behaviour; these techniques are opening new gates to the unreachable and unexplored areas of the brain. It has been investigated by a team of workers that there is more blood supply to the part of the brain which is actively controlling behaviour at that point of time. For this, doctors give the

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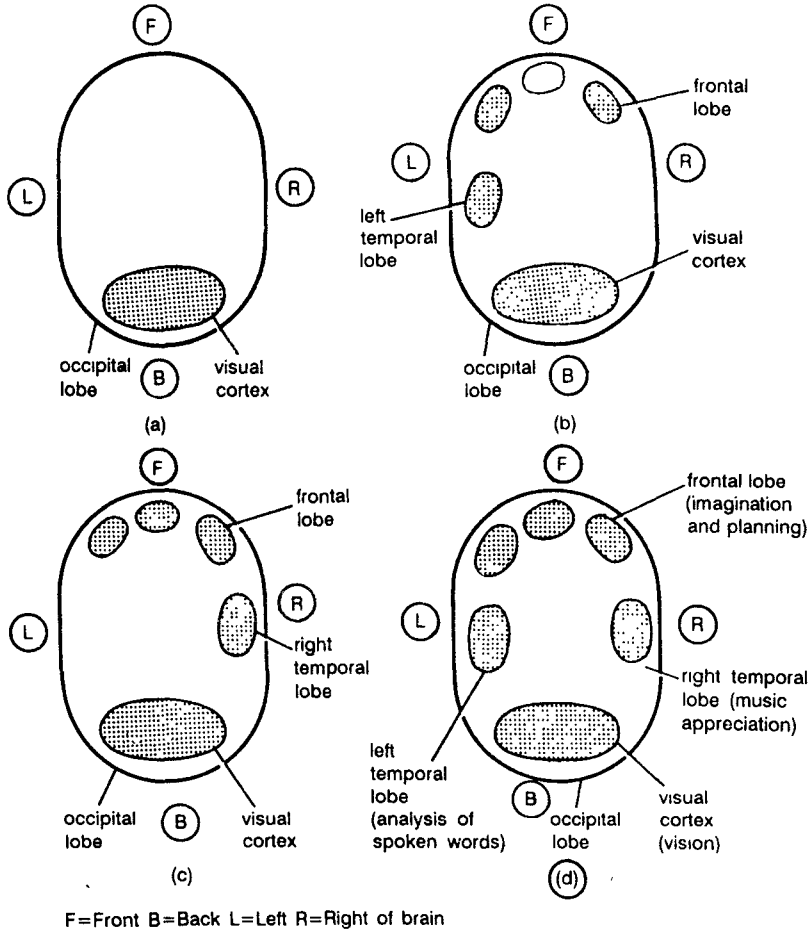

Fig 10. Diagrammatic representation of PET Scan photographs (a-d).

person to be tested, a special solution of sugar - this sugar is tagged with a radioisotope brewed in a small, **low energy cyclotron**; by tracing the radioactive substance, a doctor can pinpoint areas of normal and/or abnormal activities. The PET scanner detects the rate at which different parts of the brain "burn" or use up this special test sugar. A computer attached to the PET scanner shows the activity in idifferent colours on a TV Screen.

In an experiment the object (person) was allowed only to see. Dark spot at the back of the brain (Fig. 10 a) indicated that the eyes of the object were open and the visual cortex was active. Then object was allowed to see and hear words from friend. A dark spot appeared on the left side of brain (Fig. 10 b). The spoken language was analysed by the left hemisphere. The dark spots in front indicated that the words heard brought the brain imagination *(Z–37/Ani. Beh.)*

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and planning into action, which is a function of frontal lobe. In third situation (Fig. 10 c) object was seeing and listening to music. Alongwith imagination and planning, music appreciation centre on the right temporal lobe of the brain also got active. (Fig. 10 c) and lastly the object listened to music with one ear, heard friend with another and was also allowed to see. The PET Scan showed dark spots at all sides. (Fig. 10 d).

Other new breed of imaging devices like CT (computed tomography), MRI (Magnetic Resonance Imaging), sonography, DSA (Digital subtraction Angiography) have been developed which enable doctors and researchers to watch vital organs at work along with the brain and behaviours.

Each method described here has its merits and demerits. A comprehensive and balanced understanding of neural function can be gained from the integration of results obtained with different techniques.

Studies in Wild

Behaviour can be studied at different **levels,** it can be studied at the level of whole **species** (e.g. courtship); **population** (say migratory pattern in a particular population); **family groups** (e.g. flying to food source); **dyad** (agonistic encounter between individuals); **individual** (swimming pattern in an individual); **behavioural type** (way of ingestion), **behavioural act** (catching the prey), **body parts** (hind legs, their movement and usage), **muscles** (gastrocnemius), **neurons** (tibial nerve). These levels make ethology a limitless discipline, therefore an ethologist must decide at what level he or she would be conducting research and how the study will integrate into what is already known at the other levels. The ethological approach consists of a careful stepwise procedure by which **descriptive data** are gathered and **hypotheses** are tested. The description of behaviour of wild animals in the science journals and books are often the results of days and weeks and years of careful stalking and painstaking observations. Initial reconnaissance observations are necessary to make, on which a future well designed study be based. Behaviour is a very broad term which includes large number of short acts. The logical approach is to work from the general to the specific, first determining the level of organization and then spliting into following smaller steps.

1. Level of organization. In this, it is decided whether the observations have to be carried out at a species level or an individual. Say for example we select ducks as our subject, in which certain individuals are selected.

2. Unit of behaviour. This category includes activities like moving, sitting, and eating say, we select moving i.e. we wish to carry out observations on moving ducks.

3. Pattern of behaviour. Unit of behaviour that we have selected can have following patterns — (i) walking, (ii) swimming, (iii) diving, (iv) flying. With this, one can select all of them or anything say, flying is selected.

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4. Act of behaviour. With the pattern of flying there can be many acts involved— (i) take off, (ii) flight, (iii) landing, say from this take off is selected.

5. Component of behaviour. This includes — (i) Anatomical (movement of body parts e.g. head, wings, legs), (ii) Neurological (involvement of nervous system), (iii) Physiological (movement of muscles and bones).

Ethologist mainly concentrate till anatomical components of behaviour and psychologists generally start their work from remaining two components viz. neurology and physiology.

Observations of animal behaviour under natural conditions are extremely interesting. The important steps involved are : (i) selection of subject, (ii) what to study, (iii) what are the questions and objectives, (iv) stating research hypotheses, design of research, (vi) chalking out the list of behavioural acts of interest, (vii) deciding an appropriate methodology, (viii) reconnaissance observations, (ix) taking notes without disturbing the animals in their activities, (x) Interpretation of data. All studies in wild must start by observing animals the whole day from dawn to dusk and later on a working schedule can be set up depending upon the animal's activites. The notes could be taken for 10-15 minutes at a time followed by a 3-4 minutes interval, the observer should be close enough to make accurate observations, but not too close to disturb or distract the animals. The clothes one wears also matter, dark flashy colours should be avoided and browns, greens be preferred.

Observing wild animals is not an easy task. One has to be very patient and tough to remain in the field, following and taking notes on animals of interest. Forest, savanna, desert, rain, snow or hot sun, the ethologist has to be in the field. There are many ways to record behavioural activities in the field. First and most interesting is the **naturalistic way**. That means the person has to spend most of the time with animals or virtually has to live with them and take notes on animal's behavioural repertoir-great studies have been done like this coupled with scientific methods by **Konrad Lorenz, Karl Von Frish, Niko Tinbergen, Jane Goodall** and **Dian Fossy**. They lived in large farm houses or protected forest and were naturally surrounded by variety of animals, they learned to identify animals individually, took elaborate notes on them. Konard Lorenz had greylag geese in his farm house, his keen observation and life long experimentation brought forward the concept of imprinting. **Niko Tinbergen** and **Karl Von Frish** conducted remarkable studies on a wide variety of animals, their work on digger wasps and bees, respectively is still acclaimed worldwide. Jane Goodall has been observing chimpanzees of Gombe National Park, Tanzania since 1957, she has spent her entire life studying them, she recognizes each and every chimpanzee living in the national park by its face and she can trace their family trees; **Dian Fossy** spent much time with gorillas in Africa, the 400 ebs great ape virtually accepted her as one of their group members. Not many people have this kind of devotion or

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get the opportunity of living with animals. Therefore, other methods were adopted to record behavioural acts in a comparatively short time. Notes taken haphazardly can not be quantified, the data must be collected in a systematic way which should be reliable and reproducible. While recording behaviour-states, events and bouts are noted down specificially.

State. The behaviour in which an animal (or group) is engaged in; an on going behaviour (a parrrot flying). Basically, a state is a behaviour which can be timed with a stop watch.

Event. A change of state; it approaches an instantaneuous occurrence (e.g. a robin taking off or landing) events generally occur so rapidly that they can only be counted.

Bout. The term bout is generally applied to (i) a repetitive occurrence of the same behaviour (e.g. a bout of pecking) or (ii) a relatively stereo-typed sequence of behaviours that occur in a burst (e.g. courtship display)

While taking the field notes it is made sure that they are complete, accurate, clear and concise. Ethograms (set of comprehensive descriptions of the characteristic behaviour patterns of a species) of many animals have been prepared using different observational techniques.

Most widely accepted methodology was proposed by **Altmann** in 1974. He formulated following method :

(1) Ad libitum sampling,
(2) Focal animal sampling,
(3) Scan or Instantaneous sampling,
(4) All occurrence sampling,
(5) Sequence sampling,
(6) One zero sampling.

[I] Ad libitum sampling

This is the simplest way of recording behavioural acts. In this, one selects a group of animals and remains with them for some time, which could be hours, days, months or years depending upon the research problem, and whenever the behaviour of interest takes place it is noted. Ad Libitum sampling provides ideas for future research and often reveals rare, but significant behavioural events. What is recorded are generally the behaviours of those individuals (or groups) that are most easily observed. This technique is used when an ethologist is merely recording as much as he can during (i) an unplanned encounter with a species (ii) during reconnaissance observations for a later study, e.g. If the behavioural observations are being made on mother and infant relationship in deers and occasionally adult males come and interact with them, the notes could be taken on males also. In that case, we would say that interaction of adult males with mother - infant dyad were taken Ad libitum.

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[II] Focal animal sampling

In this method, one individual is the focus of observation during a particular sample period; that is, a particular individual of interest receives the highest priority for recording its behaviour. Suppose we are interested to note how female langurs wean their infants. Then we should select some adult females from a langur group, identify all those females individually by using body cues; then take notes on only those activities in which we have been interested. To take notes using focal animal technique, the experimenter has to formulate criteria and follow them strictly viz, this should include :

(1) Individual identification of animals of interest.
(2) Prior decision about behavioural acts of interest.
(3) Formation of a check sheet to be carried out in the field. Abbreviation of long descriptive words.
(4) Each animal has to be observed at predetermind time interval (sample period)
(5) Every time the animal observation performs an act of interest its frequency and duration is noted. According to **J. Altmann** (1974) with proper choice of behaviour units, sample periods and focal individuals this method is the best to use.

[III] Scan sampling

By this method, several individuals are observed one after another in quick succession in predetermined time interval. Their behavioural acts are noted on a well designed check sheet. One important use of this method is to estimate the percentage of time the individuals of a group spend in various predecided activities.

For example, we want to know what the members in a deer group do the whole day or how do they budget their time in a day/month or year? Like other methods following criteria have to be decided : (i) activities we are interested in (ii) time duration for scan, depending upon the group size, (iii) duration of interval. The scan records activities of all individuals of that group between a predetermined sample time, this task is preferably carried from dawn to dusk. If the notes are taken for a day then at the end you would know how many activities you noted (total number) and out of that percentage of other activities can be calculated. Similarly, if the data is collected for fifteen days, six months or one full year, activity pattern of that particular herd of deer can be known.

[IV] All occurrence sampling

It may be desirable to focus on one or a limited number of behaviours and record all occurrences of them. This is in contrast with focal animal sampling where the focus is on the individual. For example, we are interested to know

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if there is any interaction between rhesus and langurs, then select a research site where they co-exist, spend time with them and whenever there is any interaction, note it. In this, the notes could be more specific e.g. one can note what kind of interaction was there, agonistic or amiable? If agonistic then whether it was chase, supplant, tail pulling, threat, or bite? All occurrences of selected behaviours are possible if the following factors exist :

(1) Observational conditions are adequate.
(2) The behaviours have been carefully defined so that they all are easily recognized.
(3) The behaviours do not occur more often (or more rapidly) than the observer can record them.

[V] Sequence sampling

In sequence sampling the focus is on a chain of behaviours. These may be performed by a single individual e.g. courtship displays in male ducks (Fig. 11), parturition in female, courtship display in sticklebacks. The initiation of a sample period is usually determined by the beginning of a sequence and the sample period terminates when the observed sequence terminates.

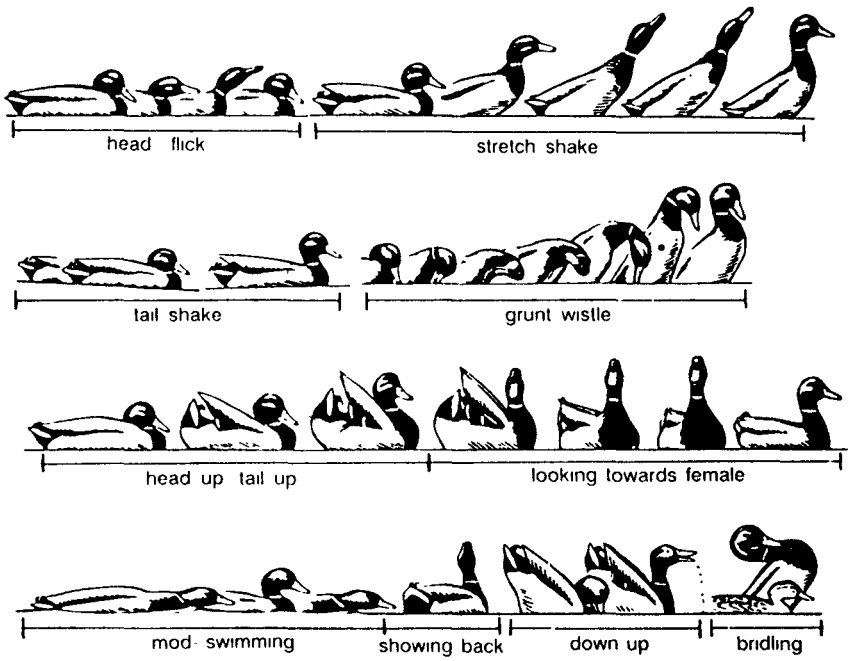

Fig 11. Observation of sequence of courtship in male mallard duck (Hermann Kacher, 1972).

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[VI] One zero sampling

It is a sampling method in which the observer scores whether behaviour occurs (one) or not (zero) during a short interval of time (sample period). It is suitable for recording states and or events, this method is also called as Hansen system (**Eisenberg**, 1972). This method has the following features :

(1) In each sample period the occurrence or non occurrence is scored.
(2) Behaviour of one or two individuals is recorded in each sample period.
(3) Occurrence refers to either an event or a state.
(4) The sample periods are generally short.
(5) Results are presented as frequencies (number of sample periods in which it occurred divided by total number of sample periods).

One has to be very careful in selecting the method because different methods help in generating different data for different interpretation.

Identification and Naming of Individuals

While studying animals' behaviour it is very necessary to learn to identify them age and sex wise, and individually by looking at natural marks, in the absence of such marks the animals are captured and marked either by ink, coloured collar or numbers. Data collection equipment varies from simple note book and pen to the complex online computer terminal along with clocks, counters, stopwatches, compass, range finder, radio telemetry-gadgets event recorders, stenographs, audio tape recorders, still and motion photography are some of the most useful equipment used in behavioural research.

A necessary prerequisite for ethological studies is that the observer be able to recognize individuals, particularly when the studies have to be carried out for a long period (longitudinal studies).

[I] Natural marks

The best way to identify individuals is by their natural marks e.g. broken horns, cut tails, scars on body, notches or holes in ears, pigmentation. However, these types of markings are generally not sufficiently wide spread in a population to allow large numbers of individuals to be recognized, only some species provide sufficient individual variation for easy recognition e.g. facial patterns in oryx, stripe patterns in zebras, patterns on dorsal fins of bottlenose porpoises, pug marks and body marks of tigers. **Rudhai** (1973) developed a method of individual identification for African lion (*Panthera leo*) based on variations in the patterns of vibrissa spots (hair near the nostrils). The other traits for individual identification can be missing limbs, presence or absence and size of canine teeth.

Photography is not the most useful tool, chiefly because of difficulties in obtaining close up photographs of small objects from various angles in addition to poor or varying lighting conditions in the forest, moving animals and

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expenses reduce photography to a supplemental method of recording. The preferred procedure is to observe the animals with binoculars, prepare drawings, write descriptions on identification cards.

[II] Artificial marking technique

1. Trapping. Usually it is difficult, expensive and time consuming to capture live animals, there is also a risk to the animal being captured. Many kinds of live traps are commercially available, but they are expensive however, traps can be fabricated less expensively. The traps can be put at suitable places prebaited with suitable food, as soon as the animal gets trapped it must be removed without traumatizing. The larger animals are anesthetized by putting a syringe on a long stick, the safest anesthesia for medium sized animals like monkeys is ketamine (**Martin**, 1972).

2. Darting. Darting techniques are useful for capturing animals under many circumstances when trapping is difficult or impossible, there are species that are trap shy or spend most of their time high in the trees or are too large to trap. A variety of darts and projecting weapons are available. Most commonly used are dartguns, blowguns, and crossbows. Darts can be made from tuberculin syringes with the plungers weighted so that they inject upon impact. The drug or anesthesia is a crucial part of the darting system, it should have a correct ratio of lethal to effective dose, sernylan and ketamine are the chemicals which are generally used to immobilize the animal. The animals have to be followed after darting because drugs do not work instantaneously, when animals are darted in trees it is desirable to catch them, to prevent injury.

3. Netting. This technique has been used successfully in capturing birds, monkeys, apes and deers. Rocket nets and mist nets have been most widely used. The Rocket nets, explosives are attached at one side, ignition makes rockets fly along with the net, and an entire group of deers or animals could come under it.

4. Ear notches and ear tags. Ear notches are formed with scissors, by notching the pinnae of the two ears in different ways one can make a variety of distinctly different pattern by which individuals can be recognized. Ear tags are easily applied to and are more easily recognizable marks, the ear tags can bear numbers or colour codes.

5. Tattoos. For this, small holes are made in the skin with a fine needle and permanent ink is rubbed into the small holes. It is best to tattoo a relatively hairless place that is lightly pigmented. Clipping and dyeing hairs and putting a collar around the neck are also effective methods for marking animals.

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Locating Animals in Wild

Sometimes it is very essential to follow animals in forest to collect data on various behavioural processes. There are three main ways to locate and follow the animals.

[I] Following on foot

Locate the animal or group of animals early in the morning before they leave their resting site and remain with them day and night. But at times, it becomes almost impossible to keep animals in sight, the animals could be too shy, they can live in a dense forest where following becomes difficult, the weather can be too harsh for the experimenter to remain in the field. In this case, alternative methods have to be adopted.

[II] Biotelemetry or Radiotelemetry

Radio transmitters have been used for locating a variety of species. This is accomplished by installing a small, radio-transmitter on the body of the animal. This animal is left freely in the jungle. The experimenter keeps a receiver which is tuned with the transmitter. The receiver set has an antenna (like TV antenna), the experimenter rotates the antenna until the maximum signal is received. Simultaneous directional information from two or more receiving stations can then be used to triangulate the location of the animal. The ears of experimenter who has perfected the technique can detect slightest changes in the characteristics of the signal received and is correlated with the behaviour of the animal. Radio-tracking system have been made completely automatic by transferring time and directional information into a computer where it can be stored.

[III] Satellite telemetry system

It is a recent technique introduced in USA. This system consists of two polar orbiting United States National Oceanic and Atmospheric Administration (NOAA) satellites, along with numerous earth based receiving stations and data processing centres. The purpose of satellite is to collect and process data from radio-collared animals from earth. They have been successfully used to track dugongs, manatees, muskox, polar bears and species of marine mammals (**O'Shea** and **Kochman**, 1990). For large species that range widely, satellite telemetry is much less expansive than traditional biometry. The signals which are given out from radio are received by satellite, which directs them to earth to be received by a dish linked to computer (Fig. 12) for analyses. It forms an important part of Geographic Information System (G1S).

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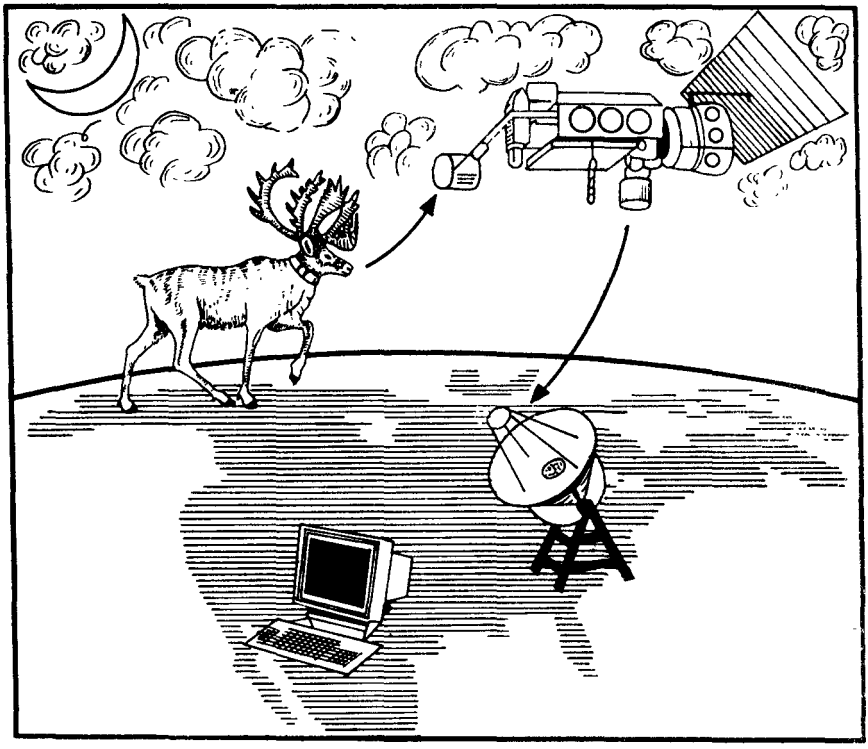

Fig. 12. Satellite telemetry system.

IMPORTANT QUESTIONS

➤➤ ***Long answer type questions***

1. Describe briefly methods used to study animals in laboratory.
2. Describe briefly methods used to study animals in wild
3. Write notes on (i) Neuro physiological techniques, (ii) Focal animal sampling technique, (iii) PET Scan.
4. Write notes on following techniques (i) Neuroanatomical, (ii) Neurochemical, (iii) Ad libitum and all occurrence.
5. Write notes on radiotelementry and satellite telemetry system.

➤➤ ***Write very briefly***

(i) Names of famous naturalists and their works, (ii) Neuro-anatomical technique, (iii) Neuro-physiological technique, (iv) Neuro-chemical technique, (v) Lashley's expt, (vi) Focal animal sampling, (vii) Scan sampling, (viii) Identification of animals

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➤➤ ***Define the following***

(i) Law of equipotentiality, (ii) Level of behavioural organization, (iii) Unit of behaviour, (iv) Component of behaviour, (v) Radio-telemetry, (vi) Satellite telemetry, (vi) Write full forms of CT, PET, MRI and DSA

➤➤ ***Explain the following***

(i) Stereotaxic atlas, (ii) Broca's and Wernick's areas, (iii) role of hypothalamus, (iv) The experiment of Holst and Paul done published in 1960, (v) Tomographic technique, (vi) One–zero sampling

➤➤ ***Differentiate between***

(i) Psychoactive and psycho mimetic drugs, (ii) Physiological and Foreign agents, (iii) Pattern and act of behaviour, (iv) State-event-bout

➤➤ ***Draw the following***

(i) Schematic diagram showing correlation between body parts and size of sensory cortex, (ii) Schematic diagram showing correlation between body parts and size of motor cortex, (iii) Types of brain waves in human

➤➤ ***Multiple choice questions***

1 Jane Goodall studied
(a) Gorillas in Smoky mountains
(b) Chimpanzees in Gombe National park
(c) Baboons in Africa

2 Salim Ali is India's famous
(a) Ethologist (b Ornithologist (c) Herpatologist

3 Neuro anatomical technique involves
(a) Chemicals (b) Electricity (c) Removal

4 Stereotaxic atlas for cat was first prepared by
(a) De Grrot (b) Jasper and Marsan
(c) Lin et al

5 Infra structure for speech is controlled by
(a) Broca's area (b) Wernick's area
(c) Both

6 Dictionary or learned words is housed in
(a) Broca's area (b) Wernick's area (c) Both

7 Law of equipotentiality was proposed by
(a) Hess (b) Ferrier (c) Lashley

8. Sleeping behaviour in cats was induced by stimulating
(a) Cortex (b) Pons (c) Brain stem

9 Tranquillizers and sedatives are
(a) Psycho mimetic drugs (b) Psycho active drugs (c) None

10 Adrenalin, histamine are
(a) Physiological agents (b) Foreign agents (c) Both

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11. Which method you will use to take notes on mother-infant relationship
    (a) Focal (b) Scan (c) Don't know
12 Which method you will use to record group activity
    (a) Focal (b) Scan (c) Ad libitum
13 Which method will you use if you want to note one particular behaviour
    (a) Ad libitum (b) All occurrence (c) Focal

Answers

1 (b), 2 (b), 3 (c), 4 (b), 5. (a), 6 (b), 7 (c), 8 (c), 9 (b), 10 (a), 11 (a), 12 (b), 13. (b).

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4

Communication

Introduction

Chirping of crickets, roaring of tigers, singing of birds, monkey calls, barking of dogs, distinctive smell of urine of cats and dogs, coloured feathers of birds and beautiful wings and fins of butterflies and fish are all used by animals for communication. Communication has been defined as :

(1) Action on the part of one organism that alters pattern of behaviour in another organism.

(2) A fundamental property of all social systems. It occurs at several levels between individuals, among members of groups and societies and among societies that live in the adjoining territories.

(3) According to **Scheflen** (1964) - communication includes all behaviours by which a group forms, sustains, mediates, corrects and integrates its relationship.

(4) Transfer of information from one individual (producer or signaller) to another (receiver) that influences the listener's behaviour.

(5) An action on the part of one animal that alters the behaviour of another (**Wilson** 1975). After receiving the signal, the second animal modifies its own behaviour accordingly.

(6) Mutually beneficial transfer of information between signaller and the receiver when they have the same interests.

(7) Signals given out by one animal that are used by another to predict the behaviour either of the first animal or of something else in their environment, after perceiving the signal, the second animal modifies its own behaviour accordingly.

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The essence of communication is the relationship between **signaller** and **receiver**; a bird gives an alarm call towards an approaching cat, and all the other birds fly away, the bird that had spotted the cat passed on the information to the other birds.

Animals use **communication** to attract mates, ward off predators, mark territory, and to identify conspecifics. Communication helps animals survive, therefore, **it is adaptive**.

The advantages of communications are :

(1) It helps in recognition of species, individuals, neighbours, castes (social insects), kin, and demes.
(2) It facilitates courtship and mating between males and females of same species through acceptance or rejection.
(3) It prevents agonistic interactions and promotes the establishment of social status between conspecifics.
(4) It facilitates social animals to herd at dusk or at the time of danger.
(5) It accelerates coordination among hunting animals.
(6) It plays crucial role during parental care.
(7) It alerts kins in a social group through alarm calls

Communication can take place :

1. Between prey and predators. Startling in gazelles and other ungulates, sudden flash of eyespots in butterflies and moths, hissing in snakes, colour change in chameleon.

2. Between prey species. Alarm calls given by birds are understood by mammals and vice versa.

3. Between competitors. To defend territories, to possess mates.

4. Between parents and offspring. For recognition, about food, shelter and danger. This can be seen among colonial birds which nest together. When the parents leave to forage, they must recognize their off springs on their return. Many other animals such as **bats** and **marine mammals** are also found in large colonies without very distinct boundaries. They depend on sound communication with their babies. In **penguins** and other **seashore birds** the parents recognize their chick by vocalization.

5. Between potential mates. Mating is a complex act and it is vital for an individual to transfer information about : (i) its species (ii) and its readiness.

Types of Communication

Animals use four types of communication. Each one of it is described in details in the following pages.

Auditory communication

Sound is the most used form of communication in animals. Proper vocalization in vertebrates and noises made by invertebrates using special structures are

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included in this category. **Crickets, birds, amphibians, bats, whales, primates** all have extensive use of **sound (Acoustics)**. The **deer** give **alarm calls** for approaching tiger; male **frogs** call to **attract females; bats** use **echolocation** as a form of communication as well as for hunting. **Bird song** serve both territorial and courtship functions. Other animals use sounds to communicate **danger, reproductive readiness,** and **species recognition.**

Animals make different sounds to communicate. From the spine chilling roar of a lion to well composed whale songs to chirpy songs of birds. Sounds are waves of alternating pressure changes that pass through a medium; air, water or solid. The intensity or volume of sound is measured in decibels (dB).

Decibel rating of various sounds

30 dB ———— Whisper
50 dB ———— Average domestic living room
60 dB ———— Normal conversation
90 dB ———— Heavy town traffic
120 dB ———— Human pain thresh hold
140 dB ———— Noise of jet plane
200 dB ———— noise of space rocket

Sound is formed of **pressure** peaks. The **wavelength** is the distance between the pressure peaks and the **frequency** is the number of waves that pass in one second. One complete **wave cycle** passing per second is one **Hertz (Hz.)**. The longer the wavelength, the lower would be the frequency (Fig. 1) and therefore lower the note that is heard.

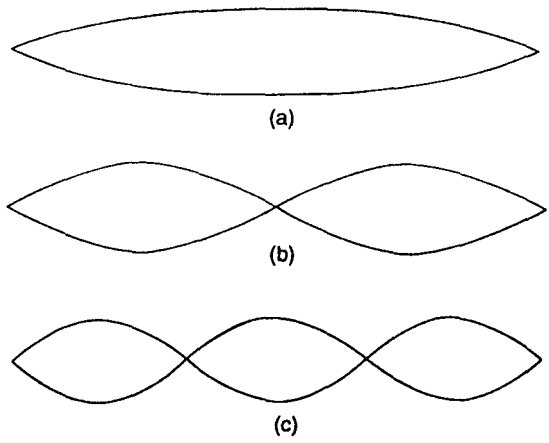

Fig. 1. (a) Low frequency sounds · Growl, grunt, (b) Medium frequency sounds · Bark, Moan, (c) High frequency sounds Scream, Shriek

(Z–37/Ani. Beh.)

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Frequencies of different vocalizations

The Average human can hear sound between 20 Hz and 20,000 Hz (or 20 kilohertz). Some animals can make use of sounds, which are out of range of human hearing, these are **ultrasounds**, **bats** produce and hear sound right up to 200000 Hz and at the other end of the scale are very low rumbling noises, known as **infrasound**. **Pigeons** detect infrasonic sounds down to less than one hertz. Animals with **vocal cords**, blow air across membranes e.g. mammals, birds, reptiles, amphibians. Some **frogs, toads, howler monkeys and gibbons** have **resonating air chambers** that even help them amplify the sound signals. Few **Insects, spiders and crickets are instrumentalists**, they produce sounds by **tapping, scrapping, bending, chirping** or **rubbing** parts of their exoskeleton. **Grasshoppers** scrape a comb on the hind appendages across the surface of the front wing. The **lesser water boatman (Corixa punetata)** rubs a series of bristles inside the foreleg against the head. **Cicadas** have a skeletal plate on either side of the body; they rub their appendages on them. The **death head caterpillar** makes a series of land snapping noises much like electrical sparks, when handled. Certainly one of the best examples of acoustic communication can be seen in **bird song**. Why does a bird sing? Is it trying to tell anyone something? The answer is-yes. His song is not a meaningless chirping of sounds that is nonsensical. His song has a two-fold meaning and can be easily understood by individuals of his species. To other males, his song is a **declaration of territory**. To the females within the range of his voice, his song is an **invitation**.

Fish make sounds, they **vibrate their swim bladders**, and they **grind** their **teeth**. **Rattle snakes** despite being deaf to airborne sounds vibrate their hard dried scales at the tip of the tail to give a warning **rattling sound**. Some birds, such as **storks**, clap their beaks together, **snipe** make flapping sounds with wings as they land, and the **humming bird** hums by beating its wing very fast. **Gorillas** use their chests as drums, many other primates shake branches, and beat sticks on the ground, **rabbits and deer** stamp their legs on grounds, **beavers** snap their flat tail on water, and **porcupines** shuffle and rattle their spines. **Crickets** hear through their elbows, **spiders** detect vibrations through their feet and **fruit flies** hear via antennae.

In most of the species belonging to the subfamilies - **Myrmeciinae, Ponerinae and Myrmicinae** the workers rub specialized parts of the body together to produce a "**Chirp**"-a sound that can be heard by the unaided human ear. In ants the chirp are specifically produced by raising and lowering the tip of the abdomen. **Spangler** (1967) noticed this chirp in **harvesting ants**. The purpose of this sound production remained a mystery for a long time. First clue to the function of sound production was proposed by **Grinnell** and **Wilson** who discovered that harvesting ant workers produced sound when they were confined, in particular when they were held by a pair of

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forceps, pressed under some heavy object or restricted to a small space in a container. This sound signal was a call for help sent out by trapped workers.

The chirp produced by **leaf cutting ants** is much louder and sharper when they were prevented from moving freely. The **leaf cutting ants** form underground nest with many galleries, if any gallery collapses, the trapped ants tap on walls as help signal, and the fellow ants come to rescue them on hearing the sound. Sound production is one of the most conspicuous and best-studied aspects of **termite** behaviour. **Konig** (1979) and **Smath Man** (1981), recorded that disturbed termites make audible sound by vibrating their heads or abdomens against the ground. This sound production serves to alarm other members of the same colony. There are many interesting examples from arthropods, they are considered world's best animal instrumentalists.

Spiny lobster makes a rasping sound by rubbing the projections of its rostrum on a serrated pad at the base of its antennae. **Ghost crab** makes a sound from the ridges of the inner side of its appendages with the help of its large claws. **Pistol shrimps** release their claw from a body space causing a loud sound. Some spiders tap on dried leaves to make a sound. The male wood spider rubs its mouthparts on the joints of pedipalps. Everyone is familiar with the mating chirping of a cricket "**Jhinger**" commonly found in our houses. Jhinger rubs its wings to make this sound. **Burying beetle** rubs its dorsal surface of the abdomen against the tip of the elytra.

Infrasound Communication among Elephants and Whales

The **sound below the human hearing** scale is known as **infrasound** and **above** the scale of human hearing is called **ultrasound**, both are inaudible to us. Infrasound can be generated by wind, thunder, volcanoes, ocean storms, and earthquakes as the result of huge movements of air, fire, water and earth. **Female elephants** use infrasound to greet each other, to communicate danger, and to attract the opposite sex. The lowest frequency of an **elephant rumble** is **14 to 35 hertz**. From research in Namibia, Zimbabwe, and Kenya, it has been learned that elephants use **infrasound** for **communication** over many miles. Researchers were surprised when a group of elephants, which was silent in their daily activities, suddenly look flight for no apparent reason. These sounds were recorded by special equipments and amplified for analysis. Until this research, low frequency sound was not considered to play a role in the lives of animals. An elephant's forehead skin will flutter and vibrate as air is passed through the nasal passage. This is recognized as the activity of infrasonic vocalizations.

Quickness of males to locate a female in estrus is amazing in elephants. A sexually active female gets surrounded by "**musth**" males within a short time. It is believed that the female can inform males of her condition with a sequence of intense, low-frequency calls used by the female during estrous. The **rumbles (infrasonic sounds)** begin as **slow** and **deep**, but rise in pitch *(Z–37/Ani. Beh.)*

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to become stronger and higher. The intense, infrasonic calls of **finback whales** have also been recorded. Whales use infrasound frequencies to communicate through water for distances of over one hundred miles. For years the actual function of whale song has been a mystry. Recently, playback experiments in humpback whales revealed some interesting functions of their songs. Most **cetacean** appear to have a very **species specific song pattern**. This song is fairly simple. However, humpbacks and other whales enter into long exchanges and the songs used in these exchanges is complex. Whales modify their songs year after year. Whale songs are similar to bird song. If whale songs are played at faster RPM (revolution per minute) they sound like bird songs. **Dolphins and sperm whales** use loud sounds to knock their prey; these are called "**sound lasers**".

Humpback whales sing a distinctive and complicated song, which changes gradually during the course of the year and may be associated with migration and courtship. **Dolphins** use a variety of sounds, which appear to aid social co-ordination. **Vervet monkeys** and **ground squirrels** use different sounds to identify specific types of predator. Chimpanzees use both sounds and visual signals to communicate in the wild.

Sonar, Navigation, and Communication

Killer whales, pilot and sperm whales, dolphins and porpoises are all classified together as the **odntocetes**-the toothed whales. Characteristically they are all noisy animals. These animals have been studied well because of their amusement value in water parks. They constantly make noises, in the

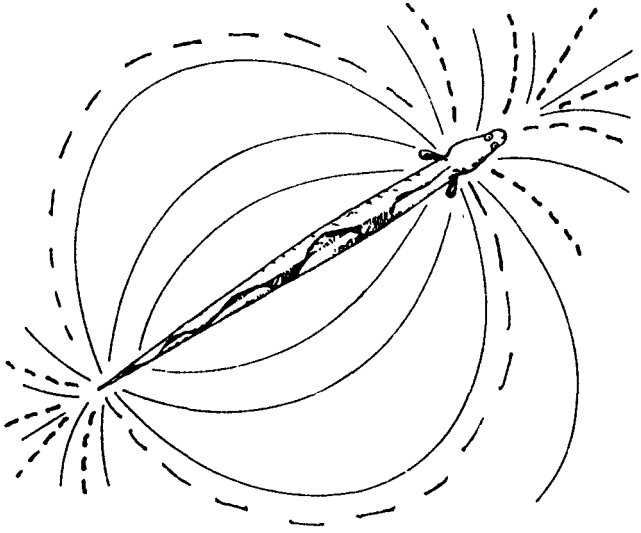

Fig 2 The Nile electric eel creates an electrical field around itself to communicate with other eels

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form **of ultra sonic sound waves (sonar)**, their sounds have been classified as : **squawks, whistles, squeaks, burps, groans, clicks, barks, rattles, chirps and moans**. Much of the sonar is used during **navigation**. The sonar pulses are reflected back from objects in the environment, and the whales either steer clear of these objects, or if the object is prey at close range they move to eat it. Can such navigational signals also have a role in communicating information about the environment to other whales ? **Clarke** and **Ellison** (1987) tracked whales as they approached a large ice berg. The lead whales or earlier arriving whales detected the ice berg at fairly close range and moved away from the ice berg accordingly. However, later arriving whales appeared to know the ice berg and avoided the berg better than the earlier whales, suggesting that they had used information from the previous whales encounters to adjust their paths accordingly.

Nile **electric eel** creates an electrical field around itself that enables it to detect disturbances and food (Fig. 2). Echolocation in bats is known world wide. **Oil birds of South America** also use a system of echolocation. They emit a high pitched sound that echoes back from solid objects (Fig. 3). Dolphins live in groups and form different types of patterns (Fig. 4a) while swimming. The form of pattern is comunicated through sonar.

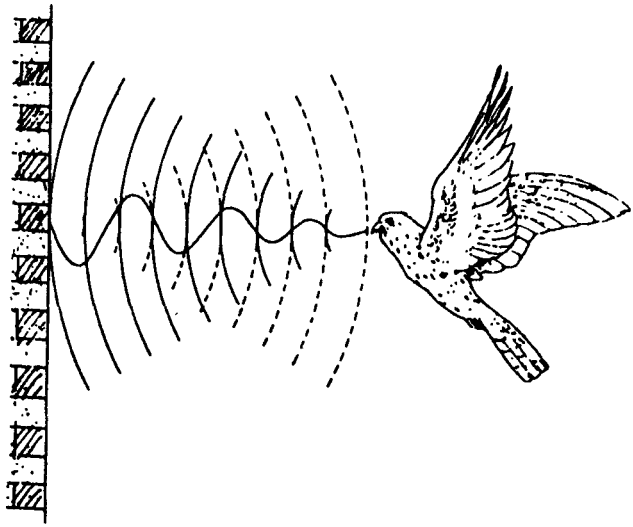

Fig. 3. Echolocation in oil bird. They produce infrasonic sounds that echoes back from solid objects and helps them in communication with conspecifics.

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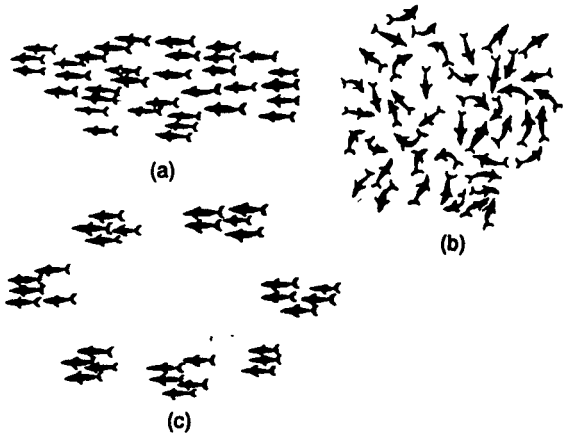

Fig. 4. (A) Dolphins are most commonly found whales. They move in large schools. (a) Oval formation is ritual pattern, (b) Pattern breaking into confusion is to trap food, (c) Normal loose formation these patterns are maintained and changed by sonar communication.

Vocalization in Non-human Primates

The noises made by monkeys express their mood, and are effective in communicating it to others. One barrier to understand noises lies in the difficulty of describing them. All non-human primates have a great variety of vocalizations and use them extensively.

Thelma Rowell (1972) considered two sorts of noises separately in primates :

(1) Sounds made with gestures.
(2) Sounds made without gestures.

The first group of noises are used by animals when they can see each other i.e. during **fights** and **sexual** activities, **threatening** and **friendly** situations. These sounds are produced along with facial expressions

The second group of noises are used when animals can not see each other. These sounds are clear and tuneful. Monkeys of a group are usually not able to maintain continual **visual contact**. They maintain group cohesion by making occasional calls indicating their general whereabouts to each other. This form is most used by species that live in large groups like **baboons** of **Africa** and **rhesus** of **India**.

The different sounds made by monkeys has a great variety. A set of nine sounds is listed and described by **Thelma Rowell** (1962) in rhesus monkey :

Roar. Loud, fairly long noise, made by very confident animal, when threatening another of inferior rank.

Pant threat. A similar noise but broken up into small syllables (combinations), made by less confident animal of wanting the support of the rest of the group in its attack.

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Bark. Like a single bark of a dog, given by a threatening animal insufficiently aggressive to move towards the other.

Growl. Differentiated from a bark in being a quieter and rather shriller, broken up with very short sound units, like a rolled "r" given by a mildly alarmed animal.

Shrill bark. The alarm call of the species given to predators.

Screech. Typically has an abrupt pitch change up and then down. Made when threatening a higher ranking animal.

Geckering Screech. A similar noise to the previous one, but broken into syllables. Made by an animal being threatened by another.

Scream. Shorter than screech and without the pronounced rise and fall. Made by loosing monkey in a fight while being bitten.

Squeaks. Short, very high pitched noises made by a defeated and exhausted monkey at the end of a fight.

According to **Jane Goodall** (an authority on chimpanzees, studying them since 1956) - "The calls in **Chimpanzees** range from the **low pitched** "**hoo**" of **greeting**, **low grunts** while **feeding**, of **loud excited calls** and **screams** which occur when two groups meet. One call given in defence, is a loud "**wraaah**" this is a spine chilling sound of African forest. Another call is a series of hoots, that is a sound meaning —"Here I come"

According to **Desmond Morris** (Great Zoologists & Anthropologist) the sounds produced by **New world primates** can be broadly classified into two types :

(1) High pitch sounds.
(2) Low pitch sounds.

[I] High pitch sounds

These can be divided into two subgroups. The first includes **squeaks**, **whistles and trills (vibrating sound)**. Infants of some species such as **night monkeys** utter such sounds as **distress** signals. Adults of all species make the same or very similar sounds. These sounds may indicate low intensity **hostility** or **friendly** or **sexual** tendencies. The second type of high pitched sounds include **screams**. These are expressions of high intensity distress in infants and of very high intensity hostility, including strong **escape tendencies**, in juveniles and adults of all species of new world monkeys.

[II] Low pitched sounds

The most common patterns of this group are short, rather harsh notes that can be described as **grunts** in some species, as **barks** in other. Other low pitched sounds may be described as **moans**. They are produced by **hostile** animals.

Many species of new world monkeys produce sharp alarm or warning notes which do not fit very well in these two groups. In some species some

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ultra-sonic sounds are produced which are completely inaudible to human ears. **Vervet monkeys** in a social group produce different sounds for different preys such as cats, raptors, and snakes. Alarm communication is found in **lemurs** that recognize and use different alarms for meat eating birds and terrestrial predators.

"Can monkeys talk? They have of course no words for objects and specific acts, but they have well articulated sounds for communicating their personal feelings to one another, and to this extent it can be said that they have a language."

Leonard Williams has written in his book - **Man** and **Monkey** about the language of Wolley Monkey (New world monkey). He noted following sounds and their translations indicating the scope of development of their vocal communication.

1. eolk. A soft, sweet, short and enchanting sound. It is made by the adult males, females and infants. It can mean any of the following - Hello or I am delighted to see you. In another context it expresses pleasure in the discovery of a new object.

2. eeolk. A variation of eolk, it is less communication and expresses an element of surprise as well as a pleasure. It means-"what a pleasent surprise to see you".

3. eeeeolk. Another variation, but unlike eeolk it has a strong elements of self induced surprise. An adult, lying completely relaxed, perhaps on the verge of sleep, may suddenly eeeeolk! for no apparent reason. One gets the impression that the monkey has suddenly become aware of the fact that - "what a wonderful day".

4. eeooooollk. Similar to other forms of eeolk, but very strong and continuous. It expresses extreme pleasure and happiness. Such sound is produced either by seeing a very delicious food or to welcome the arrival of a special monkey friend.

5. EEeeeooooolk. A long distance call, that is usually heard only in the trees. It is strong and most beautiful sound. In general it means - "all is well here" or "I am feeling marvelous how are you?"

6. oohh-oohh. They are made to express to another monkey or human friend that - "I am ready for a game" or "May I have your attention please."

7. Ogh-ogh-ogh. This is a gentle and affectionate sound. Known as creaking. It expresses intense willingness to accept. It is the desire to be friendly together with the fear of being rejected.

8. aarrrhgk. These are usually made by mothers for their infants expressing that - "I am your mother". "Please do come to me and don't be afraid."

9. huh - huh. A type of strong laugh usually, but not reliably, it is an invitation to a game or a play-fight.

10. argch - argch. An aggressive warning sound, short and sharp. It is made with open and teeth exposed.

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11. Yoohk - Yoohk. This sound must be regarded opposite to eeolk. It means danger, fear and distress. It is also made when an adult female is annoyed by a male. This can be interpreted as - "I am not at all pleased with the way you are carrying on."

12. Offw - Harff. An aggressive warning sound that is rarely used. It is a cough bark, explosive, short, hollow, like a pistol shot with the sound of "arr" in the middle of it.

Monkeys generate sounds other than vocalization. Like by colliding their own body with objects. Many monkeys and apes **shake branches** in the course of **aggressive display** (e.g. Red spider monkey), generating noise that communicate something to the animals of the same species or to opponent. Several species produce sounds by **striking the bases of the trees** with their palms. Chimpanzees produce sound by **clapping**; Gorillas make similar sound by **beating their own chest** called **drumming** or chest beating. There are air sacs in their chest, which are filled with air just prior to beating to work as a drums. These sounds serve as signals to communicate with other members of the species over considerable distance.

There is no evidence of any non-human primate showing even rudimentary forms of language, although some recent experiments using computers with chimpanzees have indicated capacity of learning and expressing symbolic language.

The draw back with sound is that it is not as private a form of communication as sight is. The advantage is that sound can travel much longer distances even through thick forest. It is also advantageous that lots of information can be communicated in a short time. As contrast to visual signal the resource of sound signal cannot be located easily by a predator.

Echolocation in Bats

For a long time it was a matter of wonder and puzzlement as to how bats are able to move about and catch the prey in the darkness. This curiosity led **Lazzro Spallanzani** to experiment with bats. He blindfolded them and was amazed to see that they could still avoid obstacles. He tried removing various senses like touch, smell, taste etc., but could not understand the mechanism behind this ability to see in the dark. Finally after years of labour by many workers who toiled in this field, it emerged that hearing plays an important part in this. It is only that bats are nocturnal animals and hence acuity of vision is not that important in situations of low light. In fact fruit bats would not even fly on a moonless dark night, thought they have better night vision. However most of the bats do fly in the night, dark or otherwise, and they are able to negotiates obstacles with ease because of a special type of orientation behaviour, the **Echolocation**. Here the bats emit high frequency or ultrasound and are then able to catch and analyses it's echo. Echolocation is also seen

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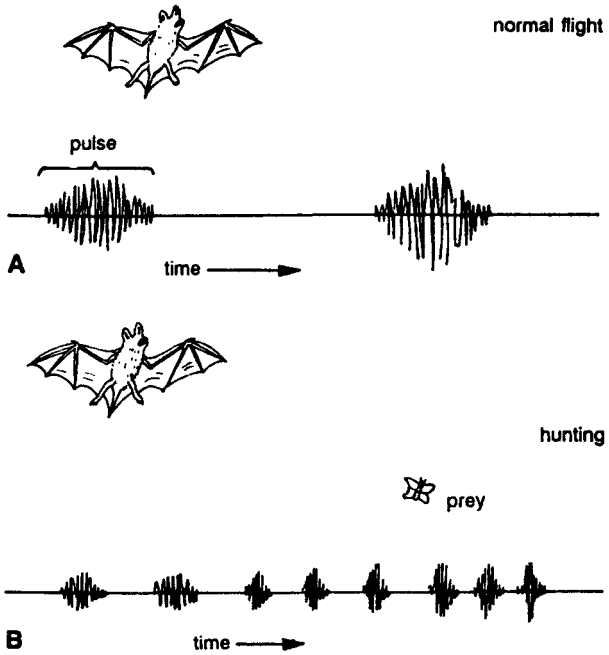

Fig. 4 (B) Nature of sound waves produced by the bats for echolocation during, (a) normal flight and (b) hunting for prey.

in some other animals like the **oil bird**, *Steatomis caripenis* and **dolphins**. However most of the research on echolocation has been done in bats.

The bats emit the ultrasound which is quite suitable for the purpose of echolocation. Its **short wavelength** makes it easy to bounce back from small objects and it can give a better directional bearing than long waves. The bats utilize the echo to gain the information about the obstacles in the way or the prey in two ways; it can find out the time it takes for the echo to come back and it can detect the changes in the frequency of the returning sound. The *Vespertilionid* bats emit ultrasound in short pulses with a wide band width. These characteristics make it ideal for measuring the range. Each pulse is of very short duration in milliseconds and the band width may be like 40 kHz to 80 kHz (1Hz is one cycle in one second). The pattern of emission of sound pulses varies with the activity of bats. In normal cruising flight, the pulses are larger and have a wide band width whereas during hunting as the bat approaches a prey, the pulses became shorter, more frequent and have narrower band width (Fig. 4 b). Bats also use the **Doppler effect** which is the shift in frequency if the source of sound is approached or moved away. The range of ultrasound usually produced by bats is 20-100 kHz. Bats are capable of achieving remarkable degree of precision with echolocation avoiding wires as thin as 0·1 mm. The ultrasound is produced through their mouth and nose and its auditory system is exceptionally developed to interpret the echos.

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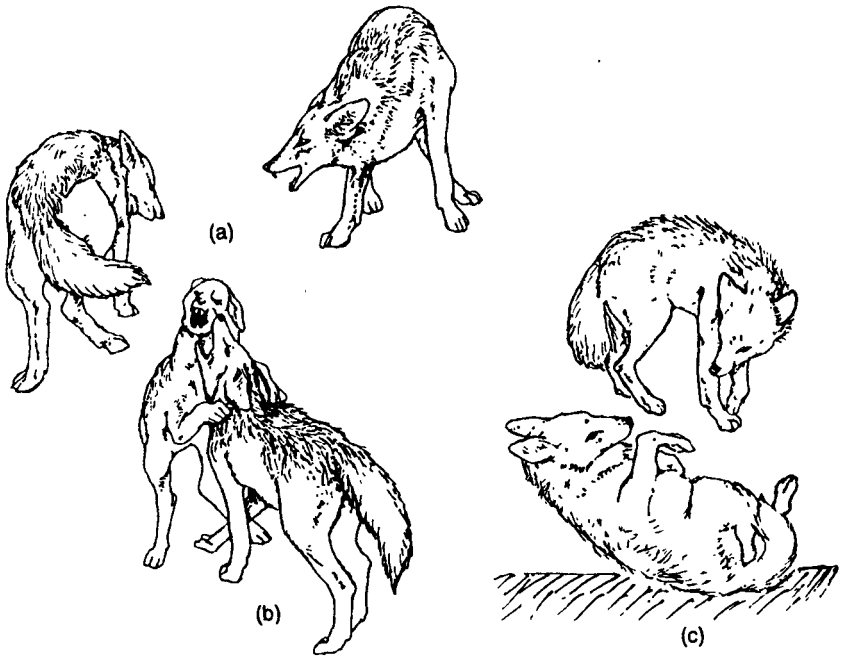

Fig. 5 Wolves, jackals and dogs establish a rank order, (a) Two individuals come closer, circle each other, growl, show canines, (b) One tries to bite other, (c) One adopts submissive posture This postural communication helps establishing dominance hierarchy and prevents fighting.

Visual Communication

Light signals detected by the eyes come into this category- like **gestures, postures**, and **facial expressions**, raising of hair, courtship, colour change and aggressive displays in many birds, fish, amphibians and mammals, are some of the good examples of visual communication.

There are two types of visual communication.

1. Badges. Includes the colour and shape of the animal. This involves, morphology.They are **structural adaptations**. like fur, feathers.

2. Displays. These are the things or acts animals do to communicate. They are **behavioral adaptations**.

Visual communication is most used during dominance displays, agnostic behaviour and in courtship. **Wolves and Jackal** (Fig. 5) use visual signals to establish rank order. Two competitors circle each other, try to bite, one assumes submissive posture and lies on the ground. To show dominance they also stare at each other, raise their fur, and bare their teeth. Male **stickleback fish change colours dramatically during breeding season. Tinbergen** studied them extensively and found that the **red belly** of the male attracts the female. Females have adapted to use a head-up posture to initiate courtship. The

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male uses zigzag motions to lead the female to the nest, where she deposits her eggs for fertilization.

Understanding vision and visual systems involves an understanding of the properties of light. While humans can only see light from **sun** in a visible spectrum, many animals can see **infrared** and **ultraviolet** light invisible to human. Some animals have exceptional **colour vision**, others have poor colour vision. Some have exquisite **night vision**, others have poor night vision.

The **large eyed predatory ants** have excellent vision and are expert in detecting moving objects. Their workers do not respond to prey that are standing still, but run toward them as soon as they begin to move. **Stager** (1931) and **Wilson** (1960)) noticed that, when workers of *Formica lugubris* locate a prey, they dash in erratic circles around it and thereby attract other workers exploring in the close vicinity. This communication is evidently mediated by vision along. Stager labelled the phenomenon "**Kinopsis**"

The animals can use a combination of different types of communication. The **leaf cutting ants** move in a **row (visual)** cutting circular pieces out of leaves, and follow a trial of **pheromones (chemical)** tapping **antennae on each other (tactile)**. They carry the leaves to their nest, where they clean them and chew them to pulp, out of which they make their spongy homes. These ants grow a particular fungus over chewed pulp, on this fungus the ants feed; any other type of fungus is removed by the workers. When a young queen leaves the colony, she carries a sample of this fungus for her workers to see **(visual)** and grow it in her new nest.

Visual signals are used by many organisms as a means of communication between individuals of the same species. Very frequently to recognize each other. For example, down in the depths of the ocean, far below the limit where light can not penetrate, live a number of species of fish that possess **light-bearing organs** known as **photospheres**. Many unusual functions have been attributed to these organs, but it now appears that their main function is recognition between individuals of the same species, the fishes flash their lights in a particular fashion that is recognized by conspecific.

Visual signals are used in recognizing differences between the sexes. Reproduction is a vital process in nature, the success of the species depends upon the reproductive success, elaborate procedures and patterns of flashing bright light have developed to ensure that this process takes place efficiently. The female of a species must be able to extract those visual signals from male of her own species from the vast array of sights which are all around her. Similarly the male must be geared with the proper equipment in order to give away or advertise the correct signals to correct females. In summary, the proper signals, correctly interpreted by the right individuals are important for proper breeding and ultimately to the evolution of a species.

Many species change their visual appearances as the breeding season approach, invariably reverting from a dull appearance to much more colourful

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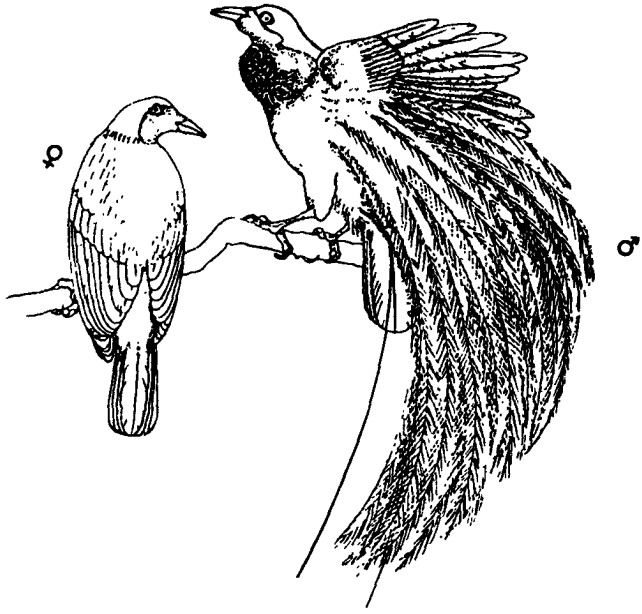

Fig. 6. Male and female bird of paradise.

fur, feathers, skin and scales. Mostly this change occurs in the male as they compete for females. A male who fails to adopt his breeding colour fails to obtain a mate. Although birds represent the best example of this type of communication, it by no means is restricted to that group. For example, there are fishes who adopt colours e.g. **three spined stickle backs** adopt nuptial colours and **sambar** (*Cervus unicolor*) develops impressive **antlers as secondary sexual character** in each rutting season. Monkeys exhibit darker and deeper colours on their face and hindquarters when they are ready to communicate for their readiness for mating.

Some species of birds, for example the **red-winged blackbird**, do not change feather colours from season to season, but remain the same throughout the year. The male redwing always has a bright red shoulder patch that, during most of the year, is kept hidden. When the breeding season arrives, he displays his beauty assuming a posture that is recognizable to the female. In Central and South America a commonly found bird is **royal flycatcher**, under normal conditions is a plain brown insignificant bird with nothing distinctive about it except for its long crest feathers. Its only when a male raises his crest feather, the reason for his royal name becomes obvious. He immediately transformes from a plain brownish bird into an object of great beauty, his erect spread crest feathers resembling the tail of a peacock. The **bird of paradise** (Fig. 6) of New Guinea and Northern Australia is extremely brilliant in getup. They are the most ornamented and colourful birds of the

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World. In male bird of paradise, the development of special feathers for the attraction of the opposite sex reaches its peak, not only in varied bright colours but in strange and fancy shapes too. Closely related to the bird of paradise and living side by side with them is another interesting group of birds known as **bower birds**. Comparatively the bower birds are colourless and plain and totally devoid of ornamental structures. Since this bird is lacking in natural beauty, the male makes up for his deficiency by constructing a beautiful nest called bower. Much efforts and time is spent by the male in building this home, designed for no other purpose than to attract a passing female that he is a hard working male, worth of her attention. **Bower birds** are of **three types** according to the type of bower (nest) they construct to give visual stimulus to their females. These are : (i) **having nest** covered with **fresh leaves** (ii) having nest decorated with **fresh flowers**; and (iii) **having** nest with **pebbles, bleached bones, shells, leaves**, and **flowers**.

Visual signals have reached their ultimate development in communication between the opposite sexes. Some visual signals indicate **aggression** or **submission**. Our dog, for example, when scolded for wrong doing or is told to go outside, if he prefers not to, he will roll over on his back, all fours extended, in a posture of total submission. He indicates his inferiority to us and at the same time, is pleading for mercy. This type of behaviour and signal he uses if he encounters a larger dominant dog almost as the wolves do (Fig.5). An **elephant** uses its trunk to communicate **aggression** and **submission** (Fig. 7). Breeding **Grant gazelles** are aggressively territorial and engage into visual communication, they avoid a fight by using visual displays.

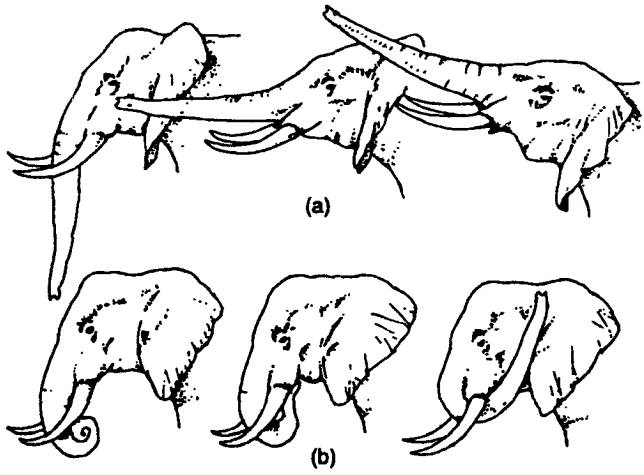

Fig. 7. Elephants use their trunks to communicate in sign language : (a) Pulling of trunk straight and then raising it almost to 45° is a sign of threat and aggression, (b) Coiling of trunk then taking it out near ear is a sign of submission.

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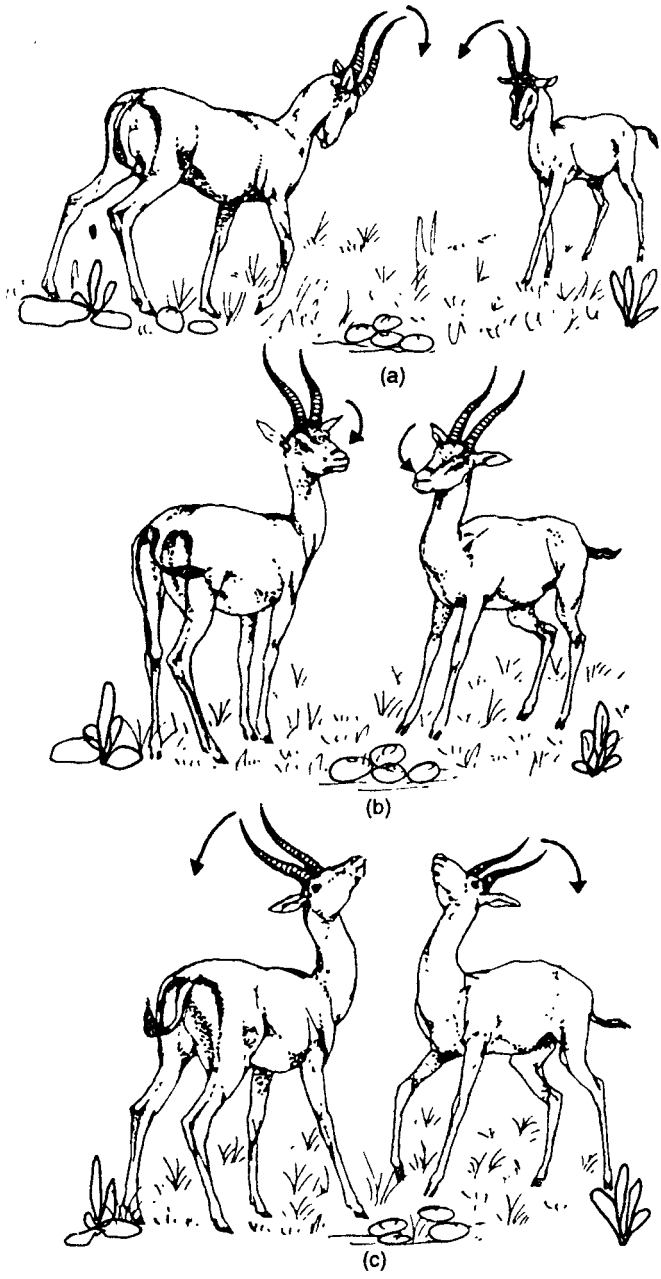

Fig 8 Grants gazelles avoid fight by communicating through displays (a) Two males approach each other pointing their horns, (b) Then turn their heads on the sides, (c) Raise their heads pointing the horns backwards The weaker male retreats and leaves without a fight

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They approach with forward horns, turn their heads and take horns away (Fig 8). This means no fights.

Visual signals are used widely to give **warnings**-brightly coloured **wasps** signal stings, **red** and **yellow** colour combination in caterpillars convey bad taste, in **snakes** these colours indicate deadly **venom**, red belly in male three spined sticklebacks prohibits other males to enter his territory.

Visual signals may be used in **pleading** for food or alternately indicating the presence of food. The **red spot** on the lower mandible of a **herring full** serves as a visual signal to the **hungry chick**. The chicks peck at the red spot of the parent and this pecking by the chicks acts as a tactile signal requesting the parent to regurgitate food. **Niko Tinbergen**, a famous behaviourist, constructed a number of **cardboard dummies** resembling the heads of adult herring gulls. Only one of the dummies was made to look exactly like the head of a gull; all of the remaining were altered. All of the dummies had red spots painted on them. Tinbergen tested the reactions of newly hatched gulls and found that all the dummies worked. The chicks pecked at the red spots on any of the dummies regardless of the position of the spot or the nature of the dummy. In fact he found that they would also peck at a small red stick that had no resemblance to a parent's bill. On the other hand, when Tinbergen presented the chicks a dummy of a gull's head that was perfect in every detail except for the red spot, there was no reaction in the chicks. Red colour was significant for communication.

Many animals use **visual bluffs**, **howkmoth caterpillars** inflate their heads resembling a snake head; swing them to and fro, as if ready to strike. **Peacock butterflies** combine visual and acoustic signals. When a bird approaches; the butterfly opens its wings and exposes eye spots on wings and hisses like a snake. There is a fly that lifts its abdomen when approached by a predator to resemble a hunting spider. **Hog nosed snake** turns upside down, and produces a stinking substance pretending to be dead ,decaying and rotting to discourage the predator, so it uses a combination of visual and chemical signals. The West Indian **wood snake** can really scare a predator because it exudes stinking fluid resembling decomposing flesh. It has very special blood vessels in the eyes, when agitated it makes the eyes look red and also cause little blood to drip from the gapping mouth. Collectively chemical and visual signals ward off predators.

In the **snapping turtle's** mouth there is a fleshy appendage resembling a worm **(visual signal)** the turtle keeps its mouth open and shakes this worm looking appendage, the fishes are attracted towards the worm the moment a fish is lured towards that worm turtle eats the fish.

Praying mantis is a thin slow moving insect and has adapted well to different habitats. Its anti predatory tactic is camouflage. Some **mantis** resembles a **dried twig** and some resemble the **petals of a beautiful orchid**, insects are bluffed, they take mantis as a flower and when sit on or near

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it they are eaten up by mantis. **Honeybees** communicate the location of food sources by **waggle** and **circle dance** when they return to the hive. Features of the dance inform other bees about the direction, distance and type of food source, **flashing of fireflies** or **dance of a peacock** are day to day examples around us.

Facial expressions in higher animals are used much more than other forms of communication. Visual communication is most important to **monkey** and **apes** and certainly the best described and understood. Primate eyes have exceptionally good capability of perceiving very small movements and small differences in shapes. Visual signals in non human primates include :

(1) Postures
(2) Gestures (including facial expressions)
(3) Movement of tail
(4) Pilo-erection

Postures

Posture includes whole body, e.g. **standing**, **sitting**, **lying**. A great deal of information is conveyed by the general postures of a monkey as it sits or walks from place to place, by the shape of the vertebral column and by the angles of the limb joints. When a gorilla is alarmed it pulls vegetation, beats his cheast and stamp his feet (Fig. 9).

(1) The monkey which lacks confidence does not sit upright, its head drawn into the shoulders, its limbs flexed (bent) tightly towards the body. Hands between the knees, touching the ground.
(2) It walks with knees and elbows bent, tail hanging down.
(3) A confident money sprawls (carefree) comfortably when it sits, legs stretched.

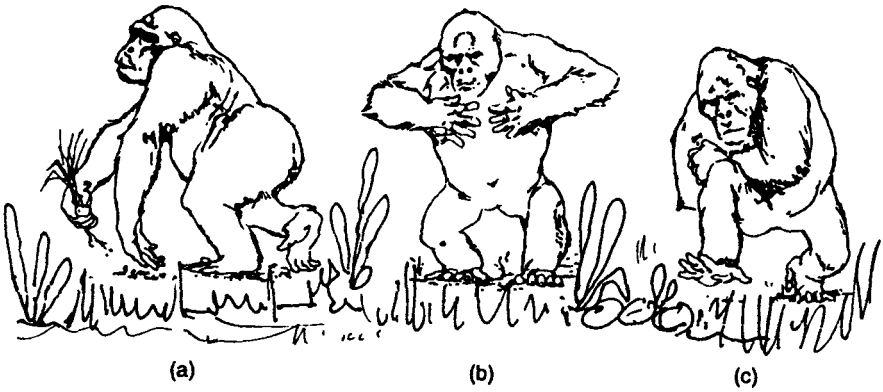

Fig. 9. Threat display by dominant male in a Gorilla group : (a) On seeing an intruder, the male starts pulling the vegetation, (b) If intruder still does not leave he starts beating his chest, (c) Extreme aggression is stamping of feet on the ground and running towards the intruder.

(Z–37/Ani. Beh.)

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(4) It walks normally, with tail pointing upwards. During ground movement it walks leisurely with the head held high, the tail curved over the back and takes long strides.

A special postural signal is given by the leader of gorilla group. It prepares other members of the group for departure by facing in the chosen direction and standing motionless for as long as 10 seconds, with front legs and hind legs spread far apart from each other than usual.

Gestures

A gesture is either just facial expression or use of a body part like tail. It is any action that sends a visual signals to an onlooker. For instance if a student supports his head on his hand (**called head rest**) while listening to a lecture – his posture is sitting but his gesture is bored or tired

Branch shaking or vibrating some large objects, making a loud noise is commonly seen in non human primates. Usually the animal goes through the movements of jumping up and down on a branch, so that the branch is shaken up and down several times in a second. While shaking, the mouth is kept open and the teeth slightly exposed. This is common among males. Branch shaking occasionally occurs in the absence of any stimulus but is seen to occur by sudden loud noises e.g. noise of jet aircraft. Branch shaking is also performed on the approach of strangers, and during bouts, of threat, it is often infectious, many males start this activity seeing each other (**Rowell** and **Hinde**, 1961).

In non-human primates all the facial expressions can be studied under this heading. There are many gestures of greeting in Chimpanzees. When two chimps meet they put their arms around each other in a delighted embrace. Friendly social gestures include holding hands, patting one another and even a sort of kiss. Chimpanzees close their mouth and pout their lips during aggresion, they open their mouth wide and expose all teeth in a howl and close their mouth and show their teeth during (Fig. 10) an alarm.

Fig 10 Chimpanzees have an expressive face, this allows them to communicate their emotions (a) Attention, (b) Aggression, (c) Alarm

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Movement of tail

In many mammals the tail is of special significance in communication and primates are no exceptions. Placing the tail between the legs is characteristic of **sub-dominant** rhesus monkeys specially in the presence of **dominant** monkeys). A raised tail in rhesus monkey signifies a dominant animal. In rhesus, upward or side way tail movements are associated with presenting of genital region and inviting for mounting or copulation. In Langurs, on other hand, a lowered tail is part of the female's invitation to mounting.

Pilo-erection (hair raising)

Many **small sized** new world monkeys show general pilo-erection display, in which all the hair on the body and tail are raised. All or more of the **tamarians** and **marmosets** have several different types of localized pilo-erection. They can raise different tracts of hair independently as different signals.It will be noted that all the species with pilo erection displays are of very small size and have little variety of facial expressions. Presumably raising long hair is visible over a longer distance than a change in facial expression.

Visual communication has the advantage of quick transmission. Visual signals are best used to attract mates or prey, but many a times also to ward off predators. However, this signal has its own limitations;

(1) they can not be sent long distances, through forest.
(2) colours attract predators, therefore, in most animals these colours are kept hidden and are only flashed when needed e.g. sudden opening of wings, bloating of throat. It can cause a delay in action.

Chemical Signals

Communication through chemicals falls in this category. Substances that can be picked up by the sense of smell are **pheromones**. They are produced by special ducted glands and are proteinaceous in nature. Found widely in insects and mammals

Chemical signals are the primitive form of communication among animals This form of communication has been well studied and documented. Chemical signals sent and received by individuals of the same species are called pheromones. Pheromones are powerful, a few molecules released into the air or water through **urine**, **sweat**, or **other bodily secretions** are enough to influence another animal's behaviour. Unlike visual, sound, or tactile signals, pheromones can **persist in the environment** for a long time. This is important for many cat species to scent mark a large area. Females release pheromones signalling fertility without knowing when the males will receive them. Because of their long duration, scent has the great advantage that it can be left to

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transmit information while the animal that made the signal goes away and does something else. It is however, a **relatively slow** form of communication, and has its own short comings :

(1) Pheromones are not effective carriers for complex or changing messages.
(2) The direction of these signals is determined more by air or water currents than by the sender.
(3) Rain and wind can greatly weaken the effectiveness of pheromones.

House shrew, striped hyena and black tailed deer produce scent under stress, other mammals mark territories, mates, pups, and their habitat with scent. The scent is released in many ways viz., along with urine, faeces and saliva, they are also produced through special glands.

[I] Use of urine and faeces

Urine or faeces of many animals have pheromones or scent through which they can communicate with conspecifics. The most common use of urine and faeces is to identify or scent mark **core area** (an area, used extensively and defended actively), **home range** (an area around core area, actively used but not defended actively) or **territory** (a bigger area around home range used or exploited but not defended). Some animals use urine and faeces for identifying pathways, resting grounds, feeding grounds and sleeping sites. Some animals urinate or defaecate on rivals, opponents, defeated conspecifics etc. The most interesting and strange example comes from mammals. The male **hippopotamus** mark their pathway between aquatic resting place and grassy feeding ground, by the deposition of dung at places along the trail, usually close to some conspicuous objects. As hippopotamus defaecates while walking on the trail it keeps moving its tail rapidly from side to side, (Fig. 11) so that the faeces are splashed out and get deposited all over the vegetation above ground level and thus, places it at nose height to make it more noticeable; **rhinos** mark their pathway by defaecating at prominent land marks and depositing piles of faeces so that it can be both smelt and seen. **Tigers** select specific places and mark their territories by their droppings. Main land serow of family Bovidae, found in northern India has fixed pathways of movements, initially these pathways are used visually and later the animal marks traditional spots by depositing its droppings there, so that it can just follow the scent and others are kept away. **Polecat** (a weasel like animal) and **civet** (Fig. 11) deposit urine and faeces at particular places along their trail too. The male **giant rats** and **skunks** have their own style of marking, they place their droppings above ground level by standing on fore limbs and hindlimbs supported against some solid object as they defaecate and urinate (Fig. 11), this is done to mark the area at nose level for easy detection. **Dogs**, **coyote** and **foxes** (Fig. 11) use just the urine to mark their territories, the scent left with urine indicates minute details like individual identity, male

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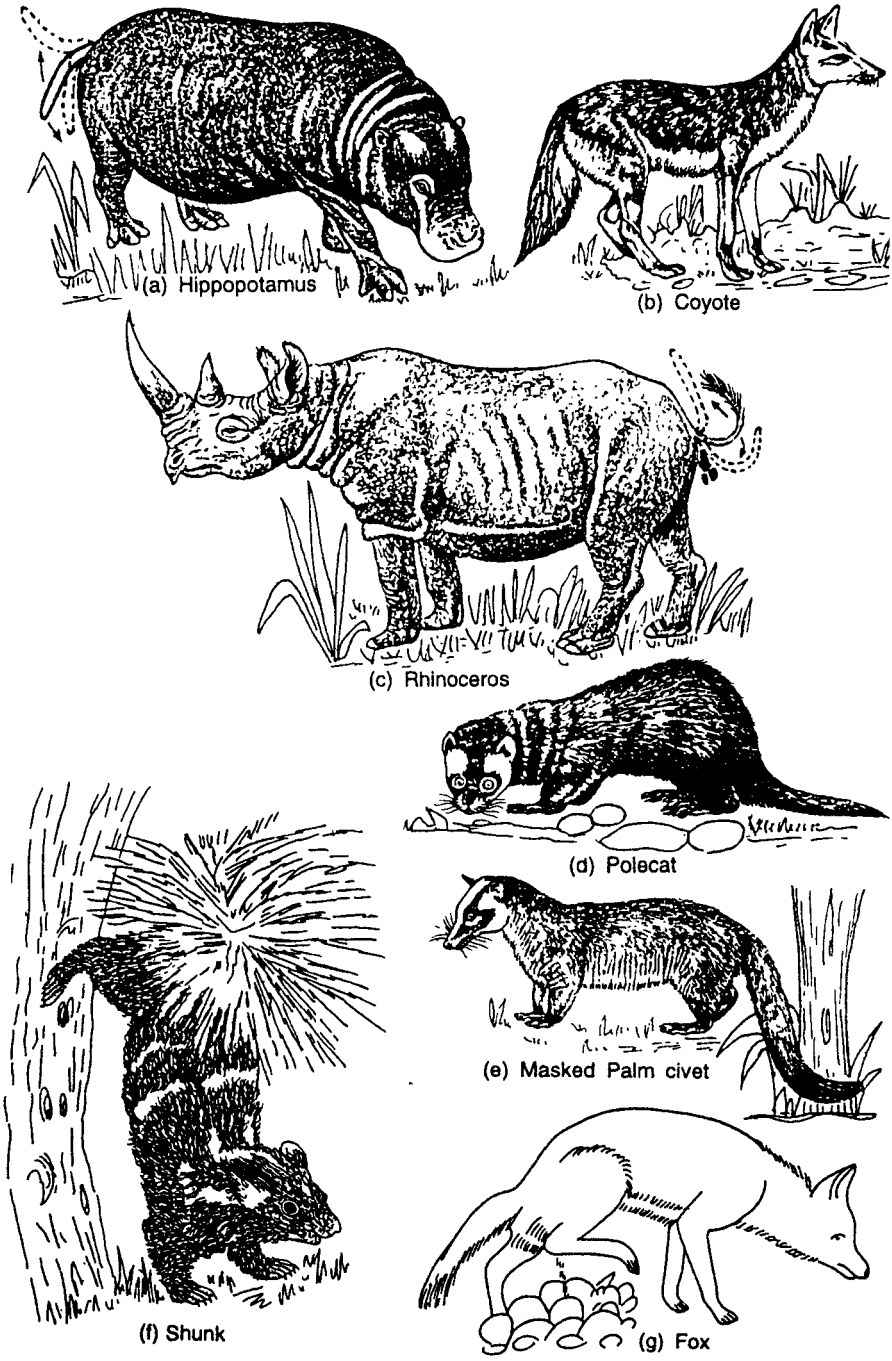

Fig. 11. Animals who use urine and faeces for scent marking

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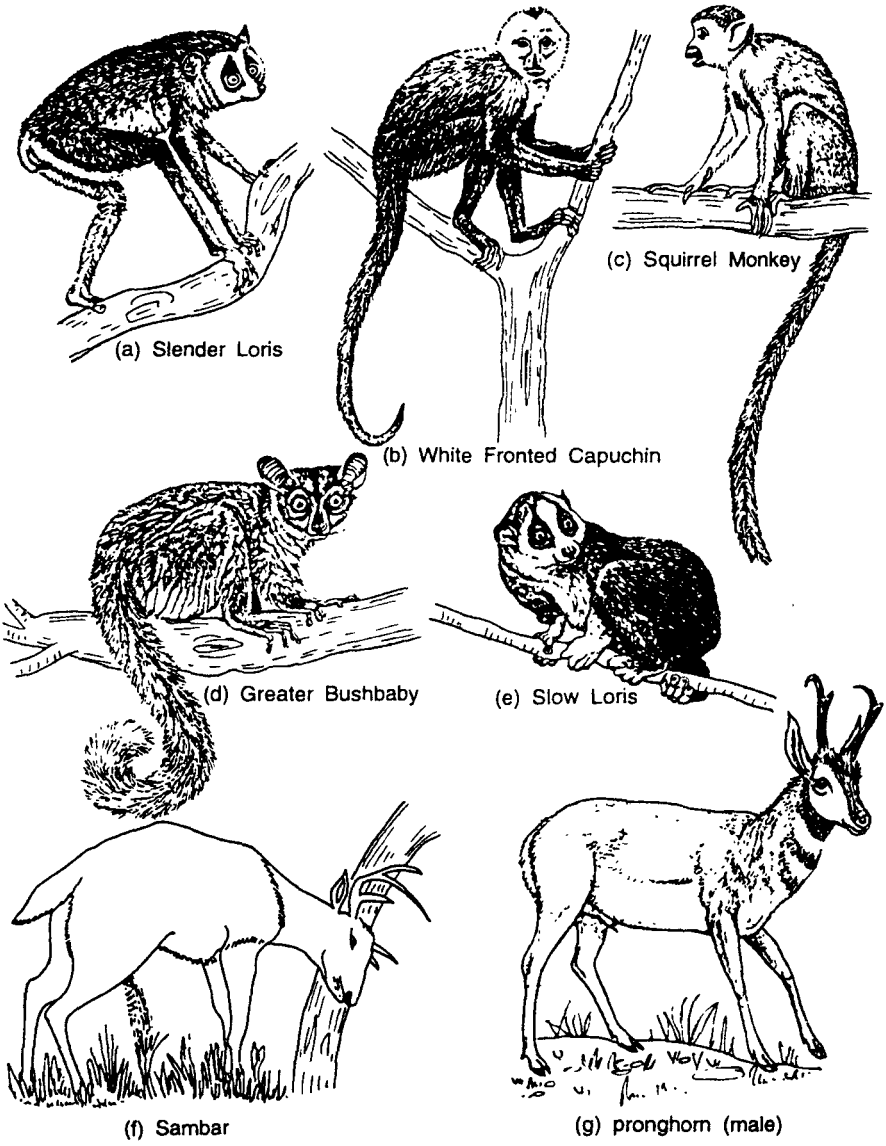

Fig. 12 Animals who use urine and faeces for scent marking

or female, dominant or subdominant, adult or subadult and also how long ago that area was marked.

Slow loris (Fig. 12) found in south east Asia are small sized primates,they occupy small territories which they mark by their urine. **Capuchin** (Fig. 12) a new world monkey, found in southern Central America lives in large groups among the dense foliage of forest trees, each group has its own home range

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in which the members move about. The adult members soak their feet and hands in their urine known as "**urine washing**" and smear it on the foliage. Urine washing is also seen in **slender loris** (Fig. 12). It is a small sized animal found in India. They sprinkle urine on tree trunks to mark their territory. Similarly, common **squirrel monkey** (Fig. 12) of northern South America, for demarcating its own territory, leaves a scent by soaking its body specially, tail in urine. **Proghorn** (Fig. 12), an antelope found in Canada, USA, Mexico and **sambhar** (Fig. 12) a common deer in India live in herds, during mating season the adult males become territorial and mark their areas with droppings and urine.

In greater **bush baby** (Fig. 12) the habit is further peculiar, while urinating one hand is held cupped in front of the urine which is rubbed on tree branches. In both cases the scent marking is done to identify the home or area where they spend maximum time. Some **lemurs** (non - human primates found in Madagascar) mark their territory by smearing their faeces on branches, quite like painting the house.

Lions, tigers leopards, and all other big and small male cats mark their home range with pheromone which is passed with urine. The cats select some suitable objects, back up to it, extend the back legs, raise the tail, as the urine is passed, the tip of the penis is curved backward so that the urine is given out as a fine jet between the hind legs (Fig. 13). **Bears** use two

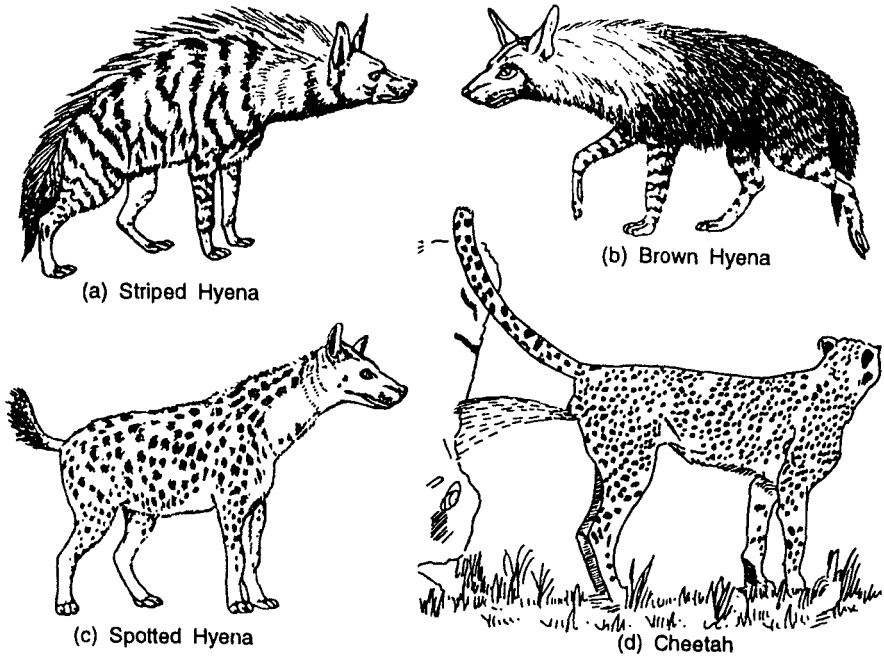

Fig. 13. Animals who use urine and faeces for scent marking.

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different ways, they first mark a tree by scratching and chewing the bark, and in addition, they frequently urinate on such trees to consolidate the marking. All three species of **hyena**, **striped**, **brown** and **spotted** (Fig. 13) mark the areas of their movement with urine and faeces, they also have special anal glands for the production of pheromones for the same purpose. Use of pheromones through urine and faeces had its own limitations, that the animal has virtually no control over their production and release and this could have been one of the reasons which led to development of special glands to produce pheromones.

[II] Use of special glands

Many species are not dependent on urine or faeces but have evolved special glands producing the scent, these have the advantage that their use can be restricted to necessity, that the animals could use pheromones as and when needed or production of pheromones remain under control, to prevent its automatic, unwanted release with urine and faeces.

1. Anal gland. The commonest scent producing glands are anal glands. The usual procedure among animals in applying secretions is to evert the anal glands and rub it on the ground or on object to be marked. Marking of this type occurs mainly in **Monotremes**, **Marsupials** and in **few Placentals**.

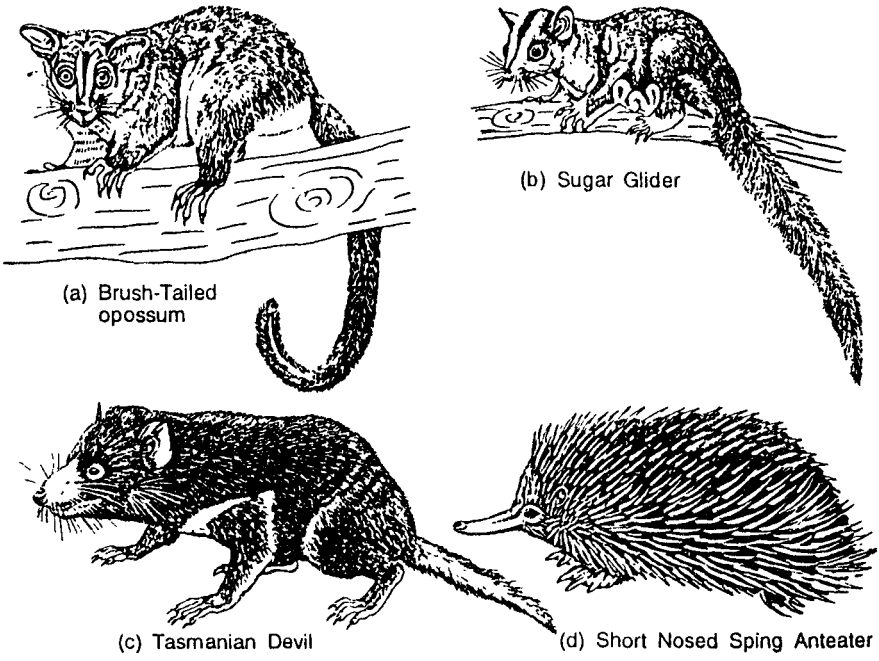

Fig 14. Animals who use secretions of anal gland for scent marking.

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The male **beaver** is tenacious about keeping strange beavers out of his neighbourhood, he virtually erects "No Trespassing" signs by pheromones on dams, lodges and feeding trails. He makes mounds by scooping up mud from his pond and on them he squats to deposit a smear from his anal scent gland. **Spiny ant eater** (Fig. 14) everts the cloaca and rubs it on the ground leaving a smelly mark. The **brush tailed opossum** and **sugar glider** (Fig. 14) have two types of cloacal glands with the help of which they mark their nests which is the most precious area for them. In the yellow footed marsupial mouse cloacal secretions are rubbed on twigs and branches around their small territory. The anal gland of **black and red tamarin** (Fig. 14) produces a strong smelling secretion which keeps others away. Male **tasmanian devil** (Fig. 14) has scent glands around its anus which it rubs on objects like stones, branches, ground and grass to protect his fe-nale and young ones. In most mammals marking the territory is the job of the male but in few selected ones like, **ring tailed lemur** (Fig. 15) which are small sized, long tailed primates found in Madagascar, both male and female have scent glands in their fore arms and anus, both rub their glands to mark their territory, however, males have additional scent glands, under chin and by the penis which produce pheromones to attract females. **Verreaux's sifakas** (Fig. 15) also found in Madagascar mark territories with urine and with secretions of males' throat glands. Brown hare of Europe, normally lives solitary and marks its territory with strong smelling secretions produced from glands situated in its anal region, around its face and inside its cheeks. These secretions are also important in its mating season to attract the mate.

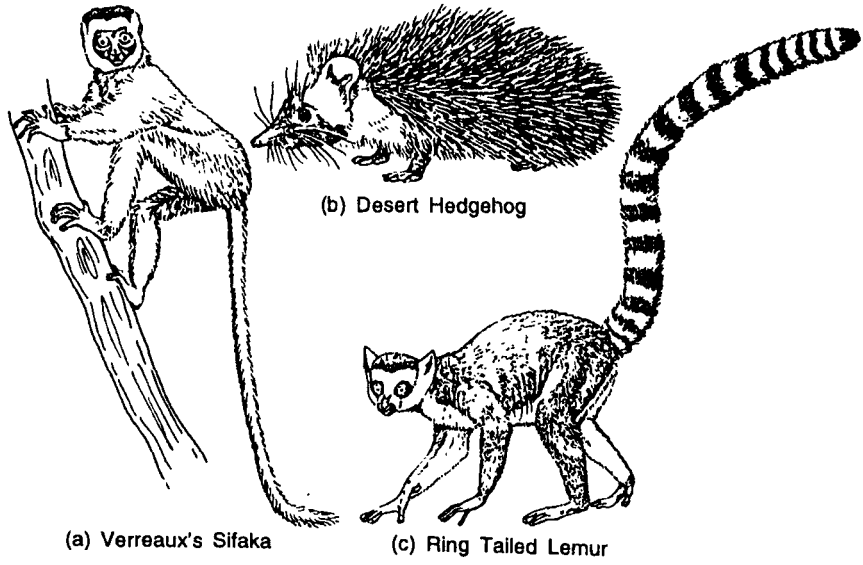

Fig. 15 Animals who use secretions of glands found in forearm, throat and saliva.

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2. Salivary gland. Saliva is a secretion available to all mammals, which has been used as a marking agent by bears, dogs, pigs and a number of other animals. Most marsupials deposit saliva on twigs by chewing them and hence marking the foliage of their territory. **Lesser hedgehog** (Fig. 15) first salivates

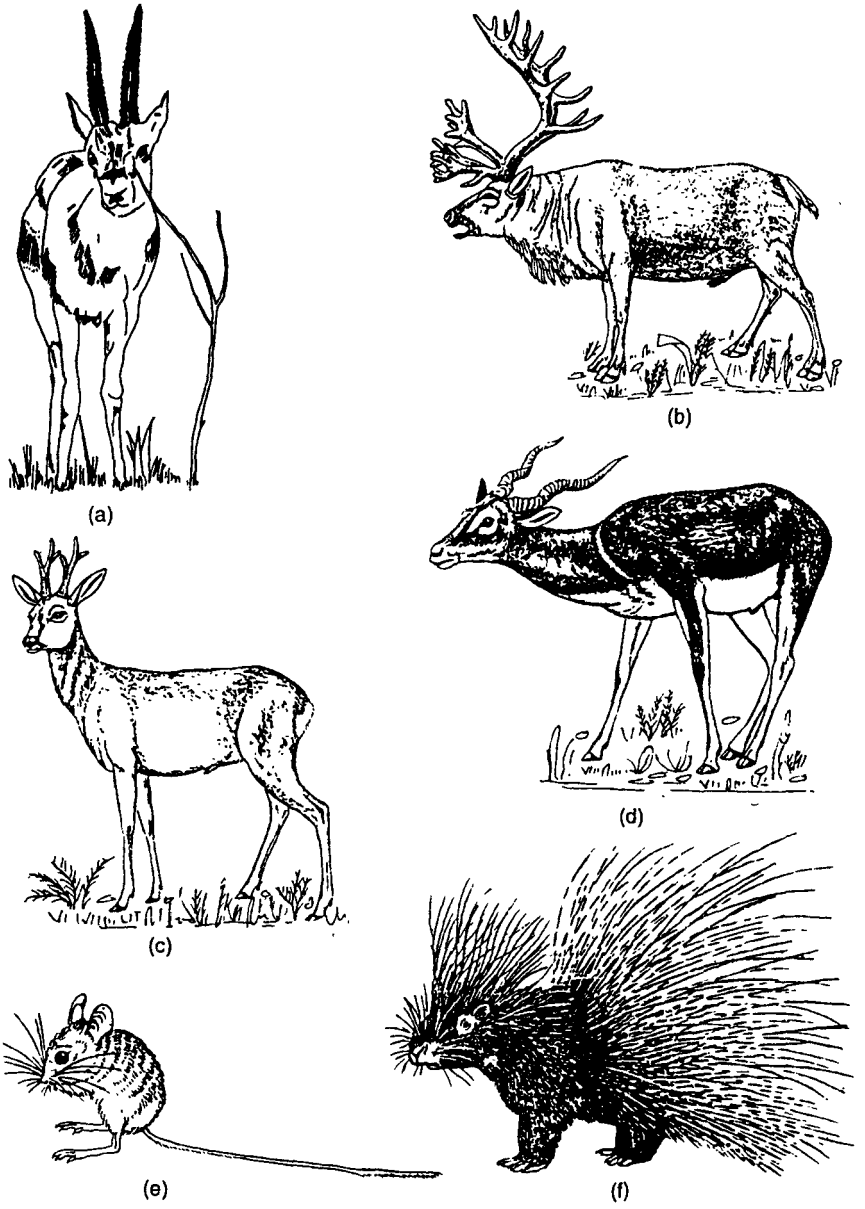

Fig. 16. (a) Thompson's gazelle, (b) reindeer, (c) roedeer, (d) black buck, (e) hopping mouse and (f) porcupine.

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on the object to be marked and then scratches it. A female rat licks its nipples to scent mark them so that its blind pups can reach them. A female wildebeest will lick its baby to scent mark it through its saliva for recognition.

3. Miscellaneous. There are many other glands via which the scent marking can be done. **Roe deer** (Fig. 16) of order Artiodactyla found in Europe and Northern Asia live in small groups, the stag marks its territory with secretions from glands on the forehead, anal and metacarpal glands and urine. **Roe deers, black bucks and sambar** (Fig. 16) found in India rub facial glands found just below the eyes against trees to mark them. Red brocket, found in Central and South America are small sized solitary deer, during breeding season, males mark territories by strong smelling substance produced from a gland situated at the base of the antlers, the females are attracted to this smell.

Thompson's gazelles found in Africa mark their territory by depositing scent on long twigs and grass (Fig. 16), this scent is a tar like substance which is produced by glands situated just below their eyes. Bulls of elephants have temporal glands which produce a scent to indicate that they are musth i.e. ready to mate and looking for a cow elephant in breeding season. The dominant male reindeer (Fig. 16) have scent glands between their hind toes, which help them to leave scent trails for the remaining members of the herd. **Ground squirrel** and **American porcupine** (Fig. 16) mark their mates and territories by rubbing with sides of the head. In marmot, the scent glands occur in the area between eye and ear. The secretions from these glands are used to mark their territory and mates. In Australian **hopping mouse** (Fig. 16) the scent glands are found below the chin which it uses to mark pups. In the camel the glands are situated on the neck which are rubbed against the object to be marked and plays an important role in mating. **Black tailed deer** has 5 different scent producing glands (Fig. 17), located at various places, producing different pheromones to carry out different functions.

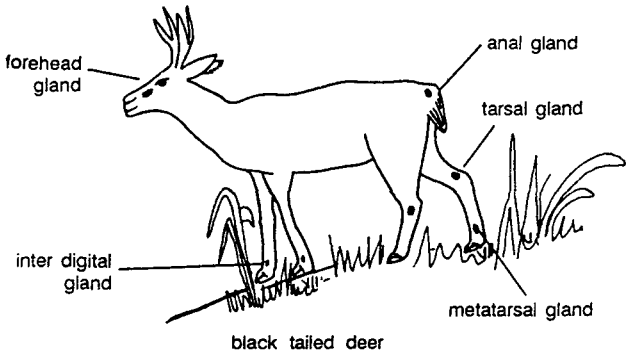

Fig. 17 Location of different scent glands in black tailed deer

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Functions of Scen. in Vertebrates

Not everything is known about pheremones and their secret functions. Much remains unexplored, decoding of chemical messages has been a difficult task. More than often, the pheromonen have been used as marking agents, and for mating purposes in most of the mammals. The knowledge about their utility in other functions remains obscure.

Roth-Kolar observed that for animals, any new object was a source of unease until it had been made safe by marking. It gives them a sense of belonging. In one instance, a sleeping box of a **fox** was removed for cleaning and returned after being thoroughly washed, the animal found it unfamiliar because all its body scent was washed out too. The animal stayed out all night and was found dead in the morning due to cold. The familiar smell gives a feeling of safety and sense of belonging by receiving its own body scent from its dwellings, it gives them a feeling that "this area belongs to me and I am safe here"

The scent increases the self confidence of the animal. **Kuhme** (1963) recorded that the **African elephant**, when facing a rival, during the breeding season will sometime turn his trunk round and smell his own temporal gland. This appeared to increase the animal's confidence and make him more likely to attack.

Scent plays an important role in sexual behaviour, the males mark their territories and ward,off the rivals which is most commonly seen in deer and antelopes or the rivals do not tresspass marked territory as seen in tigers and other cats. This behaviour can be easily observed among dogs, frequent urination by dogs, on all possible landmarks is a way of marking objects within their territory. Scent brings two sexes together in most of the vertebrates.

Many animals **mark** their **trail** just to leave a record of their comings and goings to be read by themselves and subsequent visitors as in **hippo** and **rhino**. These sign posts are regularly visited and inspected by neighbours and thus each animal can keep a check on his fellows without actually seeing them, a newcomer in the area will at once be detected and may be challenged. By marking the pathway animal does not loose path and conserves energy by not finding the way afresh every time it moves.

Scent is used for **marking the territory**, the territory is First acquired by fighting, then the territory is loaded with animal's scent indicating that no more fights are required for this particular territory. Sometimes males also mark their mates with scent e.g. male rabbit marks his female with his chin gland during mating. The male **rabbit** also marks the youngsters of his own group with his chin gland secretions. In certain animals, marking is often associated with a fight, **hamsters** mark a defeated rival and the marked animal subsequently retreats. **Mice** and **rats** similarly mark a defeated opponent with urine. A **wildebeest** sniffs her newborn calf to form a permanent olfactory

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bond with her offspring. The calf also sniffs mother for her odour. Many mammals, such as **bighorn sheep, dogs** often sniff and smell at each other and, when they do so, they can probably know the sex, the group it belongs to and its **readyness for mating.**

Tactile Communication

Communication resulting from actual physical contact are through tactile signals. They are used extensively in **social bonding, infant care, grooming,** and **mating.**The type of signal most frequently used by a particular species is directly correlated to the sensitivity of their receptors. Hence an animal with keen eye sight will use visual signals, whereas, one with poor eye sight, but a keen sense of hearing will use acoustic signals. Tactile Communication is when animals use touch in one or the other ways to communicate something to each other. In our day-to-day life we see a cat rubbing its body against ours or our pet dog offers us its paw this way they are communicating their affection towards us.

Among animals, touching is not the most common way of communication but it is used in very special and important activities like social bonding, infant care, grooming, and mating. **Wolves** lick the muzzle of the dominant male in the pack as a greeting. **Monkeys** and **apes** move their fingers in each others fur coat known as **grooming** they pick bugs out of other's fur .It is also a display of dominance and affection. Touch and bodily contact are used most extensively by primates, particularly **baboons, rhesus, langurs, gibbons,** and **chimpanzees.** These animals frequently seize each other in warm embraces and also may lightly touch, push, nibble, or actually kiss each other.

Tactile communication or touch is an important form of communication for social animals. Mother **tigers, goat, deer, dogs** lick and nuzzle their babies, and **bear cubs, monkey babies, dog pups** practice wrestling during play. In most animals, touch is used to comfort each other many monkeys embrace each other, touch is also used to establish dominance between males in the form of aggression as in antelopes, deer, elephants, tigers monkeys, touch even plays an essential role in establishing attachment bonds

Billing in birds serve multi functions. **Masked Lovebirds** *Agapornis personala* billing is done by mated pair as a greeting or to end aggression. In **Canada jay** *Perisoreus Canadensis* billing is done by subordinate birds in a flock. Stags in **springbok** rub a female with head and female nuzzles him as a sign of acceptance for mating (Fig. 18).

Touch is important to many primate species. Primates are social animals. They live in large groups. Touch helps the group form bonds and stay peaceful. Female primates often hold and frequently cuddle and comfort their. Young animals are playful, they pull, push,chase,bite,wrestle . They use touch to establish social bonds. **Otters** rub their faces together and touch noses.

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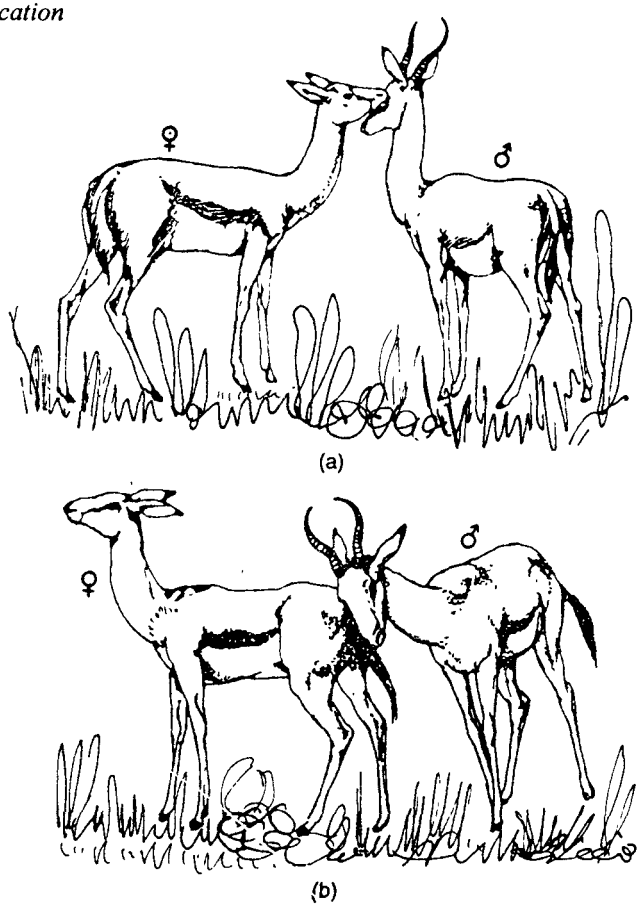

Fig. 18. During courtship (a) Female springbok gently touches and licks the face of a male, communicating him her willingness to mate. (b) In turn male rubs his head near her vagina just prior to mounting.

The sea otter may even touch noses with other animals like **seals** and **sea lions** as a friendly gesture.

Communication by touch is especially important in **social insects**. Members of an **ant** colony constantly **tap** and **touch** each other; these activities strengthen the ants' social bonds. Tactile, visual and chemical communications in bees have particularly interested researchers because of their surprising complexity. When a foraging bee discovers a new food source, it returns to the hive and performs a detailed dance, a phenomenon first interpreted by **Austrian zoologist Karl von Frisch**. Information is communicated primarily by physical contact as hive mates follow and touch the dancing bee. The orientation and speed of the dance, as well as the size of the area covered by the dancer, tell the other bees precisely the distance and location of the food. Zoologist Karl von Frisch found that bees use two types of dances to

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provide information about the location and direction of food. The **round dance** is a circle pattern used when food is nearby. The **waggle dance** is a figure of eight pattern to show food is further away. The details are given ahead.

The effectiveness of tactile communication is limited by distance-one animal must be touching another in order to convey information but the advantage of tactile communication is that it can be carried out even when it's totally dark. Even in dark interior of a hive a returning bee, having found a source of food, by tactile communication can notify her fellow bees. Tactile communication differs from the others in that the sender of the message must be in **physical contact** with the receiver. Frequently this type of communication is associated with the **courtship process** and the relationship between members of a **mated pair**. **Birds** of a mated pair are frequently observed **preening** one another in such a way, that to an observer, they appear to be displaying real love for each other.

Some insect species use ants as their **body guards**, e.g. **aphids** keep ants, ants surround them for protection, in turn, aphids pay them back a honey like substance to eat, when ants are hungry they tap their antennae on aphids. The ability of animals to communicate with members of the other species also occurs. A female **killdeer bird** may move as if its wing were broken with the result that a predator is distracted from her nest.

It's been agreed upon that sound, vision, touch and smell are of primary importance, and their extent of use and importance varies from species to species. Its been well documented that **communication by sound** is better over other forms, by using sound animal can get "**more information packed into a signal for a given unit of time**" whereas using pheromones, it becomes difficult to get rid of the first part of a message in order to send the next bit and it would be almost impossible to send a long, complex message through chemicals. The same is true with visual signals, the animal has to indulge into motor activities to communicate. this is limited to distance, the receiver should be within a short distance to see, whereas, sound can be sent on long distances. For tactile communication the animals have to be very close to establishing a contact. The sound signals can be turned on and off quickly, the other signals cannot be. At night sound has obvious advantage over other forms of communications. Visual signals attract predator easily whereas, locating a sound source in forest and at night is difficult. Sound also enables animals to announce its territorial rights without having to visit all parts of its domain.

Animals also use a **combination of communication methods, ring tailed lemurs** have long black and white tails for visual signalling, a large repertoire of sounds, and special glands for scent marking. In an experiment with **turkey**, a deaf female-laid eggs, sat and incubated them normally, but behaved in a very odd way when they hatched. She was unable to recognize the chicks and

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ran to kill them, normally females learn to identify the calls of their own chicks and rush to kill strange chicks, but because this female was deaf, therefore, could not identify even her own chicks in spite of visual information. This indicates that she was more dependent on sound for chick identification than looks. It's very common to note that communication between individuals in nature involves not just one type of signal but a combination of several types.

Animals do not rely on a single sensory modality (e.g., vision or sound), but can use a number of signals. For example, lekking in **golden collared manakins** involves the visual signals as males jump about from perch to perch and auditory signals that is synchronized with the visual as a male makes a leap it makes a loud snapping sound. Same category of signals can also be used twice eg large herbivores give a "pursuit invitation display" that involves two visual cues. When they detect a predator, **deer (and gazelles)** lift their tail to reveal a white patch of fur and they also move away with a stiff legged gait.

Communication is utilized to recognize individuals of own species to avoid infertile mating between members of closely related species. One study on two species of albatrosses– one is a white bird with a dark back and wings, while the other, the black-footed albatross, is brown in colour with a whitish area at the base of the bill. It is rare to find these two species breed with each other though they nest within inches of each other. Courtship dances of the two species were filmed and were found different. Elaborate courtship pattern in two closely related species has developed for one function only—to ensure that female albatross of one type can recognize a male of her own type.

As mentioned earlier multiplicity of signals are used: visual; acoustic; and tactile. **Complex** and **varied signals reduce the possibility of error and increase the integrity of the species.** Wasteful hybrid production is eliminated because hybrids are usually sterile. Production of sterile progeny destroys the species therefore, from evolutionary point of view hybridisation must be prevented.

In a bee hive or termite mound or nest of ant's class or caste recognition comes through chemical communication some bees when alarmed buzz together in such a way that it resembles the hiss of a shake, this sound is provided to scare away predators.

When threatened **Texas horned lizards** inflate head, they also burst the walls between sinuses and eye sockets, squirting out jets of blood from their eye. In the deep sea 80% of animals emit light to communicate something or the other.

Touch is probably of enormous social significance for all primates. In human beings also tactile signals are highly developed and play a crucial role in courtship behaviour and in relationship between parent and offspring. The

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only tactile signal which is wide spread and of significant importance in many primates is - **Grooming**.

If the skin and all of its various allied structures like scales and hair are to carry out their various functions efficiently, they must be kept in good conditions. As a general rule an individual will clean itself, but the individuals of certain species spend some of their time in grooming another member, usually of the same species. This kind of behaviour has been referred under a variety of names - **social grooming, mutual grooming, reciprocal grooming, flea catching, louse picking**.

In certain Prosimian Primates e.g. *Cebuella pygmae* lack grooming. In *Autus trivirgatus* (new world primate) it is rare or absent in other circumstances. *Saimiri sciureus* ('new world primate) performs autogrooming. In **Lemurs** and **Loris** grooming is a common social activity. Mutual grooming plays an important part in the social life of Chimpanzees. They will sit quietly for hours for grooming each other. Grooming involves two distinct types of behaviours.

Invitation behaviour

It involves – an individual approaching a groomer, and sitting down squarely (directly opposite) in front of it but facing sidways and presenting its back. A monkey inviting grooming will not look at the groomer, but will usually turn its head away because looking an opponent is a sign of threat. Once the groomer has started to manipulate the fur, the groomer will make constant adjustment and present different areas of the body to receive attention. If their eyes meet, their the groomer will usually lip-smack vigorously, and look ways once again. It their methods fail the animal which is inviting grooming will sometimes mount the others, who then turns and grooms it. In rhesus, the favourite wife spends much of her time grooming the male, and he sometimes grooms her. The other females groom each other, the subordinate groom the superior more than vice-versa.

Grooming behaviour

In primates, cleaning of the body surface is mainly done by fingers but use of mouth, either through licking or combing with teeth is seen too. In Lemurs, the specialized incisors of the lower jaw are used as comb. Tree shrews use the teeth and tongue for grooming.

Grooming is a conspicuous activity in macaques, troop of *Macaca radiata* start their daily routine with mutual grooming. Grooming is not very common in Gorillas. One thing important about grooming is that it appears to be roughly correlated with the kind of social structure prevailing within the species. As in **macaques** and **baboons** where animals rigidly maintain dominance hierarchy show more grooming than those in which there is a less well defined hierachchial organization like **red-tailed guenon**. Animals of

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lower status tend to groom those higher in the social hierarchy. It has been observed in *Macaca mulatta* that, a subordinate monkey (lower ranking) will groom higher rank animal with busy movements and constant adjustment to the groomees changes of position. Whereas, a dominant individual will groom one of lower ranking less vigorously.

Besides cleaning each other the primary function of grooming is to reduce or remove certain social barriers between low and high ranking individuals. Grooming helps to do so because it pleases or satisfies the individuals being groomed. Therefore, grooming is extremely important for maintaining peace and cohesion in otherwise aggressive primate societies.

Tactile communication includes grabbing or holding fur, biting, tail pulling. A high ranking **vervet monkey** will approach a lower ranking and firmly grab her fur and even pulls. **Baboons** and **Chimpanzees** use touch for greeting.

Touch has a great role in the life and relationship of mother and infant. Jane Goodall (1963) has described many interesting incidents. Once she saw a mother Chimp pulling her little kid towards her body to give warmth. The mother chimpanzees play with their babies, in her own words. "The mother first patted her kid, then pushed the kid to and fro until the delighted kid tumbled down on top of her. Then she bounced her kid up and down in air with her feet and then suddenly bent her knees so that the kid collapsed on her".

Language of honey bees

A very remarkable animal showing a highly developed pattern of orientation is the **honey bee** (genus *Apis).* This animal feeds on nector of flowers which may be at quite a distance from its hive. It is really amazing that the bee is able to convey to its hive mates the information about the food source complete in respect of distance and direction precisely. **Karl von Frisch** was the pioneer who devoted a considerable part of his career in deciphering the mechanisms by which the bees are able to communicate with its hivemates. In order to establish this fact that bees pass on this information, a very simple experiment can be performed. If a dish containing sugar solution is kept near a hive, bees may not visit it for some time but once a bee visits it, very soon many more follow suit. Somehow the first bee conveyed the information about the sugar solution to other bees. Von Frisch made glass enclosures in which a hive could be kept and bees observed. He also used coloured markings on the bees. In summary, when a bee discovers a food source near the hive it passes on the information to other bees by performing a special dance the "**Rundtanz**"or the "**Round dance**" It turns in circle, alternately to the left and right on the face of the honey comb (Fig. 19). After a short while the other bees start following this dancing bee and soon they fly off to look for the food and on return they also perform the dance thereby increasing the number of foragers (workers). The first bee also carries the scent of the flower it visited so the followers seek the flower with the same scent. There

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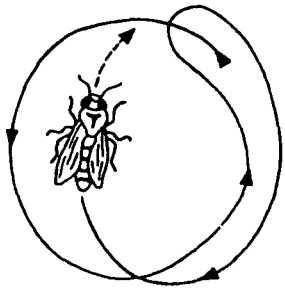

Fig. 19. Round dance of honey bee.

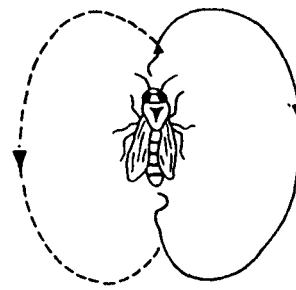

Fig. 20. Tail wagging dance of honey bee.

is a relationship in the duration and liveliness of the dance and the richness of the food source. The richer the source, the more lively and longer the dance and if it is so, more strongly the other bees are attracted. When this large number of bees have exhausted the nector, they gradually slow down and ultimately stop dancing altogether signalling the end of food supply from a particular source and a new source is then searched.

When the food source is located further than 250 feet, this round dance is replaced by another type of dance, the "**Schwanzeltanz**" or the "**Tail wagging dance**". The liveliness of the dance indicates the richness of the source and the scent points to the specific flower but in addition the information regarding the direction and the distance is also conveyed precisely. In this type of dance the bee runs in a straight path for a short distance on the face of the hive, wagging its abdomen from side to side and once on the top of the run, it returns back to the starting point in a semicircle and then starts on the straight run once again but would now make the semicircle on the opposite side (Fig. 20). This sequence is repeated many times. The tempo of the dance indicates the distance of the food source from the hive. As the distance increases, the number of complete dance pattern in a given time decreases e.g. a bee may complete 15 runs in 30 seconds for a distance of 1000 feet but may do only 11 in this time (30 seconds) if the food is 2000 feet away. However when the bees which follow this dance move out to look for the food they not only know the distance but also the direction as well. This information about the direction is conveyed taking into account the position of sun as reference. The bee while searching for food remembers the position of the sun and when she comes back and performs the dance she orients herself in such a manner that on the straight run of her dance, she keeps the sun on the same side and same angle. This is possible only when the dance is performed on the horizontal surface and most of the time it is performed on the vertical face of the hive which is also dark. In such a case the angle of its straight run to the vertical, points to the food source. The vertical represents the direction of the sun. If the food is directly in line of sun, then the straight run of wagging dance would be straight up the face of the hive, and if the food is in opposite *(Z–37/Ani. Beh.)*

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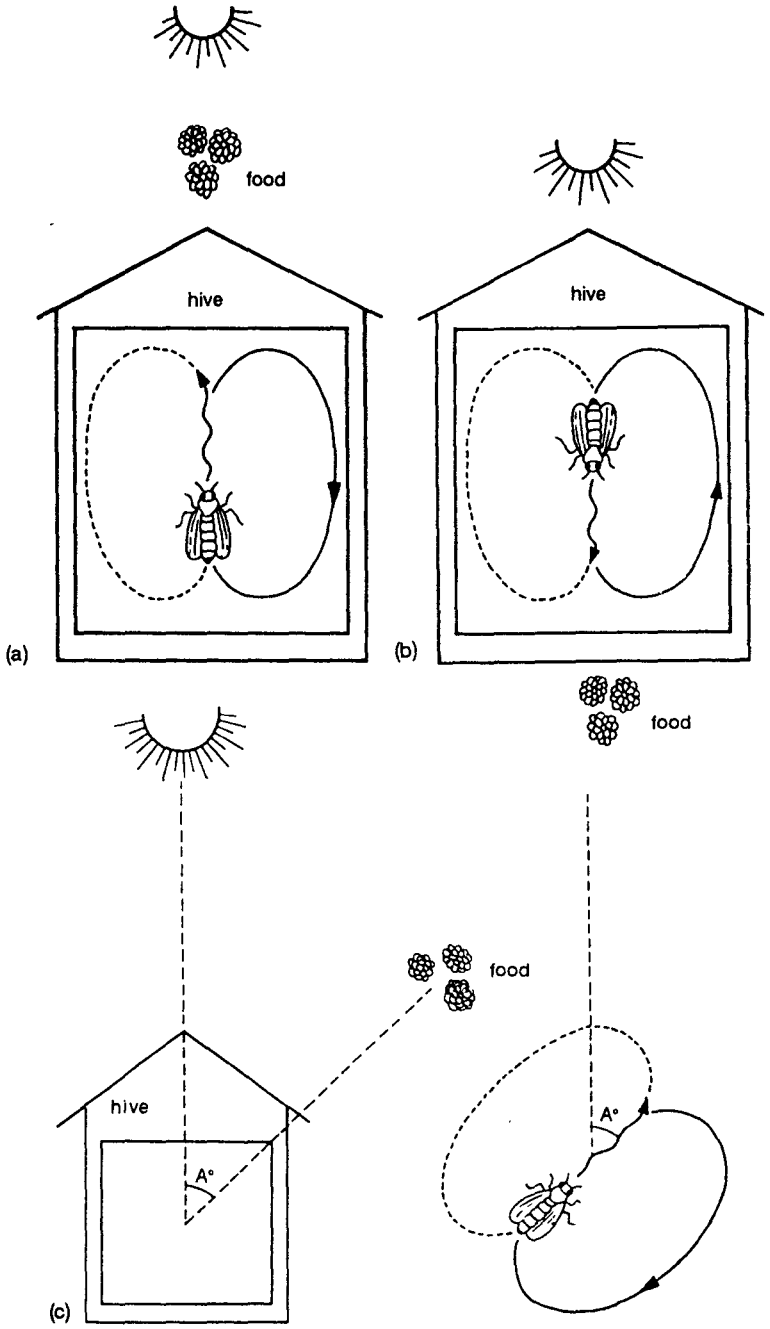

Fig 21. (a) (b) (c) Honey bee performing tail wagging dance to indicate the location of food source with respect to the direction of sun

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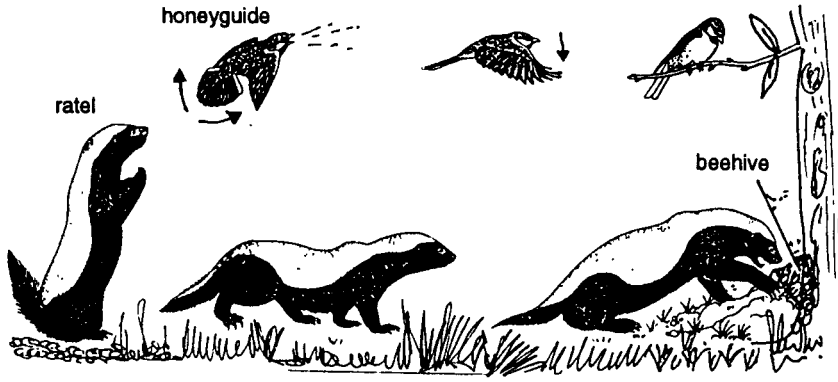

Fig 22 Communication between two species A honey guide bird locates a bee hive in a hollow tree trunk Finds a Ratel, attracts its attention by calling, tail fanning and wing flapping The Ratel follows the bird Finds the hive, breaks it While Ratel feeds on honey and comb, the bird catches bees

direction to the sun, then the straight run would be down the face of the hive but if the food is, say 30° to the right of sun then the straight run would be 30° to right of the vertical. (Fig. 21 a, b, & c).

Interspecific Communications

Communication can take place between the individuals of same species or between different species. Communication between individuals of the same species is the most common, yet in nature it is not unusual within a community for individuals of one species understand the signals given by different species. The **rove beetles** live as parasites in the **wood ant** colonies.The host ants feed and groom the beetle larvae as well or better than they does their own young. How do these beetles get all this from ants? They have mastered the ants' language and are able to mimic perfectly their communication signals, both chemical and tactile .they are so perfect, that they can often obtain more food than the ant larvae themselves. An interesting relationship, exists between a bird and a mammal. The bird, known as the **honey guide**, actually leads the mammal, the **honey badger** (Fig. 22) to a bee's nest. The tribal people is exploiting this unique relationship and by imitating the voice of the honey badger, can gain the services of a honey guide. What does the honey guide gain from this relationship? Its dinner of beeswax and bee larvae. The African native is, by no means, the only man who has successfully intercepted animal signals. There are many such examples where human have learnt to identify animal ways of communication and are taking advantages from them and forest.

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IMPORTANT QUESTIONS

➤➤ *Long answer type questions*

1. Define communication. Write briefly on each type.
2. Write advantages of communication and describe sound communication in details.
3. Compare acoustic and visual communications, giving details of each.
4. How animals use chemicals for communication ? Write in details.
5. Describe low, medium and high frequencies of sound with diagram and examples, mention decibel rating of various sounds. Add a note on ultra sound communication.

➤➤ *Short answer type questions*

1. Auditory communication.
2. Visual communication
3. Tactile communication.
4. Chemical communication.
5. Infra sound communication.
6. Ultra sound Communication.
7. Echolocation.
8. Tactile communication in non human primates.
9. Use of urine and faeces in communication.
10. Use of saliva in communication.
11. Use of special scent producing glands.
12. Scent marking in vertebrates.
13. Language of honey bees.
14. Interspecific communication.

➤➤ *Very short answer type questions*

1. Definition of communication.
2. Advantage of sound over sight.
3. Infrasound communication.
4. Ultrasound communication.
5. Waggle dance.
6. Circle dance.
7. Doppler effect.
8. Interspecific communication.
9. High pitched sounds in non human primates.
10. Low pitched sounds in non human primates.
11. Decibel rating.
12. Gestures.
13. Postures.
14. Pilo erection.
15. Grooming.
16. Visual bluff.

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➤➤ ***Fill in the blanks***

1. Penguins recognize their babies by.....
2 Bats use..... .. as a form of communication.
3 Decibel rating of human whisper is.....
4 Human pain thresh hold for sound is ....
5 Human ear can hear sound between .. .. and .....
6 Howlers and gibbons produce sound from ... .
7 Rattle snake produces sound from. ... .. .
8. Storks make sound by .....
9. Beating of chest for sound production is done by. ..
10. Ghost crab produces sound by rubbing ..... . and . .
11 Sound lasers are produced by..... ..
12. Grunt and bark are.....pitched sounds produced by . .
13 Squeaks, trills are .. .... pitched sounds produced by... ...
14. Evolution of colour and shape (badges) are . . . .adaptations
15. Evolution of display of feathers and fins are.....adaptations
16. Light bearing organs in fish are..... .....
17 Bird of paradise in found in.. . ...
18. .. ... collects fresh leaves and flowers in its nest.
19 Hippo and Rhino use ..... . for chemical communication.
20. Skunk and Palm civet use .....for chemical communication.
21. Urine washing in done by .....
22. Greater bush baby and white footed capuchins use.. .and . ..for chemical communication
23. Sugar glider and Tasmanian devils use .. . for chemical marking.
24 Hedgehogs use . .for scent marking.
25 Sambar scent marks by rubbing.. gland
26. Pilo erection is . . ....

Answers

1 sound, 2 echolocation, 3 30dB, 4. 120dB, 5. 20Hz and 20,000Hz, 6. resonating air chambers, 7. dried tail scales, 8 clapping of beak, 9 gorillas, 10. claw with appendage, 11. dolphins and sperm whales, 12 low, monkeys, 13. high, monkeys and dolphins, 14. structural, 15 behavioural, 16. photosphere, 17. New Guinea and North Australia, 18. Bower bird, 19. urine, 20 urine, 21. Capuchin monkey, 22. urine and faeces, 23. anal gland, 24 saliva, 25 facial gland, 26 raising of hair.

➤➤ ***True and false***

1. Penguins recognize their babies by sound.
2 Bats use echolocation as a form of communication.
3. Decibel rating of human whisper is 30dB.
4. Human pain thresh hold for sound is 120dB.
5 Human ear can hear sound between 20Hz and 20,000Hz.
6. Howlers and gibbons produce sound from resonating air chambers
7 Rattle snake produces sound from dried tail scales.
8 Storks make sound by clapping of beak.
9. Beating of chest for sound production is done by gorillas.
10 Ghost crab produces sound by rubbing claw with appendage.
11 Sound lasers are produced by dolphins and sperm whales.

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12. Grunt and bark are low pitched sounds produced by monkeys.
13. Squeaks, trills are high pitched sounds produced by monkeys and dolphins.
14. Evolution of colour and shape(badges) are structural adaptations.
15. Evolution of display of feathers and fins are behavioural adaptations.
16. Light bearing organs in fish are photosphere.
17. Bird of paradise in found in New Guinea and North Australia.
18. Bower bird collects fresh leaves and flowers in its nest.
19. Hippo and Rhino use urine for chemical communication.
20. Skunk and Palm civet use urine for chemical communication.
21. Urine washing in done by Capuchin monkey.
22. Greater bush baby and white footed capuchins use urine and faeces for chemical communication.
23. Sugar glider and Tasmanian devils use anal gland for chemical marking.
24. Hedgehogs use saliva for scent marking.
25 Sambar scent marks by rubbing facial gland facial gland.
26. Pilo erection is raising of hair.

Answers

1. True, 2. True, 3. True, 4. True, 5. True, 6. True, 7. True, 8. True, 9. True, 10. True, 11. True, 12. True, 13. True, 14. True, 15. True, 16. True, 17. True, 18. True, 19. True, 20. True, 21. True, 21. True, 23. True, 24. True, 25. True, 26. True.

➤➤ ***Multiple choice questions***

1. Normal human conversation has sound level of
   (a) 30dB (b) 120dB (c) 60dB
2. Communication by echolocation is found in
   (a) Bat (b) Oil bird (c) Both
3. Chest beating is seen in
   (a) Chimpanzee (b) Gorilla (c) Rhesus
4. Leaf cutting ants when trapped
   (a) Tap or knock (b) Produce pheromones (c) Both
5. Claw is released with a noise in
   (a) Spiny lobster (b) Ghost crap (c) Pistol shrimp
6. Infra sounds are
   (a) Below human hearing scale (b) Above human hearing scale
   (c) In between human hearing scale
7. Infra sounds are produced by
   (a) Elephants (b) Finback whales (c) Both
8. Ultra sonic sounds are produced by
   (a) Elephants (b) Finback whales (c) Porpoise
9. Leaf cutting ants
   (a) Grow fungus (b) Grow mushrooms (c) Grow nothing
10. Secondary sexual characters in a male Sambar are
    (a) Antlers (b) Horns (c) Fur coat
11. Bird of Paradise is found in
    (a) Africa (b) New Zealand (c) New Guinea
12. Bright colours, specially yellow and red in animals generally mean
    (a) Danger and warning (b) Beauty and mating (c) Nothing
13. Chicks of Herring gulls peck at
    (a) Beak (b) Red spot (c) Both

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14. Lip smack is a
    (a) Gesture (b) Posture (c) Both
15. Pilo erection is seen more in
    (a) Big sized animals (b) Small sized animals (c) Only in reptiles
16. Rundtanz means
    (a) Circle dance (b) Waggle dance (c) Nothing
17. Schwanzeltanz means
    (a) Circle dance (b) Waggle dance (c) Nothing
18. More information packed into a signal for a given unit of time -is
    (a) Chemical communication (b) Sound communication
    (c) Tactile communication
19. Thelma Rowell studied
    (a) Chimpanzees (b) Rhesus (c) Gorillas
20. Jane Goodall studied
    (a) Chimpanzees (b) Rhesus (c) Gorillas

Answers

1. (c), 2. (c), 3. (b), 4. (a), 5. (c), 6. (a), 7. (c), 8. (c), 9. (a), 10. (a), 11. (c), 12. (a), 13. (c), 14. (a), 15. (b), 16. (a), 17 (b), 18. (b), 19. (b), 20. (a).

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5

Reproductive Behaviour in Animals : Courtship and Mating

Introduction

Species survival is dependent on two most important things :
(1) Eat and avoid being eaten.
(2) Mate and reproduce to pass genes to the next generation.

Courting birds and fish have always fascinated people with their apparent graceful movements and the beauty of their body parts and eye catching colourful displays. Scientists define the term "**display**" as "behaviour patterns that expose special structures and colours". German ethologists have coined the word ***Ausdruksbewegungen*** **(expressive movements)** because they express moods and interaction between individuals. The general understanding is that **Courtship refers to all expressive movements involved in pair-formation and copulation.**

Everyone has been fascinated by this behaviour, perhaps through direct observation of animals, perhaps through books or films. One very common example is the courtship of peacocks, which can be seen easily and is an extremely attractive sight. Important function of courtship is to synchronize the reactions of male and female so that copulation can take place.

A courtship situation does not always have to be very noticeable, nor do we necessarily perceive it as either beautiful or bizarre. Even certain single celled animals display a complex preconjugation behaviour, such as *Paramecium* they swim around each other for up to half an hour, roughly on the same spot by constantly changing direction. They can lose each other, find each other again or continue this ritual with a new partner. Once two

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paramecia have met the preliminary ritual enters a new phase. The partners no longer swim around each other but remain side by side, separated by a distance equal to the length of their cilia, their anterior ends pointing in the same direction, swimming back and forth on the same spot for about a quarter of an hour. During the final minutes they come closer and closer, then suddenly jerk and cling together and exchange nuclear material. Undoubtedly this can be called as **beginning of courtship**. The courtship can be seen in animals having either external or internal fertilization.

Types of Fertilization

It is common for individuals of a species to be divided into **males**, **females** and **hermaphrodites**, which have to mate so that genetic material can be combined or exchanged and passed on to the offspring. **Union of sex cells is the characteristic of sexuality.**

Following two types of fertilizations are found in animal kingdom.

(I) External,
(II) Internal.

[I] Exernal fertilization

Courtship among animals having external fertilization like **fish** and **amphibians** leads to prolonged interactions between male and female. The **elaborate courtship** has evolved largely as an adaptation that **ensures** that eggs and sperms are released into the outside world at precisely the **right moment** so that the **risk** of their being dispersed before they can meet and fuse are **minimized**. The external fertilization can further be of two types :

The male and female never meet. One finds a suitable place, spawns and leaves; the other mate chemically locates this spawn and spawns over it and fertilization takes place. In this kind of fertilization there are great chances of wastage of important vital cells.

In another kind, **the male and female stay together**, they indulge into some kind of rituals whose biological significance is to attract each other, check each other's genitalia for readiness, or excite each other for synchronized spawning. Thus ensuring fertilization. Because in this, egg and sperm cells are simultaneously ejected into the water, where they unite. Thus there is little wastage. Groups of diverse aquatic animals show this type of fertilization, such as **Ctenophores, Echinoderms, Chaetopods Mussels, many fishes and frogs.**

Example of **mouth breeding** is very unique in the category of external fertilization.In the mouth breeding **Cichlid fish** of the genus *Haplochromis,* the female picks her eggs into her mouth cavity immediately after spawning, when they are not yet fertilized. Next, the male swims past the female's mouth, with his body leaning to the side and his anal fin spread out pointing

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toward her. This fin has a row of yellow spots that greatly resemble this species' eggs in size and colour. The female rubs her nose against these "dummy eggs", as though she wants to pick up some that she had "forgotten." At this moment, the male ejects a stream of sperm fluid which the female inevitably takes inside her mouth. In this way the eggs in her mouth get fertilized.

[II] Internal fertilization

The sperms are deposited inside the body of the female. This kind of fertilization can be carried out in two ways :

(1) The more **primitive way** is that the sperm cells are deposited in packets (**spermatophores**) which are actively taken up by the female e.g. **Smooth Newt, Sharp ribbed Salamander and Palmate Newt.** In these the males deposit a bundle of sperms on the ground, the female follows, keeping her nostrils close to cloaca, the male moves away giving her way, she moves over the spermatophore and her cloaca picks it up (Fig.1a, b, c).

(2) **In advanced way** there is regular **mating** or **copulation.** In this, a **physical contact** is established between the male and the female e.g. **arthropods, snakes, birds, mammals.** In this, the male deposits the sperms inside the body of female with the help of special copulatory structures found on both male's and female's bodies.

Internal fertilization in vertebrates evolved as an adaptation to terrestrial life. In **fish** and **frogs** the fertilized eggs remained in water, but as the **reptiles** emerged on land the eggs had to be with a shell to protect them

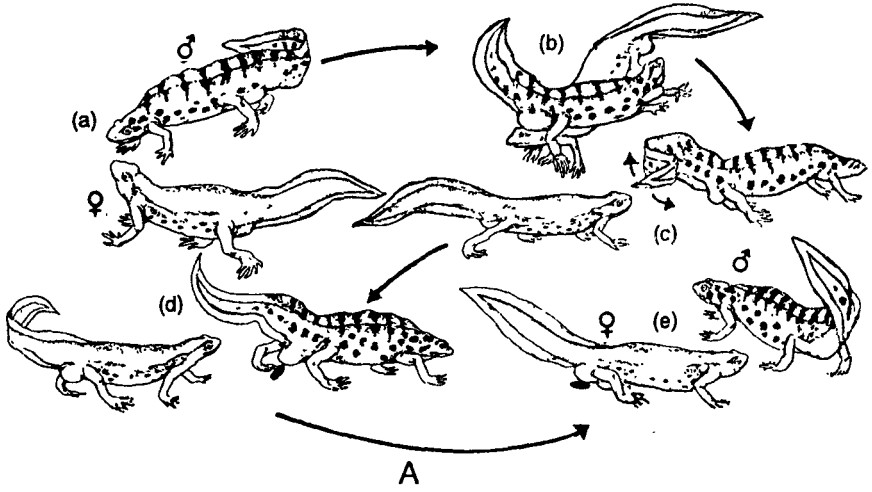

Fig. 1. (A) Courtship is smooth newt : (a) Male and female approach each other, (b) Male and female check each others cloacal openings, (c) Male vibrates its tail, female watches, (d) Male deposits a spermatophore, (e) Male moves ahead, female picks spermatophore into her cloaca

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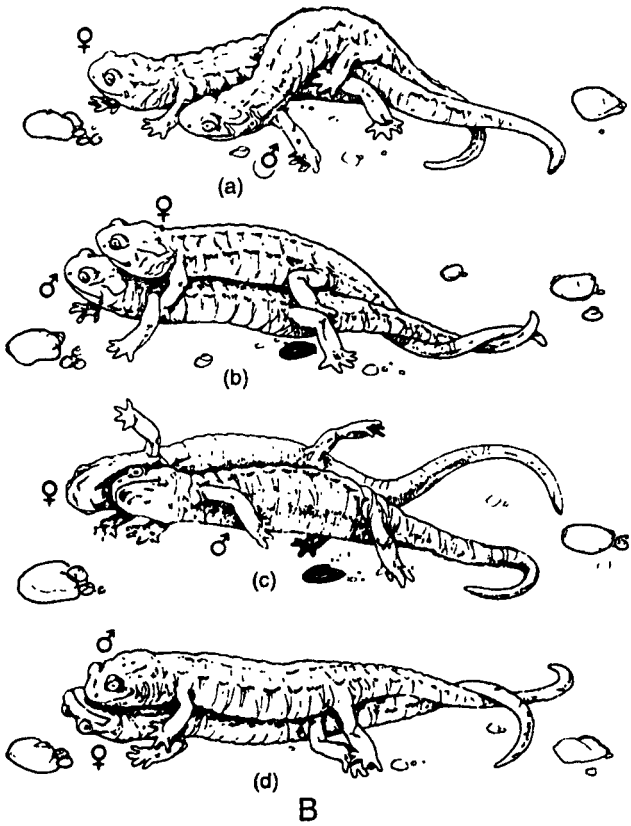

Fig. 1. (B) Courtship is sharp ribbed salamander : (a) A male finds a female and grabs her, (b) Male goes under female, she grabs male. Male deposits spermatophore on the ground, (c) Male moves pushing the female, spermatophore stays on the ground, which is picked up by female, (d) Rarely male and female mate in a face to face position

from dehydration and the shell can only be formed after the eggs are fertilized. Therefore, true internal fertilization evolved as reptiles evolved, their shelled eggs are deposited with fairly large yolk reserves.

For internal fertilization animals started attracting each other, this gave rise to simple **premating** or **precopulatory behaviour** gradually leading to proper **courtship** for synchronization of gamete production and fertilization.

For this type of fertilization : (i) The sexual partners have to find each other; (ii) They have to coordinate their activities in such a way that sperms are deposited inside the female body without harming her.

In some species finding each other is not a problem because in nature **conspecifics** (individuals of the same species) of both sexes live together within a narrowly defined area or geographical zone. In other cases, where males and females live away the partners must show a behaviour that is

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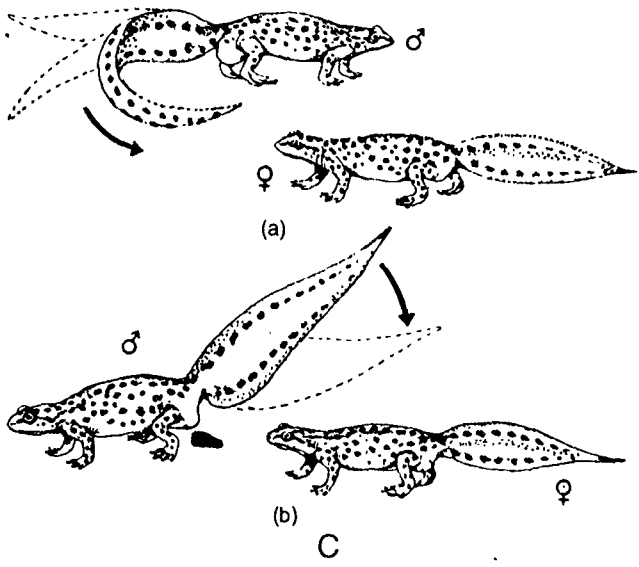

Fig 1 (C) Courtship is Palmate Newt (a) Male and female find each other Male lashes his tail from side to side female watches, (b) Male moves his tail up and down and deposits spermatophore Female moves over it and picks it up in her cloaca

actively oriented towards each other (i) either males and females should stay together for a long time so as to cover breeding season or (ii) should make permanent pairs or swarms, or (iii) they must have well developed methods to find each other during the breeding season, then recognize each other as suitable partners, and lastly synchronize tneir movements for a successful mating.

Successful mating requires four important conditions :

(1) Both partners must belong to the **same species**;
(2) With the exception of hermaphroditic species such as earthworms and land snails (mostly invertebrates) the partners must be of **opposite** sex;
(3) Both must be **willing to mate**.
(4) In many animals it is also necessary that proper conditions for **rearing** the offspring are established before mating begins.

Encounters may be controlled by external events causing all individuals of a species to gather "automatically" in a precise spot at a precise time as do **Palolo worms** (gather on full moons). But even in **Syllidae**, which are close relatives of the Palolo worm, the partners respond to each other directly and attract each other with light signals. Even where sex cells are produced in very large numbers, as with **Salmon** or **Mackerels**, fertilization would be virtually impossible if these cells were merely shed randomly at some time or in any place. Here, the male and the female must coordinate their activities. After the partners find each other or ensure that they stay close together, the

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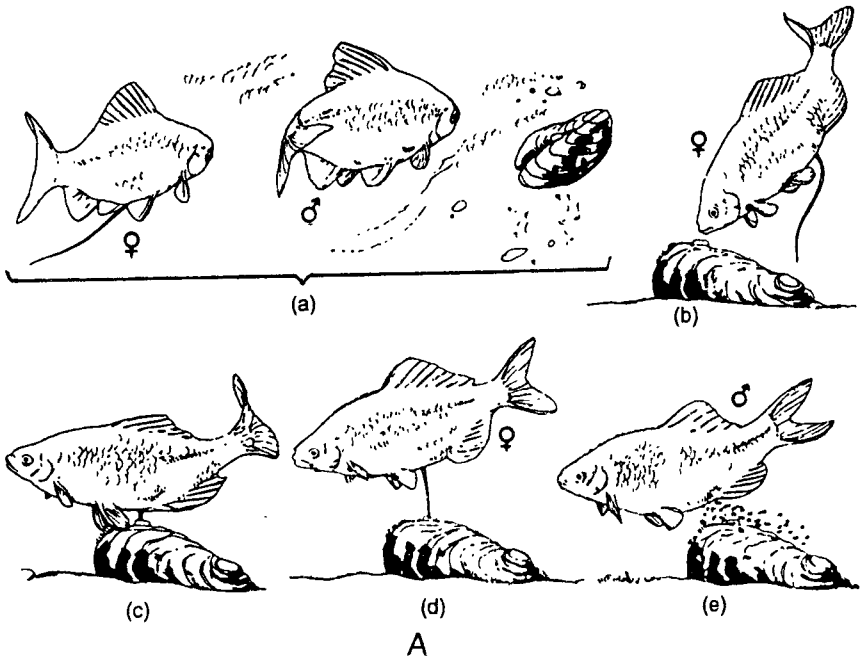

Fig 2 (A) (a) Male bitterling guides female to a bivalve. (b) Female with long egg laying tube examines the bivalve. (c) She inserts her egg laying tube. (d) She deposits her eggs into the bivalve's gill chamber. (e) Male discharges his sperms. fertilization takes place inside the gell chamber

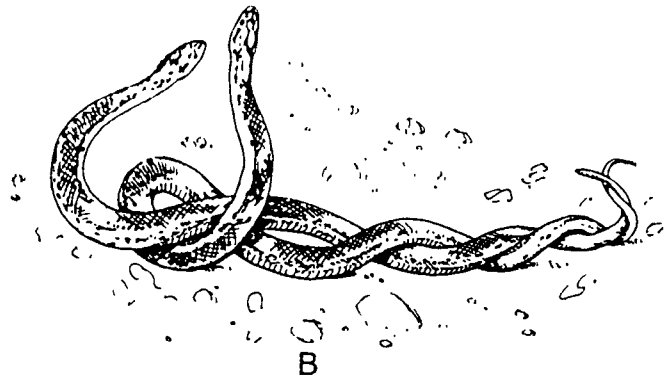

Fig 2 (B) Courting snakes entangle their bodies together for an hour. Male deposists sperm inside the cloaca of female

egg and sperm cells must be released simultaneously. This may be induced by external factors. In the **Bitterling**, for example, the presence of a live pond mussel (into which the eggs are laid) is a precondition for the growth

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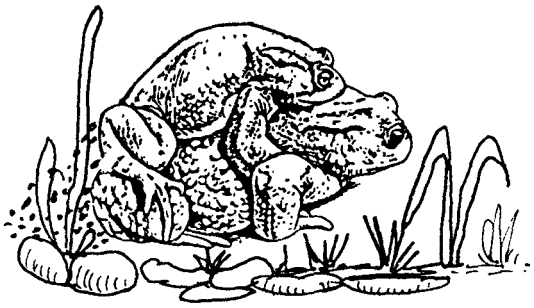

Fig. 3. Male frogs and toads climb on the dorsal side of females Clasp her tightly Both spawn and fertilization takes place in water.

of the male's spawning and the female's oviposition, both indicating readiness to spawn (Fig. 2a). In other cases the sexes perform some behaviour for each other leading to mating, courting snakes twine their bodies together (Fig. 2b), lizards chase and grasp.

Amphibians form a **connecting link** between the **external** and **internal** fertilization. Their breeding behaviour bears a startling resemblance to real copulation, despite the fact that fertilization in external. The eggs are released, cling to her then only the eggs are released. Male **Frogs** and **Toads** climb on their female's back and cling to her (Fig. 3). Sometimes by making certain movements and sounds, the two partners synchronize their spawning in such a way that the eggs are fertilized immediately after shedding. The courtship behaviour has two important characteristics :

(1) It is performed in species specific sequence , it is genetically controlled therefore is instinctive (fixed action pattern).

(2) The male and female of same species must synchronize their courtship sequence ensuring fertilization.

Sequence and Synchronization

Most animals court and breed only at certain times of year. Breeding in individuals of the same species is **synchronized**. This is influenced by **environment** when the **food is in rich supply** at the time of mating as well as when the babies are born. **Day length, temperature** also play key role in **triggering the courtship**. Courtship is found almost in entire animal kingdom from simple following as mentioned in *Paramecium* to extremely complex rituals or displays or dances of birds and mammals. The onset of courtship behaviour is closely regulated by **biological clock**, it is influenced by day length and temperature via the endocrine system.

Courtship is most pronounced in **Arthropods, Molluscs, Fish, Birds and Mammals**. Free-living peacocks in India court virtually all year round, the hens do not allow copulation until the monsoon rains start. It is the greenest

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time in North India. This is important because the young can be safely reared during the rainy season when plants grow, blossom, and bear fruit. Uninterrupted courtship requires the cock to defend a territory and to drive away all rivals. His territory remains quite stable, and the cock maintains it even when he cannot see any hens. The males leave their territorial guard positions only at night to rest peacefully in trees, where they sleep. The

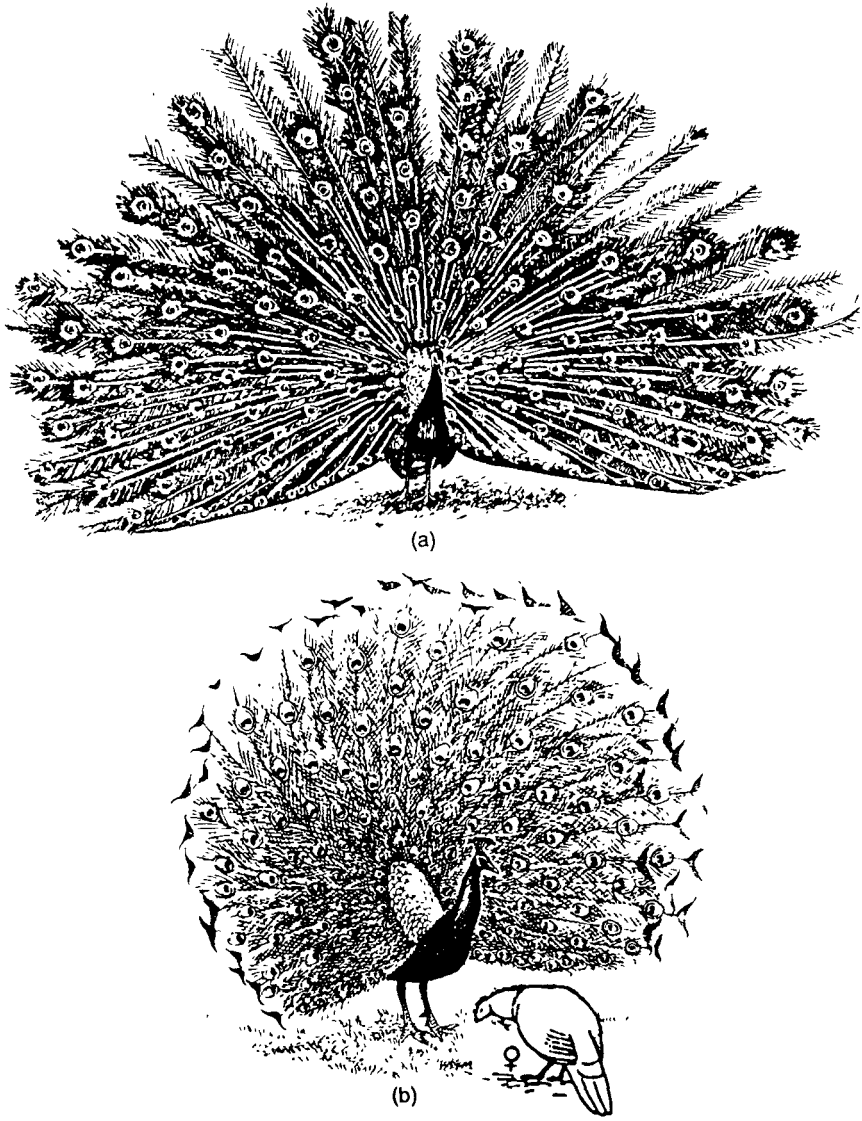

Fig. 4 (a) Courting/dancing peacock, (b) Peacock brings his feathers in front over the peahen and vibrates them in most enchanting manner

(Z–37/Ani. Beh.)

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reason for having a territory is to prevent others from interfering with courtship and copulation activities.

As mentioned earlier courtship displays include a sequence of activities, they are most evidently seen in courting or dancing peacock (*Pavo cristates*) :

(1) The peacock unfolds and lifts its long and beautiful feathers of his tail to form a shield (Fig. 4) in which the eye spots contrast with the rest of the feathers, shinning green to red-brown to turquoise depending on light. Each of these eyes have a core of dark blue, surrounded by an area of turquoise and one of brown, and the whole pattern is bordered by violet and green-gold. It is not unusual to see several cocks opening and raising their feathers at the same time. But they always stand clearly apart, never directly beside each other.

(2) The hen moves around in the vicinity of the cock, obviously pretending that she is in search for food. She seems to ignore the courting cock completely. But he does not simply stand motionless.

(3) He approaches the hen in a peculiar way, walking forward-backward with small steps as if dancing.

(4) At the same time leaning his beautiful feathers over the front, and

(5) Fanning rhythmically with outspread feathers and takes them back, it looks like a dance. If the hen does not want to mate, she will ignore the cock and soon goes away. He will then fold up his tail feathers.

(6) But if the hen is receptive, she will respond to his backside approach by walking towards him and around to face the front part of his feathers.

(7) She performs this movement quite causally while continuing to peck for food.

(8) The cock has been watching, and as soon as the hen appears laterally at the edge of his feathers.

(9) He will turn toward her with a jerk,

(10) Tilt the feathers as far over as possible, and shake them in "happiness". But still the hen does not look up.

(11) If she keeps on pecking the ground.

(12) He continuously shakes his feathers.

(13) If she stops, the cock once again turns his back and starts shaking feathers.

(14) The cock's turning away, the hen's approach to his front, the turning of the feathers toward the hen, and ecstatic tail shaking is repeated several times.

(15) Until finally she invites him to copulate by offering her lowered back end.

(16) The cock then moves toward her and mates with her.

This impressive sequence of courtship behaviour in peacocks is eye catching. Sequence in courtship are followed strictly, they are species specific. Rigidity in courtship displays can be seen in other animals too. The Zig Zag

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dance of **Three spined stickelback** fish has been well documented by Niko Tinbergen.

Courtship in three spined stickleback fish

Fish vary greatly in their courting behaviours. Some are territorial, some are not, some prepare nests, some don't , some change colour, others don't, some are social, and others are not. Their mating habits vary too. Most are polygamous, one male fertilizes the eggs of many females. But some are monogamous - a pair of male and female true to each other, some have internal fertilization and are viviparous, but most are oviparous having external fertilization. **Parental behaviour** ranges from the **guarding of eggs and young** by one or both parents to **leaving of eggs** in carefully prepared **nests**, to simply leaving the eggs anywhere in the sea.

The three spined stickleback *Gasterosteus aculeatus* is the best studied fish for its courtship behaviour. They are small fresh water fish about 50 mm to 2 inches long. Out of the breeding season they are undistinguished grayish-green fish living in schools. The courtship of the sticklebacks - has been described by **Tinbergen** and his students (1937, 1951 & 1954). Outside the breeding season, this fish tends to live in school, that means a peaceful group that has no leader and in which there is no fighting. The most striking feature of a school is that all the individuals in it usually perform the same activity at the same time for example - they swim around and take turns together or feed together.

The **longer day length** of spring produces **increased secretion of sex hormones** and also causes **migration** from **deep fresh water** to **shallow freshwater** spawning grounds. Here, stimulated by temperature changes, the **male** undergoes dramatic changes in both appearance and behaviour, which is their courtship condition.

The **glowing blood red** colour makes the belly and sides of the **male** glossy and transparent, the iridescent **blue-green** colour and brilliance of its back can only be compared with the **illuminating neon lights**. The eyes become **emerald green** (Fig. 5a). No other animal becomes so completely transformed when in love; no one glows in such a literal sense with passion as stickleback. **Female** is distinguished by her silvery colour and by her enlarged belly she does not change colour.

After developing this colour the **males** leave the school and set up territories in an area of sandy bottom containing water plants where they **build** a **nest**. The nest is made up of plant material such as **algae** and **weeds**. This nest is made in the same pit which was dug in the sandy bottom. The **territory** extends outwards and upwards from this nest. Male secretes a sticky fluid from kidney over the loose pile of algae and weeds. This material functions as **glue** and the nest is given a **tunnel shape** as the male always swims *(Z–37/Ani. Beh.)*

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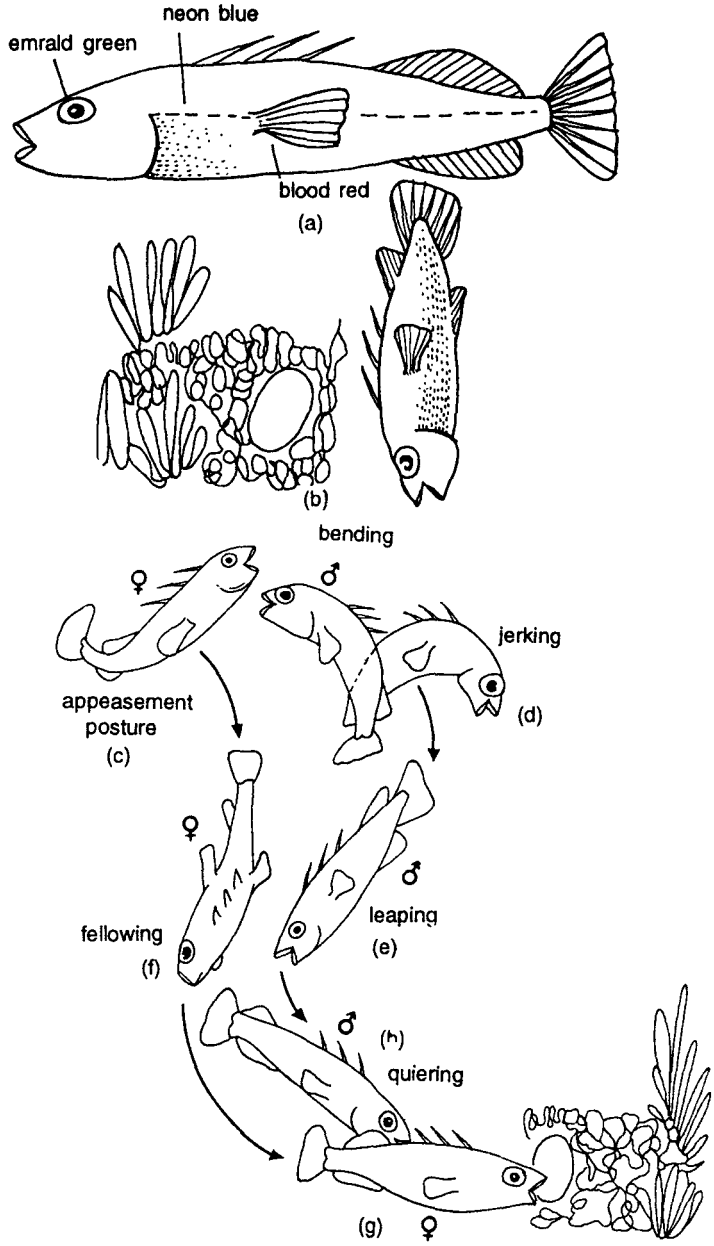

Fig 5 (a) Male three spined stickleback in nuptial colours. (b) Male constructs a nest and adopts a vertical position exposing its red belly. (c) Female assumes appeasement posture. (d) Male bends towards female and goes away with a jerk. (e) Male leaps and dashes towards the nest, (f) Female follows, (g) Female inspects the nest, (h) Male gently taps his head against females caudal side

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through it to complete it. Therefore, the male thinks of making love only when the cradle for the expected babies is ready.

The territory is defended against other males in one common thereat posture, the male adopts a vertical position with head down, near his nest, (Fig. 5b) thus **exposing the red belly** to the intruder. After completion of the nest the male goes through another colour change, the upper portion of his body turns bluish. This colour pattern attracts females towards him. The egg filled belly of a female stimulates the male to display a peculiar type of movement - popularly known as zigzag dance (Fig. 5c to 5h).

A male begins to advertise for females by swimming close to the surface in a curious jerky fashion. Ripe female are bold intruders, females do not go away even when butted and bitten, instead they adopt the so called '**appeasement posture**' i.e. hanging obliquely upward in the water. This posture is also adopted by male rivals, defecated in a fight. It always inhibits attack, and offers a chance of escape for males and a chance to court for females. This posture displays belly. In females, this is silvery and swollen with eggs.

The most conspicuous feature of courtship is the Zigzag dance formed of many steps :

(1) A male swims **jerkily,**
(2) Alternates **leaping** towards the female.
(3) With a side ways **jump** away from her.
(4) He **circles** around her. The side way jumps are always roughly in the direction of the nest.
(5) From time to time the male makes a dash towards the nest, that is known as **leading.**
(6) Male comes back and again performs the **zig zag dance.** Courtship can proceed no further unless
(7) The female follows at the nest.
(8) He shows his nest entrance by lying on his side and **thrusting** his snout into it. The female responds by **pushing** her way inside the nest if she does not then
(9) The male immediately starts **quiering (gentle tapping)** with his head against her tail then.
(10) She enters the nest and **spawns** and then swims out from the other side.
(11) The male follows her through the nest and **fertilizes** the eggs.
(12) The male repairs his nest and invites other females. One male can bring in many females.

A female who is not quite ripe will fail to respond at some point, and although the male may continue to court her for a while, he will eventually chase her away. Alternatively, an unready male, particularly one whose nest is not complete is likely to be too aggressive and will frighten females away.

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The male tries to mate with as many females as possible. Occasionally, when he has just persuaded a female to come to his nest, he may notice another female at the edge of his territory. He may rush to invite the second female to his nest even before he has had a chance to fertilize the eggs laid by the first female. **Desmond Morris** a famous anthropologist and behaviourist discovered that the second female only looks like and acts as a female, the fish infact is a sneaking male in disguise, lacking the red belly. While pretending to lay eggs the pseudofemale fish fertilizes the eggs of the first female. After the sneaker leaves, the proud albeit foolish owner of the territory attempts to fertilize the already fertilized eggs often unaware of the trick that has been played on him.

After mating with about 4-5 females the male begins his parental duties and resumes his original, non breeding colouration. He aerates the eggs by fanning water over them. When the brood hatches about a week after fertilization, the **male guards** the young. If one strays too far from the nest, the **male** takes the **hatchlings** into his **mouth** and spits them back into the nest.

Courtship in Jewel fish

The **Jewel fish**, *Hemichromis bimaculatus* (Fig. 6a) has been studied by **Bernards** and **Van Room** (1950). This fish resembles the stickleback in having out of season schooling behaviour and in being territorial at breeding time. It also lays eggs and has external fertilization. It differs from the stickleback in three important features of courting behaviour.

(1) Female Jewel fish also hold **territories** before mating and therefore, tend to be aggressive like the males.
(2) There is **no nest**, and male and female choose a **spawning site** together.
(3) A single **pair stays together** for the whole season and rear the young.

The females defend their territories vigorously and have **bright marriage or nuptial colours**. Females leave their territories at the time of the ripening of the ovaries, and begin to visit male's territories in neighborhood. The female Jewel fish are attracted to red males in preference to pink, when offered a choice. The reaction of the **male** jewel fish to an intruder **male** is much the same as that of the stickleback; he **attacks** or displays aggressively. Sometimes he **charges** and **butts** in the head or abdomen, more commonly he makes a frontal attack that usually leads to mouth fighting, each fish **gripping the jaw** of the other (Fig. 6b). Female jewel fish, fight back, they are bold and beautiful, and they do not run away from males and possess an **appeasement posture** (Fig. 6c). The sexual stage of courtship is mainly concerned with the selection and display of a suitable site. However, courtship is by no means continuous, there may be periods of rest or feeding. The displays are very similar for both male and female. Either sex may initiative the courtship and other may copy it. The courtship occurs in seven stages :

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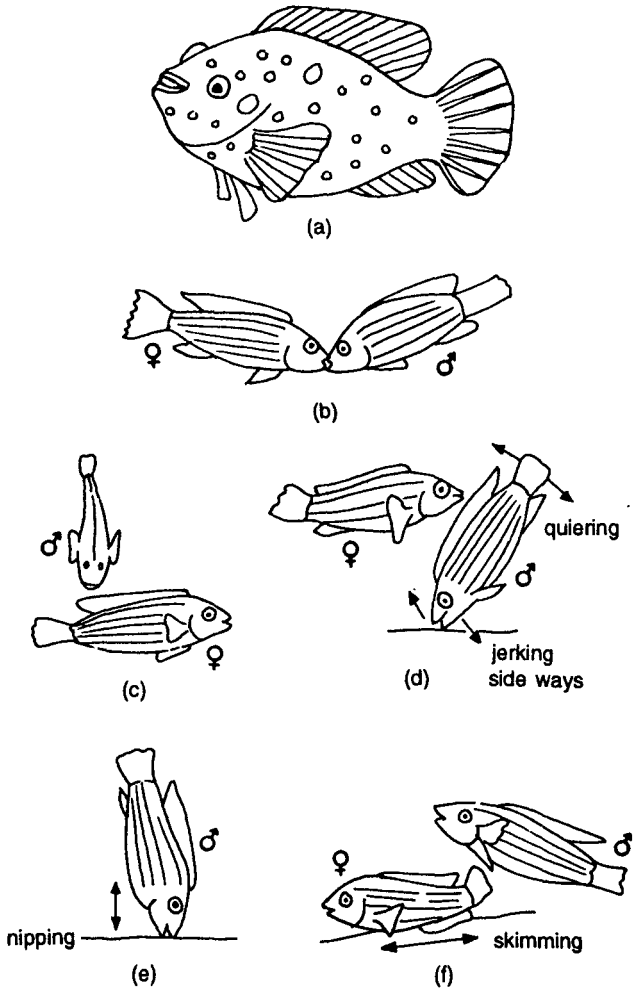

Fig. 6 (a) Jewel fish, (b) Male female make a pair and hold jaws, (c) Male female search a safe site for egg laying, (d) Male selects the site and points it out to female by jerking and quiering, (e) Both male and female clean the site by Nipping, (f) Both male and female rub their abdomens and cloacal openings called skimming to spawn.

(1) They selects a suitable place for spawning and makes movements towards it called **jerking** and **quiering**. The body is held vertical over the chosen object and the whole body **trembles** or shaken (Fig. 6d).
(2) When both fishes have jerked and quiered for a while, one partner begins a new display called **Nipping**, plants or dirt are nipped off the place and thrown away. Thus the **spawning site** is cleaned (Fig. 6e).
(3) Finally, the fish change to the third stage called **Skimming**, when they slide over the place touching and **rubbing** it with abdomen (Fig. 6f).

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(4) The tempo increases, and eventually the female lays eggs during one of her skims and the male follows and fertilizes them.
(5) A female after laying eggs stays near them, **guarding** them.
(6) Later the young are carried to small pits which have been dug in the meanwhile.
(7) The seventh stage is parental care. Male and female then alternate in **parental duties**, one gathers food while the other guards.

Courtship in *Tilapia*

Tilapia natalensis are closely related to jewel fish and also studied by Bernards (1952). Here only the male holds a **territory**, he **digs a pit** for

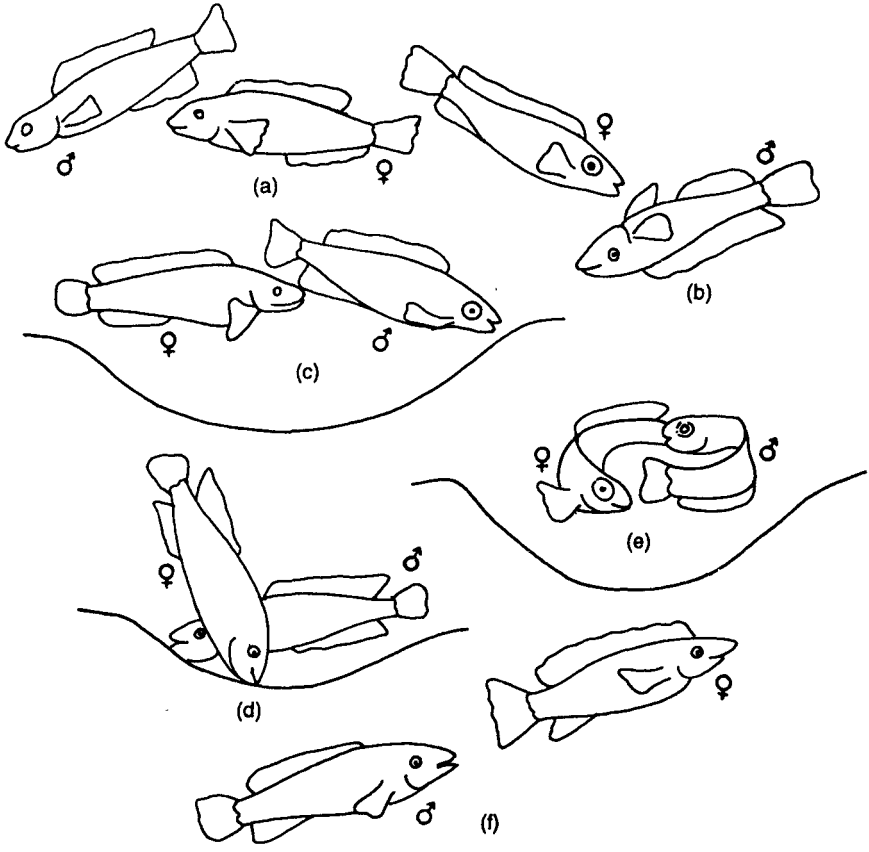

Fig. 7. Courtship mating in Tilapia. (a) Invitation . Male to female, (b) Leading : Male to female, (c) Tail wagging : By male at the selected pit, (d) Male female check and clean the pit, (e) Circling . In the pit by male and female and spawing, (f) Female picks up fertilized eggs in her mouth and male chases her away.

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spawning, before the appearance of the female. He is **polygamous** like sticklebacks; each female leaves the territory immediately after mating, carrying the fertilized eggs in her mouth for **oral incubation**.

The whole courtship can be explained with the help of figures 7a to f :

(1) **Inviting** - Male to Female.
(2) **Leading** - Male to Female.
(3) **Tail Wagging** at pit by male.
(4) **Circling** in the pit by male and female, checking each other's cloacal openings.
(5) Female **spawns**, male fertilizes eggs, female carries **fertilized eggs in her mouth.**
(6) Male chases away the female and invites another female.

Courtship in Guppy fish

The **guppy** ***Lebistes reticulatis*** is a freshwater fish. It has **internal fertilization** and is **viviparous**; the young are independent as soon as they are born, there is **no parental care** and no territory. Guppies live in large schools and are social throughout their lives.

The absence of territorial behaviour does not mean the absence of aggressive behaviour. Unlike most schooling fish, male guppies are very aggressive. Particularly when in sexual mood. There is considerable sexual dimorphism, males are brightly coloured all the year round; female are very uniform in colour. At breeding time, several black markings appear on the bodies of the males, but have no significance in breeding. Guppy courtship has following stages :

(1) A male must **peruse** a female away from the group so as to court her without interference (Fig. 8a).
(2) He must **stimulate** her to stay still and permit his approach for copulation. Bernards has called these stages **leading** and **checking** respectively. The leading stage usually begins when a male persuades a female and follows her.
(3) Soon he attempts to swim in front of her and he faces her (Fig. 8b).
(4) He **folds his fins**, and then begins a series of alternate retreats and approaches, still facing her and **swimming jerkily**. This is called **luring** (Fig. 8c).
(5) Soon after this he throws his body into a - **S shaped curve** (Fig. 8d).
(6) From this position comes a **startling jump** that may cover a distance of 10 cm or more directly away from the female. This is the most conspicuous part of the courtship (Fig. 8e).
(7) Checking develops gradually out of leading. In this sequence a male performs S-display at right angles to the females head. This is repeated many times by the male (Fig. 8f).

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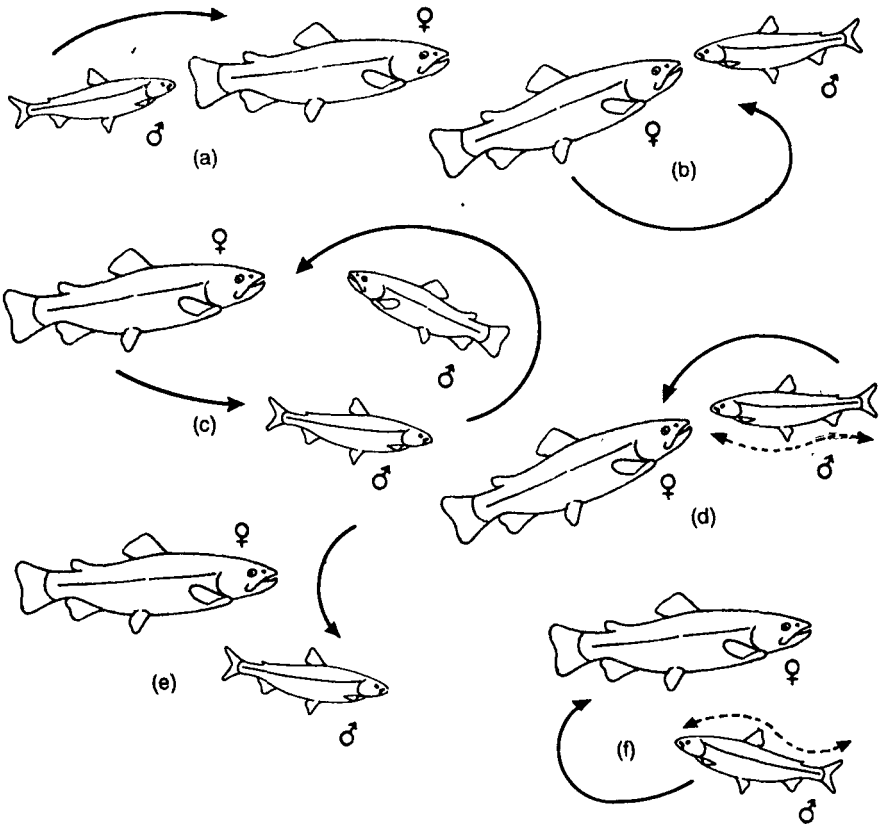

Fig. 8. Courtship and mating in Guppy fish : (a) Male selects a female and bring her out of a group~leading, (b) Male swims in front of a female-inviting, (c) Male goes away then comes back suddenly~Lurking, (d) Male again comes in front and moves his body in S-shaped curve~Curving, (e) Male suddenly jumps away ~ Startling, (f) Male checks cloacal opening of female ~ checking, then comes from back for ~ copulation

(8) After checking the female the male takes a small curve to approach from behind and attempts **copulation**. For successful copulation, the female must stay still long enough for the **gonopodium** of the male to be introduced.

(9) After mating the male leaves, and female gives birth to babies.

Characteristics of Courtship

Courting animals draw attention to themselves, they "**put themselves on display**," because they must attract a partner and show that they are conspecifics and are ready to mate. Courtship **songs**, **displays**, and **dance rituals**, all these terms indicate the display character of courtship. Movements

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are performed more intensively than usual, and the sequences are repeated over and over again. The effects of such movements may be enhanced by **colourful patterns**, **adorning body appendages**, and **various sounds or calls**.

Many species of animals show patterns of behaviour which are clearly adapted for attracting potential mates over a long distance. These advertisement displays are part of courtship and may be **visual**, **auditory** or **olfactory**, depending upon the senses that are most highly developed in a particular species.

Attention and Courtship

Regardless of whether fertilization is internal or external, one partner must induce the other to go to the spawning place or to take up a mating posture. This may be done in different ways, by producing chemical, tactile, acoustic, or optic signals. In **sea urchins** and **oysters** an arousing messenger substance (pheromone) is released together with the sperm, stimulating females and other males to release their own sexual products. In **tree frogs** the female has a "**signaling posture**" - curving her back inward - that tells the male she is about to deposit her eggs. The male then slides back until his cloacae touches the eggs (probably an additional safety measure), and he fertilizes them. In copulating birds and mammals the female's mating posture indicates the male that he can approach and perform the act.

A courting animal can draw attention to itself with a whole variety of signals in the form of **sounds**, **movements**, **odours**, **body appendages**, and **colour patterns**. Of these some signals are mentioned below :

[I] Visual

- **Displays** include colour patterns, feathers and wings, waving of antenna or appendages.
- **Light** is emitted in the form of a flash.

Very often, movements during courtship are combined with a display of colourful patterns and strange structures. We may note, for example, the play of **colours in cuttlefish**, the **colourful patterns of coral fish** and other groups of fishes, the **elongated coloured fins of fighting fish**, the **colourful feathers** of male **ducks** and wild chickens, and the magnificent **plumage of male birds of paradise** (Fig. 8a).

(1) **Wolf spider** males wave both palps to the females called **flagging**.
(2) **Male butterflies** find their females by seeing them flying in a zig-zag fashion.
(3) **Male jumping spiders** perform interesting **dances** during their courtship.
(4) **Fiddler crabs** derive their name from the conspicuous **claw-waving** movements.

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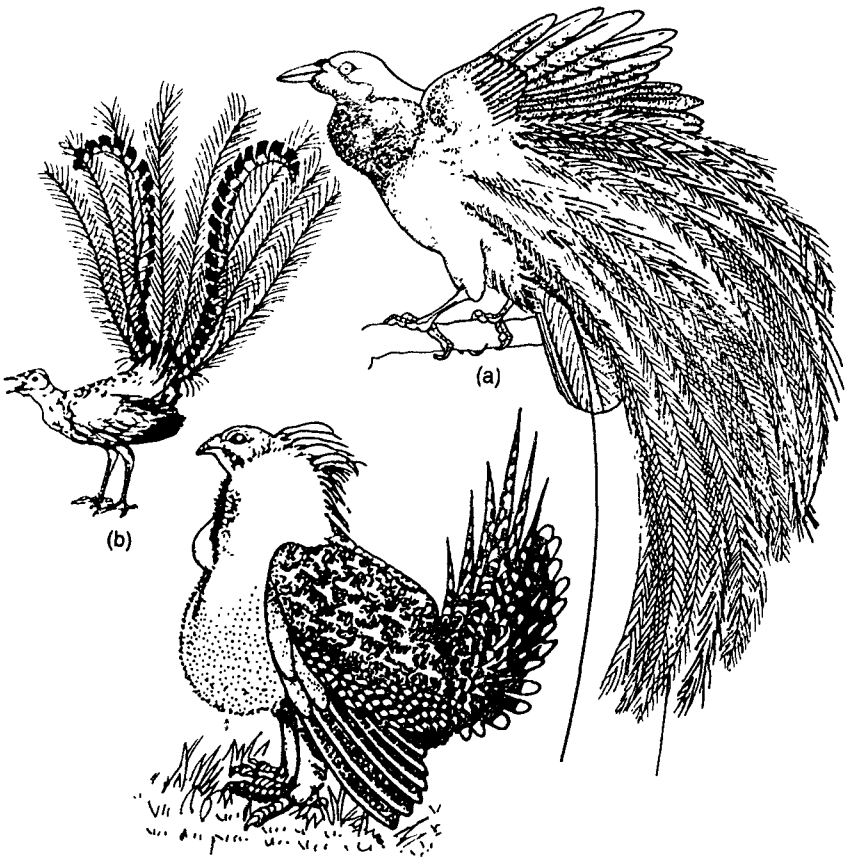

Fig 9. (a) Male bird of paradise, (b) Lyre bird, (c) Sage Grouse

(5) Other expressive movements include the **zigzag dance** of **Sticklebacks**, already described in details.
(6) **Peacocks** dance and display their feathers (Fig. 4).
(7) **Fighting fishes** get longer and more colourful fins during courtship.
(8) The face and buttocks of **Red faced monkeys (rhesus)** get redder when they are ready to mate.
(9) The male **Pigeon bloats** his throat and spreads his tail feathers and goes around the female bowing and cooing.
(10) The **house Lizard** lashes its tail to attract male.
(11) The **Chameleon** changes colour.
(12) The **Bees** go for a nuptial flight.
(13) The **Termites** go for marriage flight.
(14) The **Aplysia** dances in the most colourful way.
(15) The **Deer** display their majestic antlers and move in a special gait.

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(16) The most beautiful courtship dances and flying movements are seen in **Ducks, Plovers, Gulls, Bird of paradise, Lyrebird** (Fig. 9b) and many other avian creatures.

(17) Lek displays are common among birds and antelopes. An area used consistently for courtship displays is called a Lek or Arena. Generally the males occupy a territory and keep displaying from there to attract females. Its seen in **grouse** species (Fig. 9c), **bustard, bower birds.** Among antelopes **Uganda kob, thompsons gazelle** show lek displays. The leks are also formed by **fruit eating bats** of Africa.

[II] Sound

High pitched sound is produced among invertebrates by **flapping of wings, rubbing of appendages**; whereas, vertebrates use proper sound through vocalization in the form of **moans, grunts,** and **barks.**

Sound plays a very important role in drawing attention of mates during courtship rituals. From **wing beating, buzzing, flapping to grunts, howls, screams** depending upon the species animals have been using sound to attract/call mate.

(1) Some fishes make species specific sounds, like **Gobies (Gobidae) and Croakers (Sciaendae)** make conspicuous sounds by rapidly vibrating special muscles.

(2) Most people are familiar with the croaking of **Frogs and Toads.**

(3) Sounds or calls are important to nocturnal **Owls** and other nocturnal animals because they cant see each other.

(4) Everyone is familiar with bird songs. Birds sing regular songs with stanza, para and a melody.

There are many interesting examples from **arthropods** which are considered world's best animal "**instrumentalists.**"

(1) **Spiny lobster** makes a rasping sound by rubbing the projection of its rostrum or a serrated pad at the base of his antenna.

(2) **Ghost crab** makes a sound from the ridges of the inner side of its appendage with the help of its large claw.

(3) **Pistol shrimps** release their claw from a body space causing a loud sound.

(4) Some **Spiders** tap on leaves to make sound.

(5) The male **Wolf spider** plays music with its mouth parts rubbed on the joints of pedipalps.

(6) Everyone is familiar with the loud chirping of a cricket **"Jhinger"** commonly found in our houses during the night. Jhingar rubs its wings to make this noise.

(7) **Burying beetle** rubs its dorsal surface of the abdomen against the tip of the elytra.

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(8) **Grasshoppers** produce sound by stridulating, a process in which two limbs are rubbed together. Grasshoppers rub the top of their hind legs, which are equipped with a series of raised processes against fore wings.

[III] Light

In a number of species belonging to very different phyletic groups, members of the opposite sex signal each other with light pulses or they emit light at night, e.g. most members of **Syllidae**.

(1) Among insects, the fireflies or "Jugnoo" is most common example. The male "**Jugnoo**" produces a series of flashes as they fly around. A female waits in vegetation and responds to the flash pattern of a male of her own species by producing a distinctive series of flashes of her own.
(2) Various deep-sea fishes e.g. **Lantern fish**, and members of **Myctophoidei**, and **Anomalpidae** produce and flash light to attract mates.
(3) Females of **Glow worm** (insect) can not fly, they twist their abdomens to expose their lighted segments that can be seen from the air by flying males.

Depending on the species, the light-producing organs are usually grouped in certain patterns on the body. In some cases light can be turned on and off by the individual itself, following a time pattern that is again typical of the species. This allows members of different species to distinguish between outsiders and conspecifics, a process particularly studied in **fireflies**.

[IV] Pheromones

In olfactory communication animals convey information to each other by chemical messengers, called **pheromones** that are produced by special glands. Olfactory signalling is very important in the sexual behaviour of many mammals but the most highly developed olfactory mate location systems are found among insects, particularly moths. The **female silk** moth produces a volatile secretion called **bombykol** from glands on her abdomen, and disperses it into air by fluttering her wings, this can be detected by **male** as far as **seven miles**. Males have very large antenna to receive it.

Pheromone released by queen termite and honey bee attracts drones to follow them for marriage or nuptial flight. In giant snakes **(Boa constrictor, Python, and Anaconda)**, the male recognizes his partner by the scent from her anal glands. A very large proportion of mammals depend on scent. For example, the **elephant** bull secretes a **milky fluid** from its **orbital glands**, the marmot releases an odorous substance from its anal glands, and male dogs follow the scent trail of a bitch in heat.

Courtship in Grayling butterfly. Male **Grayling butterflies** (subfamily Satyrinae) initially pursue every other butterfly passing by the **sign stimuli** being **appearance (as dark as possible)**, **size (as large as possible)**, and **locomotory path (not straight)**. If this object turns out to be a female

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grayling, it will soon land. Now the male positions himself in front of the female and performs various movements :

(1) **Rhythmic movements of the wings.**
(2) Fanning the wings in the female's direction.
(3) Circling his antennae.
(4) The wing movements carry the male's special scent to the female, an odour released by his scent scales.
(5) In addition, the male flaps his wings together so that the female's antennae are caught between them and her olfactory organs come into close contact with the male's scent.
(6) If the female is unreceptive, she will move away and flap her own wings several times.
(7) The male then stops courting immediately.

In the **Fritillary butterfly (Argynnis and related genera)** the male reacts not only to the visual appearance of his partner but also to her odour. Like the grayling, a male fritillary can initially pursue "wrong" objects, but he continue to court only if he catches the proper scent. **Emperor moth** can detect the sex pheromone of the female as far as 13 Kms, the female carries less than 0·001 of a milligram of pheromone. Among many vertebrates the readiness of a female for mating is perceived by male through pheromones produced from vagina therefore, sniffing of the genitalia is a common sight in courting vertebrates specially mammals.

[V] Tactile

Touch plays a significant role during courtship and mating. **Rubbing, pushing, nudging, coiling, twining, licking, clasping, necking** are commonly seen in courting animals.

The **elephants** use tactile signals during courtship. The trunk plays an important role. After **chasing** the female the male **caresses** her head, trunk and tusks, then strokes her back gently until she indicates her willingness to mate (Fig. 10).

Grooming in non human **primates** and **preening** in **birds** are important features before and after mating. **Prairie dogs kiss** and **groom** each other during courtship. The males of **lions, tigers** follow, play, **lick, bite females.** While **mating** they **grasp** the **female's neck** with **teeth.** The courting **Giraffes rub** their **necks.** The **scorpions** hold each other's "**arms**" and **dance** before copulation. The courtship of **kingfishers** consists of **aerial chases,** they **circle** and **dash** towards each other. Many of the "**aquatic birds**" "**bathe**" together before and after mating. African **boomslang snakes coil** around each other after making a pair. Male **frogs** clasp their **females** tightly before spawning. **Gourami** fishes **kiss** each other during courtship. During courtships female **Sea cucumbers** wrap spirally around their males.

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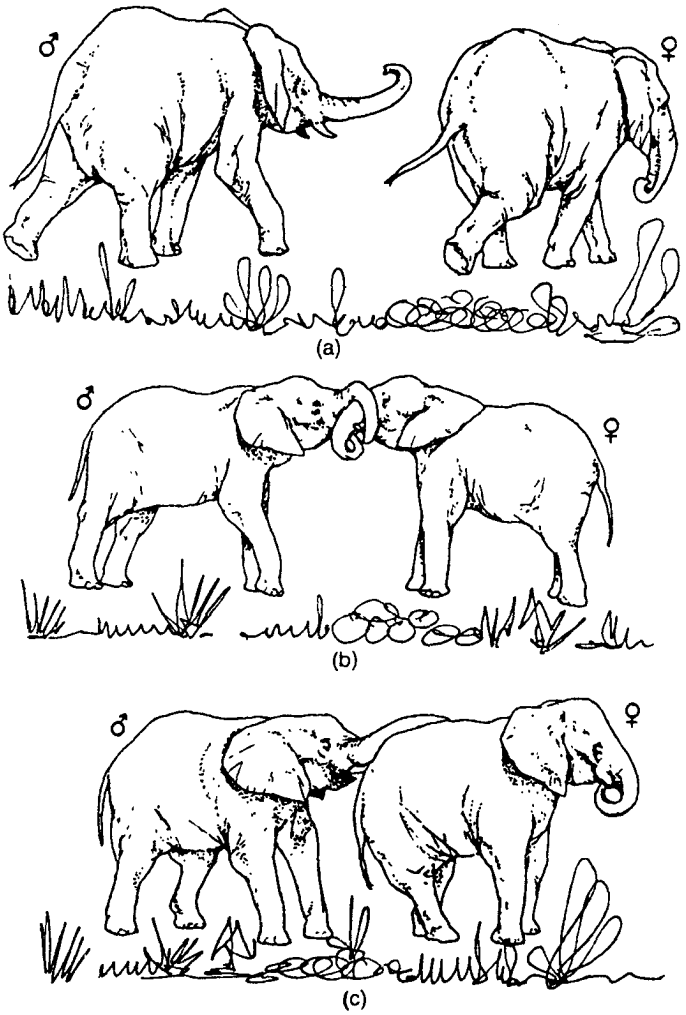

Fig 10. Courtship in elephants . (a) The male chases the female in heat Raises his trunk to receive pheromone, (b) Male catches females trunk by his own, (c)Then comes back and gently strokes her back it she allows mounting

Brood Care and Courtship

Making a nest by courting animals is an obvious sight. There can be a variety : (i) Some make nest before inviting a female e.g. **Stickleback and Jacana**. (ii) Some make a pair, court and then collectively make a nest e.g. **Streptopaelia** or dove (Fig. 11 a to 11c). (iii) Some make a nest after courting and mating e.g. **Digger wasp**.

(Z–37/Ani. Beh.)

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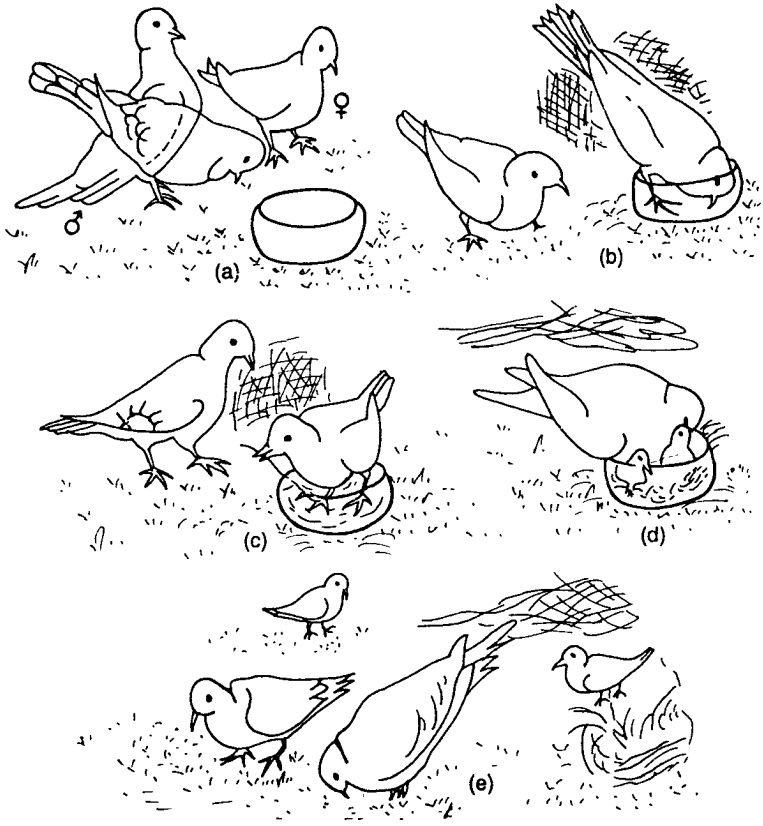

Fig. 11 : (a) Male attracts female by bowing and cooing, (b) Male female select a nest site, (c) Both of them make a nest, eggs are laid, (d) Eggs hatch, both parents feed them, (e) Male once again starts courtship the female.

Courtship behaviour and brood care are two sides of a coin. The courting male stickleback first makes a nest then lures his female to the nest and induces her to deposit her egg. In animals, sexual behaviour has just one function that is production of offspring. Mating immediately leads to fertilization, leading directly to the start of embryonal development. It should, therefore, be logical to combine nest-building, taking over of the brood by the parents, or provision of food for the future young with mating itself.

In **Anurans**, mating behaviour is followed by brood care Male and female take roles in caring for the eggs. Males of the **Midwife toad**, wrap the string of eggs around their hind legs (Fig. 12) and in the **pouched frog**, males place the eggs on the female's back where they are covered by a special fold of skin and mature within these "pouches".

(Z–37/Ani. Beh.)

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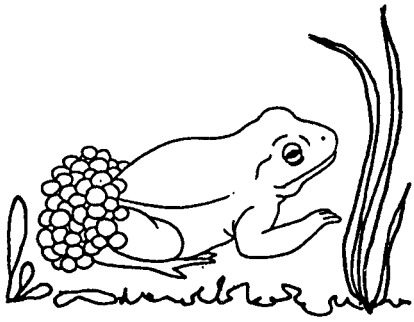

Fig. 12. Midwife toad.

In nest-building animals, the nest may be completed before pair-formation or latest before copulation. If the male is the one to build the nest, his courtship may consist of attracting the female to his site and showing her the nest structure; he may even present her with several nests to choose from. Correspondingly, the female would then take part in the ritual by viewing and accepting or rejecting the nest. Courtship behaviour focusing on the nest is found in fish and birds.

Aggression and Courtship

Courtship and aggression have close relationship because : (i) courting animals attract the attention of predators and are vulnerable to attacks. (ii) courting animals indulge into fights before coming to terms. Males of many species compete aggressively for females (Fig. 13). Therefore, courtship has to make a direct and quicker impact on the proper partner, to avoid aggression. In some cases predators exploit the courtship signals of their prey. **Predaceous Fireflies** imitate the light signals of other species in order to mislead, attract, and then to eat them. Another kind of "deception" is found in the orchid *Ophrys*, this flower not only imitates the appearances of an insect but also the smell of receptive female digger wasp or bumblebee; when the respective male insect lands on them in order to mate with what looks like a partner, they don't find any partner instead pollinate the flower.

In some species aggression between the male and female proves fatal, the male runs considerable risks when he attempts to mate with a female who may attack and eat him. Cannibalism associated with mating is a feature of a number of species of insects and spiders. Male spiders are considerably smaller then their predatory females therefore, there is a chance that the female can take them as prey. The male first "knocks" or vibrates her web in a different way indicating to her "its me-your male and not your food, please don't eat me". In some, the courtship ritual is, that the male presents the female with an insect that serves to keep her mouth parts busy while he

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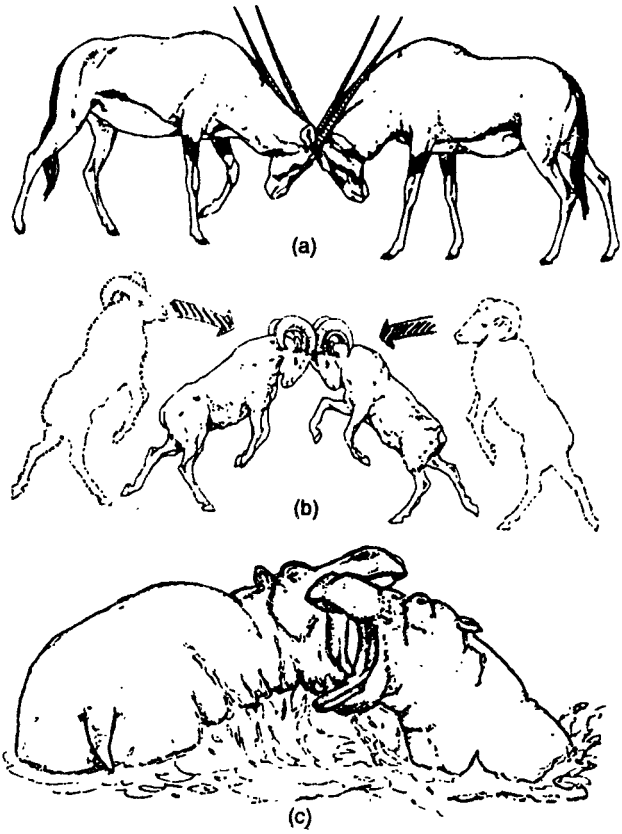

Fig. 13. (a) Gemsbock males bang heads, (b) Male bighorn rams fight during rut, (c) Male Hippos fighting for territory.

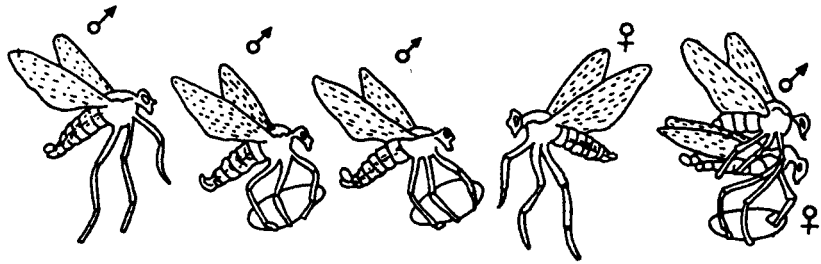

Fig. 14. Presentation of prey by male cupid fly to female.

mates with her (Fig. 14). The male Tarantula counters the threat from the female's powerful jaws by holding them open with his front pair of appendages, it is an important part of courtship. A **Crab spider** male immobilizes the female by tying her down with a network of silk threads. He then crawls under her and deposits sperms into her genital atrium.

(Z–37/Ani. Beh.)

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Aggression and sex have close relation in animal kingdom. Male and female **Black headed gulls** threaten each other by opening their bills and making noise. If both are willing to mate they assume appeasement **posture** in which they come closer, close their bills and become silent, turn their heads away, leading to mating.

In some crabs and dragonflies, and in a large number of vertebrates, the necessity of keeping rivals away has led to a system. In this way the males of a population are evenly dispersed and wait for a suitable sexual partner. In species that live in groups, the same purpose may be served by a **dominance hierarchy**, which allows some animals better opportunities for mating and prevents lower-ranking individuals from interfering with the mating activities of higher ranking males. As a general rule, the final phase of sexual activity of higher-ranking males is performance of copulation, which cannot be enacted without considerable timing and preparation. The sexual partners have to increase their own as well as each other's mating readiness. These processes depend largely on the stages of growth and maturation, and on certain other factors such as lunar phases and climatic conditions (springtime, rainy seasons, etc.), in addition to the behaviour of partners.

Female praying mantis eats his male. She starts eating from head and devours him completely by the end of the mating. This example makes some link between courtship aggression and feeding.

Evolution of Courtship

The courtship and mating behaviour did not appear in leaps and bounds it has evolved gradually with appropriate morphological feature over millions of years.

It seems courting behaviour has slowly diverged from feeding behaviour. In courtship of peafowel **Pea hen** pecks for food (as mentioned in steps number two and seven), sometimes with the greatest intensity when she is standing directly in front of the cock. It can be observed in **Ring-necked pheasants** and **Domestic chickens** that females frequently approach the cocks when the cocks are pecking on the ground for food. The hens also peck, at the same spot where the cock had "led the way." This is the very same behaviour performed by chicks when following their mother who is searching for food. In the three species of peacock belonging to the group pheasants (*Poplylectron*), we can see that the cock even holds a food grain toward the hen for a short period of time.

In the interaction between a hen and her chicks, the hens point out at the food and the young's imitate pecking .This is biologically meaningful because here the chicks are encouraged to recognize and take food. During the course of evolution courtship behaviour has made use of this behaviour. The cock symbolically takes the role of the mother hen while the hen plays the part of a chick. The complex courtship acts of the peacock are elaboration of

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behaviours normally involved in the transfer of food. The symbolism of this ritual has gone so far that food is no longer offered or shown; the cock only "pretends" that there is food in the focal point of his arched feathers. The hen, too, pecks only symbolically.

In various bird species, courtship feeding has undergone a greater or lesser degree of symbolization. African dabchick male feeds his female before mating. **Black-headed gulls** engage in real feeding, males of the parrot *Agapornis* merely balance a food kernel on the tip of their tongue before copulating, holding the bill wide open. **Courtship feeding** is used as a device for suppressing the predatory tendencies of the female by certain species of flies belonging to the family **Empidae** (cupid fly). In these creatures, the basic courtship pattern is that the male gives the female a gift of an insect which he has previously caught, and mates with her while she is busy eating it. However, different species in the empid family show a variety on this basic pattern. In some species, the male wraps the food (prey) in silk before he gives it to the female (Fig. 14). Since she has to unwrap it before she can eat it, the male gains extra time in which he completes mating, some species make a silk cocoon around prey. What has happened during the evolution of this behaviour is that the presentation of food "**gift wrapped**" has become ritualistic and essential pre-copulatory display. Females will only mate with males that are carrying cocoons.

Over millions of years of time beautiful plumage, fur, antlers, horns and complex behavioural activities to match with their displays have been selected. Peahens preferred "dancing" peacock over others so the males got all the more beautiful. This is **sexual selection**. Sexual selection is an evolutionary process, it is much more intense in males than females. **Charles Darwin** divided sexual selection into two types :

1. **Intrasexual selection.** This favours the evolution of male aggression and aggressive characters like large body size, large horns, sharper teeth and more fighting ability. In this, males compete aggressively among themselves for sexual access to females.

2. **Intersexual selection.** This favours the evolution of all those characters and movements which are used to attract females like elaborate male courtship displays, colour patterns and special structures like crests, plumes and fur.

It has been observed that even closely related species differ in their courtship behaviour. The differences between courtship behaviour in species-serve females to recognize males of their own species.The females exert some kind of selective pressure on the species as a whole by preferring males with more conspicuous plumage and more intensive courtship behaviour. Another suggestion is that males with greater colouration and more intensive courtship movements have an intimidating effect on other males, who are then inclined to stay away and not disturb the mating process.

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Courtship and Mating in Non-human Primates

A student of animal behaviour has special interest in the behaviour of monkeys and apes as they are closest to us in evolutionary tree. Therefore, their description has been specially included in this chapter.

Three things are important in courting non-human primates (i) **Attractivity** (male's degree of interest in the female) (ii) **Proceptivity** (female's active interest in the male) and (iii) **Receptivity** (female's willingness to accept the male; this depends upon levels of estrogen, progesterone, testosterone, in the blood and on menstrual or estrous cycle; **Beach**, 1976).

Courtship among non-human primates is not as attractive as it is in birds or fish. It is formed of following components :

(1) Identification of a female by a male from the group.
(2) Male follows the female, female takes a note of him.
(3) Male gets closer to female, checks her genitalia.
(4) Female indicates her willingness.
(5) Both start remaining closer, during this time female shows her genitalia by deflecting her tail, male checks her genitalia visually and physically.
(6) Grooming in mating pair is common.
(7) Pheromone marking takes place in some species.
(8) Special gestures, postures and vocalization varies from species to species
(9) Physical inspection and licking of female genitalia by male is seen in some species.
(10) Mating takes place.

Courtship and mating in non-human primates has been described under following headings :

(1) Courtship in primitive primates.
(2) Courtship in new world monkeys.
(3) Courtship in old world monkeys.
(4) Courtship in apes.

[I] Courtship in primitive primates

Receptive females of the genus **Tupaia** during courtship make short, darting runs to maintain about a meter distance from her potential male. In **Tupaia tana** (found in **South America**) the male performs a "**courtship**" **dance**; **circling** the female while **stamping** as the female vocalizes. The male's behaviour includes **licking** the female's vulva, **mounting**, and **gripping** the fur on the neck of the female with mouth. He places his forelimbs around the female's back, the female displays **arching** of the back for intromission, and he thrusts to ejaculates. After copulation, each animal grooms its own genitals.

Among **Lemurs**, (found in **Madagascar**) sexual behavioural patterns vary with the genus and species. In **Dwarf lemur**, the female lies with her belly

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on a branch as male mounts with his forelimbs around the female and his feet grasping her ankles. The **male** also **waves** his **tail, licks** the female's perineum and neck, and emits a sound. In **Galago senagalensis** (found in **Africa)** estrous includes **swelling** and **flushing** of vaginal opening, and white veginal discharge. Estrous lasts for about three days. Females are not receptive outside of estrous. While following the female the male emits a clicking sound. He mounts with his arms around the female's middle, his chin on the back of her neck, and his feet on a branch or grasping the female's legs. While mounting the male emits a **loud call** and **whistle**, then remains motionless for a time just before dismounting.

In **Galago alleni**, one male mates with 6 to 8 different females. The surprising thing is that in this species the courtship takes place independently of female estrous. In other **Lorisoids** like **Nycticebus coucang** (found in **Far East**), female **suspends** herself under a branch, **upside down**, as she invites. The male inspects her genitalia after that he mounts her in this upside down position.

[II] Courtship in new world monkeys

In **Common Marmoset** (found in **South America**) copulation is preceded by a display of courtship in which the members of a mating pair **follow** each other, both with **arched backs**, arms and legs extended, and piloerection (raising of hair). Both sexes **scent mark**, after that the male approaches the female while **lip-smacking** (kind of flying kiss), as the female **crouches** it lip-smacks at the male. Their **tongues** make **contact** a sort of kissing and they lick each other's faces and genitalia. The male then mounts the **crouching female** by grasping the hair on her waist and making seven to 10 thrusts to ejaculation. **Tongue movements** are visible throughout copulation.

Female **Cebus monkeys** (found in **Africa**) have a vaginal cycle of 16 of 23 days, but there is only irregular external mensturation in some species. Copulation coincides with ovulation. Even though **Capuchins (cebus sp** found in **South America**) are very common animals, there are no good descriptions of their reproductive behaviour. Among **Wooly monkeys** (found in **South America)** mensturation occurs regularly every 23 to 26 days. There are vaginal changes but no external swellings. Among **Owl monkeys** (found in **South America**) copulation is not preceded by a courtship display although inspection and touching, side to side rubbing, and much mutual heterosexual grooming just prior to copulation is seen among them. In **Squirrel monkey** (found in **South America**) there is cyclical sexual activity, sometimes accompanied by swelling of the females genitalia. The male squirrel monkey **jumps back and forth** between branches and his female. He **opens his mouth** and contracts his abdominal muscles. He also **chases the female**, bites her tail, and inspects her genitalia prior to copulation. Females who are receptive direct genital displays toward the male sprinkling a little **urine** as they display. The female

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initiates mounting by presenting the ano-genital region toward the male (**tail deflected**). She looks back over her shoulder toward him. Squirrel monkeys form temporary courting pairs in which **following** and **mutual looking** are common. When mounting, the male grasps the female's waist with his hands and her legs with his feet. After 10 to 25 mounts ejaculation occurs, after which both male and female inspect and **groom their own genitalia**. If the female squirrel monkey is not receptive she will move away from a courting male. During mating season, **males** become **aggressive** and **excitable** and increases their marking behaviour and sniffing of females.

In **Howler monkey** (found in **South America**) a sexually active courting pair spends a number of hours together, away from the group. **Tongue movements** and **crouching** are female invitations to the male for sex. Male howlers also make the tongue movements, and they mount as do other new world monkey males i.e. **dorso-ventrally**. During copulation howler female looks back at the mounting male and reach back to touch him with her hand. This phenomenon is known as "**Reaching back**". Curiously, after copulation, **female** howler monkeys often **roll on their backs**. There is no evidence for a mating season in howler monkeys. In **Spider monkey** (found in **South America**) the adult female has a **pendulous clitoris** which is larger than the males penis. The urine of female spider monkeys is attractive to males and males smell and lick their fingers after grabbing or fondling the female's pendulous clitoris.

[III] Courtship in old world monkeys

In *Macaca mulatta*-the common red faced monkey of north India, the periods of estrous in the rhesus are stages of female receptivity, that coincide with the ovulatory phase of the menstrual cycle. During female receptivity (i) males follow females, (ii) females approach males, (iii) courtship pair forms, (iv) heterosexual grooming between members of courting pair increases, (v) the female's skin of the face, nipples and perineum turn dark red, (vi) and her sexual skin swells (**Carpenter** 1942). During the courtship the female presents, and ejaculation in the male takes place after several mounts which leaves a **coagulated plug** in the **female's vagina. Aggression increases** during the rhesus mating season. **Grooming** is done extensively to sexually arouse the partner. Presenting by the female involves turning the hind quarters towards the male and lifting the tail out of the way.

Copulation includes a series of mounts, some of that include intromission and **pelvic thrusts**. Eventually on one of the mounts the male ejaculates. In mounting, the male holds the fur on the female's sides with his hands and clasps her legs with his feet. The **female looks back** and reaches back to **touch his thigh** or **scrotum**. When the male ejaculates he **bares his teeth** and squeals while the female looks at him and **lip-smacks**. Following are

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ejaculatory mount, the male eats the ejaculate remaining on female's back and on his own genitalia.

Homosexuality has been observed in Rhesus. In this act a male mounts a male with anal intromission and ejaculation. Female homosexual behaviour also occurs in rhesus, but less frequently than male homosexual behaviour.

Sexual behaviour and courtship activity are affected by social rank in both males and females. One final point regarding rhesus sexual behaviour deserves mention. Among rhesus monkeys there is an inhibition of mating between mothers and sons i.e. mother-son mating is rare. The incidence of brother sister mating is also rare. It has an evolutionary significance, as it prevents inbreeding.

In **Japanese macaques** (*Macaca fuscata*) the females have a 28 days cycle. Female usually courts with several males and copulation involves 8-30 mounts with one to eight thrusts per mount. As in the rhesus, the female reaches back with one hand to grab the male when he ejaculates. More dominant males tend to mate with dominant females and lower ranked males with lower ranked females. High ranking males have been seen interfering with the courtship and mating of lower ranking males. During mating season there are increased male displays such as **shaking, licking, leaping, tossing** and **swinging**. In Japanese macaques most young males leave their mother's troop, and approach a new troop during mating season.

The **Pigtail macaques** (found in **Far East**) have a slightly longer menstrual cycle (thirty two days) than does the rhesus. Also, unlike the rhesus, the pigtail female shows a very obvious sexual skin swelling for 21 of the 32 days of the cycle. Mounting occurs during this period and females court and copulate with several males. Like rhesus females, pigtail female reach back the mounted male and grasp his leg. At ejaculation male grimaces and emits a high pitched squeal. Rhesus, Japanese and pigtail macaques are also known as Multiple Mounting Ejaculators (MME). In **Stumptail macaque** (found in **Far East**), the menstrual cycle is 28 days long. There is no swelling of sexual skin. Prior to copulation, the male approaches, rubs the female's tail, pulls it aside, places a finger in the female's vagina, and sniff's his finger before mounting. Copulation involves only one mount, with many thrusts, ending in ejaculation. Thus, stumptails are referred to as Single Mount Ejaculators (SME). While mounting, the male lip-smacks exposing his teeth, chatters, then barks. At ejaculation the male bites the female back. During copulation, sub-adult and juvenile monkeys often disturb the copulating couple. There is also frequent homosexual activity between adults and infants. Besides copulation, the stumptail macaques displays a great variety of sexual behaviour, probably more than any other species of macaques. Males sometimes engage in mutual masturbation, and females also engage in mutual vaginal stimulation.

The **Bonnet monkey** (*Macaca radiata*) of **Southern India**, is SME. Bonnet monkeys have a menstrual cycle of 25 days during which the menstrual flow

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may last 10 days. There is no swelling and no vaginal discharge. There are no courting pairs formed in bonnet monkey. In addition, there is less inter group migration in bonnet males, suggesting that there is more inbreeding in the bonnet.

In **Yellow baboon**, (all baboons are found in **Africa**) there is a 31 to 35 day menstrual cycle with a menstrual flow of about 3 days. In contrast to macaques there is a marked swelling of the sexual skin in all species of this genus. In **Chacma baboon**, males and females form courting pairs. During courtship they remain with each other, follow and groom. Copulation involves a series of mounts, each with one to 20 thrusts, only the last mount being an ejaculatory one. The mount occurs just as in the rhesus with foot clasp and facial grimace in the male. The female however, emits a copulation call consisting of a number of sharp barks. After the mount, the female rapidly withdraws from the male. **Olive baboons** differ from Chacma baboons in that ejaculation occurs in a single mount, males do not grimace during copulation, females do not give copulation calls. The **Sacred baboon** lives in one male groups. Each male has a harem of females. The male copulates only within his harem. Ready female courts the male, it goes in front of him , looks back and shakes her head.

Among **Mangabeys** (found in **Africa**) the menstrual cycle is of 30 days, there is a sexual swelling at mid cycle. They are Multiple Mounting Ejaculating species like rhesus. At ejaculation, the female reaches back to grasp the male. **Patas monkey** (found in **Africa**) live in one male groups. They have 30 days menstrual cycles with no sexual swelling. Multiple mounts are required before ejaculation. The female solicits mounting by running toward the male with her tail down, eyebrows lowered and lips closed.

Langurs-the black faced monkeys of India have a 27 days cycle with a two to four day menstrual flow, and there is no external swelling. The Langurs are MME species. The males do not use a foot clasp when they mount. All mounts are initiated by the female who drops here tail to the ground and shakes her head from side to side. Courtship lasts a few hours, the male follows the inviting female. Sexually excited males emit repeated low pitched sounds. Sometimes, during copulation, subadult male langurs disturb the copulating pair.

[IV] Courtship in apes

Gibbons are the monogamous **Asian lesser apes**. In **India, Hoolock gibbons** are found in **North East**. The sex partners are attracted through pheromones, they see each other, sit and gaze, hide in the foliage, then the most interesting part of the courtship begins–**singing of the songs** in the form of a **duet song**. These are actual songs with a melody, stanza and para. Mating postures can be **dorso-ventral** (like rhesus) or **ventro-ventral** (face to face). Copulation

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mostly occurs in the morning, juveniles and infants observe. They are MME species. Gibbons form a pair for life, new mate is accepted if one mate dies.

Chimpanzee have regular menstrual cycles and a pronounced midcycle swelling. The menstrual cycle is about 35 days long with external menstrual flow occurring on 3 of these days up to 48 years. The Chimpanzee is SME species. Male and female can greet each other with **hooting**, **hugging**, and **back patting**. During this period females increase their **play** with males. The females initiate the play with slow, **gentle wrestling**. They also **mouth groom** the males. The female walks in front of a male, shows off her sexual swelling, the male examines, the female **crouches** and the male **climbs** from behind (ventro-dorsal) but at times it can be **ventro-ventral** too. The male thrusts from 5 to 20 times to ejaculate. Both male and female exhibit thrusting during copulation. The female often looks back at the male and makes screaming sounds. Copulatory behaviour includes many postures. In one case, the female stood quadrupedally and the male covered her from behind (**dorso-ventral**). He thrusted several times. Immediately afterwards the male lay on his back with legs spread, and the female fondled his testes and licked them.Sometimes they even copulate standing on two legs, i.e. ventro-ventral position, copulation also occurs in **latero-ventral** position.

In play behaviour, infants appear to touch each others lips, manipulate each other's genitalia with fingers or lips. The kisses between infants are sometimes very long in duration. **Homosexual behaviour** and **masturbation** is seen in chimpanzees. Female homosexual nentro-ventral thrusting are common. When a male chimpanzee reaches adolescence, he starts to sleep alone unless he finds a female in estrous, in which case he sleeps with her (**Riss** and **Godall**, 1976).

Among **Gorillas** a prominent genital swelling at estrons is absent in females. Duration of menstrual cycle is 30 days. The adult male identifies a ready female through pheromones. The female stays closer to male, may go in front of him. During mating both males and females thrust and make vocalizations and facial expressions. Homosexual behaviour in females occur regularly. Mesturbation has been seen in both males and females in captive mountain gorilla.

Wild **Orangutans** are solitary animals, male and female make a temporary bond only for mating. The male gives out loud calls that are identified by receptive females. They find each other, roam around in forest, foraging together. The orangutan female not only shows receptive behaviour, but she also shows **proceptive sexual behaviour**. Proceptive sexual behaviour includes **play, fast brachiation, hand and hand slapping, oral genital contact, genital-genital contact** and **pelvic thrusting**. Dorso-ventral and ventro-ventral copulation has been observed. Mothers and male infants establish genital contact. The mothers also provide oral-genital contact.

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IMPORTANT QUESTIONS

➤➤ *Long answer type questions*

1. Describe courtship in three spined stickleback fish. Draw neat diagrams.
2. Explain with diagrams sequence of courtship in Guppy and Tilapia fish
3. Write about courtship in Peacocks.
4. Enumerate on "attention and courtship".
5. What relation courtship has with brood care a, aggression and feeding?
6. Write about courtship and mating in non human primates.
7. Describe courtship mating in dove.

➤➤ *Short answer type questions*

1 Write short notes : (i) Sequence in courtship, (ii) Attention and courtship, (iii) Type of fertilization and its relation with courtship, (iv) Courtship is stickle backs, (v) Courtship in Jewel fish, (vi) Courtship in Guppy, (vii) Courtship in Tilapia, (viii) Courtship in Smooth Newt, (ix) Courtship in Ring dove, (x) Courtship in Peacock, (xi) Visual signals in courtship, (xii) Chemical signals in courtship, (xiii) Tactile signals in courtship, (xiv) Visval signals in courtship, (xv) Brood care and courtship, (xvi) Aggression and courtship, (xvii) Feeding and courtship, (xviii) Courtship in new world monkeys, (xix) Courtship in old world monkeys (xx) Courtship in apes, (xxi) Courtship in primitive primates.

➤➤ *Very short answer type questions*

1. Write in few lines :
(i) Four important conditions for successful mating, (ii) Two important characteristics of courtship, (iii) Factors triggering courtship, (iv) Intersexual selection, (v) Intrasexual selection.

➤➤ *Matching type questions*

1. Match the following :

1. Lek display	(a) Pond mussle
2. Ventro-dorsal position	(b) Smooth newt
3. Mantis	(c) Palolo worm
4. Viviparity	(d) Guppy fish
5. Gorilla	(e) Jewel fish
6. Goodall	(f) Ring dove
7. Hoolock	(g) Sexual selection
8. M. fuscata	(h) Silver back
9. Baboon	(i) Chimpanzee
10. Peacock	(j) Ape
11. Bowing and cooing	(k) Japan
12. Nipping	(l) Eating male
13. Full moon	(m) Sage grouse
14. Spermatophore	(n) Mating
15. Bitterling	(o) Africa

Answers

1. (m), 2. (n), 3 (i), 4 (e), 5. (h), 6. (i) 7. (j) 6. (k), 9. (o), 10. (g), 11. (f), 12. (d), 13. (c), 14. (b), 15. (a)

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➤➤ ***Fill in the blanks***

1 Cichlid is a ....breeder.
2. Sharp ribbed salamander deposits a . . ..
3. Fertilized eges are carried on the back by..... .. ..
4 Courtship is stickle back was documented by. . .. .
5. Scientific name of sticlke back is... ... .

Answers

1 mouth, 2. spermatophore, 3. Midwife toad, 4. Tinbergen, 5 Gasterosteus aculatus.

➤➤ ***True and false***

1. In gorillas young males have silver back
2 Sticklebacks are mouth breeders
3. Cichlid are mouth breeders.
4. Sharp ribbed salamanders have internal fertilization.
5. Palolo worms gather for mating in new moon.
6. Quiering is part of courtship of Tilapia.
7 Quiering is the part of courtship of sticklebacks.
8 Nipping at the nest site is done by Jewel fish.
9. Male Wolf spider waves its antennae to female
10. Male Wolf spider waves its palps to female.
11. Bees do not go for nuptial flight
12. Grasshopper produces sound by stridulating.
13. Males Pistol shrimps attract their females by releasing their claw from a small space.
13. Grayling butterfly belongs to subfamily satyrinae.

Answers

1. False, 2. False, 3 True, 4. False, 5 False, 6. False, 7. True, 8. True, 9. False, 10. True, 11. False, 12 True, 13. True, 14. True.

➤➤ ***Multiple choice questions***

1. Animals court to :
   (a) Synchronize release of gametes (b) for pleasure (c) to keep busy
2 External fertilization is a :
   (a) primitive form (b) an advanced form (c) both
3 Gibbons
   (a) are new world monkeys (b) sing songs (c) are found in Africa
4 Mouth breeder is :
   (a) stickleback (b) cichlid (c) tilapia
5 Proper nest is built by :
   (a) stickleback (b) cichild (c) tilapia
6. Spermatophore is deposited by :
   (a) Newt (b) Peacock (d) Guppy
7 Quiering is :
   (a) quick dash (b) gentle tapping (c) curiosity
8. Courtship is sticlkeback was reported by
   (a) Lorenz (b) Tinbergen (c) Frisch

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9. Sneaked in mating in stickleback is reported by :
   (a) Tinbergen (b) Lorenz (c) Desmod Morris
10. Hemichromis bimaculatus is the scientific name of :
   (a) stickleback (b) guppy (c) jewel fish
11. Lebistes reticulates is the scientific name of
   (a) stickleback (b) guppy (c) jewel fish
12. Pheromone produced by silk moth female can be received at the distance of .
   (a) 1-2 miles (b) 2-4 miles (c) upto 7 miles
13. Female sea cucumber courts her male by :
   (a) chasing (b) wrapping (c) both
14. Presentation of food filled cocoon is found in
   (a) crickets (b) mantis (c) cupid fly
15. Large horns, sharp teeth are the consequence of :
   (a) intersexual selection (b) intrasexual selection (c) both
16. Displays and patterns are the consequence of :
   (a) intersexual selection (b) intrasexual selection (c) both

Answers

1. (a), 2. (a) 3. (b), 4 (b) 5. a) 6. (a) 7 (b), 8. (b), 9. (c) 10. (c), 11 (b), 12 (c), 13 (c), 14. (c) 15. (b), 16. (a)

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6

Aggressive and Territorial Behaviour

AGGRESSIVE BEHAVIOUR

Introduction

Aggression is a part of **agonistic** behaviour, that comprises of everything leading to **resolution** of **conflict** between individuals. This includes **aggression** as well as **escape**. Aggression is used to adjust inter and intra specific conflicts. **Conflicts** arise when two or more individuals **compete** for same object like food, water, space (**territory**) for burrows and holes, egg laying sites, tree branches for nesting or resting and for mates.

Aggression is **expressed** depending upon its **intensity** from mild, to medium to most pronounced. Facial expression, chasing, grabbing, pulling, pushing, banging and lastly fighting and biting all are different forms of aggression. They vary from species to species. However, their functions are similar. Aggressive behaviour is formed of four **components** (i) **agonistic (threat)** (ii) **conflict (fight)** (iii) **appeasement (submission)** (iii) **escape (flee)**.

Aggression is formed of complex responses of the animal's nervous and endocrine systems, **programmed** to be used at the time of **stress**. Conflict — between conspecifics without dangerous weapons is not fatal. The opponents go on fighting until one of them is exhausted. But animals with weapons can kill each other. Aggression is genetically controlled, it has high degree of heritability, therefore, has adaptive value.

Types and Causes of Aggression

Aggression is influenced by **internal** and **external stimuli**, **hunger**, **thirst**, **pain**, **breeding** and other **social circumstances**, **genetic factors**, **learning processes**, and **frustrating memories**.

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[I] Xenophobia or aggression towards strangers

The strongest evoker of aggressive response in animals is the **sight** of a **stranger**, specially a territorial intruder. This **Xenophobic principle** has been documented in every group of animals displaying higher forms of social organization. Almost all the animal species chase away a stranger trying to come inside their territories.

[II] Crowding or proximate aggression

Close proximity and crowding cause **more encounters** and **more aggression**, this rule is applicable to all animals. Increased crowding causes decrease in the space availability per animal consequently the encounters increase. Crowding in captivity causes more aggressive interactions in rhesus than free ranging (**Southwick** 1969). Crowding in captive rats leads to behavioural pathologies like fierce **fights** and **infanticide** (**Calhoun** 1962). The introduction of a strange individual generates a substantial increase of aggression among residents because of xenophobia and also because they add to crowding. Both human and nonhuman animals tend to act most ferociously when crowded. In a mice colony a stranger can not gain entry (**Selander** 1970). Knots live in dense flocks while Ringed plovers don't, because of crowding knots are more aggressive. During egg laying period female Iguanas collect in hundreds and fight for the sandy spaces between the rocks, where they bury their eggs. Crowding at **sea shores** of **sea lions, seals, sea cows, walrus, sea gulls, penguins** always increases aggression in their societies.

[III] Space or territorial aggression

Signalling by a male to an intruder (generally male) to keep away from his area is very commonly seen in animal kingdom. These territorial males are tolerant towards females, the females entering the male territory assume **appeasement posture** e.g. **three spined sticklebacks** during their courtship mating. The most common reason for aggressive response is the territorial intruder. **Strange ants** in a colony of ants are enough to raise alarm through pheromones, within no time the soldiers come and gather around the strangers. **Monkeys** show signs of aggression when strange monkey tries to come closer to their social group. Male **lions**, normally move slowly and quietly, but adults of a pride become attentive and start roaring when strange males come into sight. East **African baboons** fight for **sleeping trees**, desert dwelling **hamadrya baboons** fight for **water**. **Fur seals** breed on rocky islands in north pacific, the males compete aggressively for a piece of **rocky area**. In breeding season impalas become territorial and aggressive (Fig. 1). Territoriality has been described ahead in this chapter.

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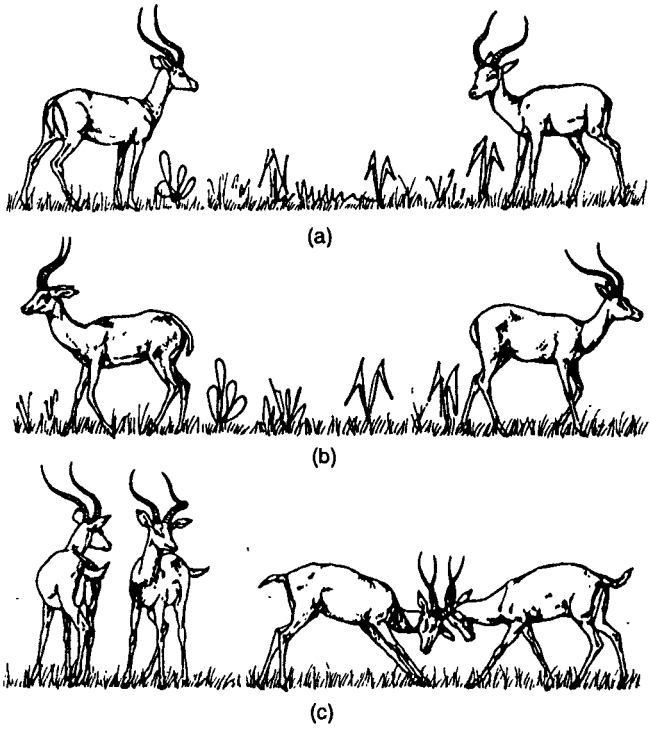

Fig 1. In the breeding season Impalas become aggressive and territorial : (a) Two males look at each other, (b) They may retreat without any aggression, (c) They may come closer, (d) Start fighting for territory and females

[IV] Seasonal changes or breeding/sexual aggression

Males threaten or attack rival males and sometimes also threaten, bite mating females. Male **Hamadraya Baboons** recruit young females for breeding into their harem by threatening them. Threating or show off of strength and not actually indulging in fights is beneficial to animals. Actual fight gets costly. Animals get gushing wounds, infections, fractured limbs, broken teeth and death. Most animals put up a show of their strength and weapons. Deer show antlers, antelopes show horns, tigers roar and show canines, wolves and dogs growl and show full set of teeth. Animals look at each other's display and decide who is weaker. The weaker animal leaves the battle field. Male **Oryx antelopes** threat each other by standing opposite to each other and by raised head (Fig. 2a), they also involve in forehead pushing (Fig. 2b). **Grants Gazzeles** often avoid a fight by using threat displays (Fig. 3a, b, c).

The aggressive interactions in most species peak in the **breeding season**. Fighting in **Tigers** is restricted to contest for estrous females. The **Sifaka** a lemur is peaceful through most of the year but erupts in fighting during

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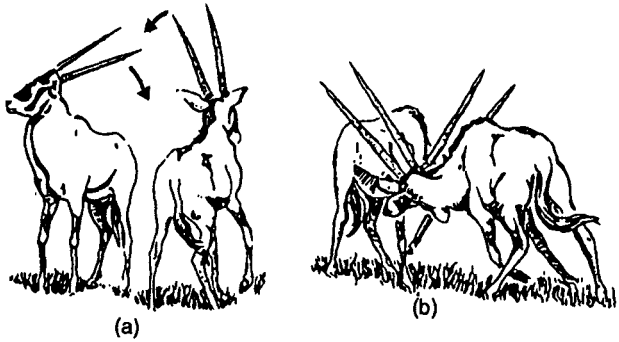

Fig 2. (a) Two male oryx come closer, stand opposite to each other pointing horns, (b) Involve in head pushing.

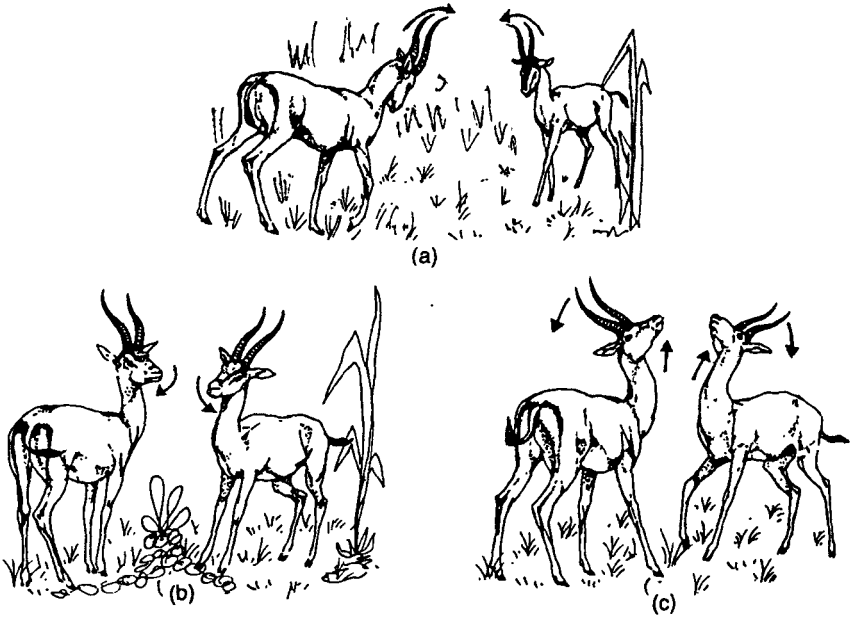

Fig. 3. (a) Two male Grant's Gazelles often avoid aggressive interaction by using just threat displays. Males come closer, tilting their horns, (b) Then turn heads on a side, (c) Raise heads and horns back. One of them leaves.

breeding season. Animals, specially females become more aggressive just after giving birth. Female **Reindeer** is a passive animal most of her life but just before and after giving birth she becomes aggressive. The bulls of seals, Walrus, sea elephants, elephants, stags of deer and antelope and most of the males in non human primates get extremely aggressive during breeding or rutting season. Mates are an important resource and are cause of aggression. Sexual aggression is highly seasonal. The correlation of breeding and

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aggressiveness is seen among ungulates. Head to head banging in ungulates is commonly seen during the rutting season (Fig. 2b).

[V] Previous experience or pain and aggression

Animals behave aggressively in **response to pain (Ulrich,** 1966). Two **rats** caged together begin to **fight** if they receive an **electric shock.** Aggression in both human and non human animals has been attributed to frustration. Offer a hungry rat access of food at the end of a runway, then put a glass barrier just before he reaches it, the rat will behave aggressively, it will scratch, bite. Never try to disturb your pet dog while he is feeding.

A variety of experiences in the life of an animal influence the form and intensity of aggression. When two rats are given painful stimuli e.g. electric shock, they attack each other. You keep the puppy of domestic dog in isolation, beat or scold him, chain him, he will grow into a ferocious dog. The past painful experiences make him more aggressive.

[VI] Social status or dominance aggression

Displays by dominant animals towards subdominant group members such as the strutting walk of Lemmings, tail up by rhesus and facial expression and tail carriage in wolves prevents unnecessary fights among the conspecifics. Establishment of dominance hierarchy helps conserving time and energy among the members of a social group. Once the dominance is established, may be by fighting, but later it is followed by just showing off the strength by exposing canines, or horns and antlers. Subordinates respond by appeasement signals. Thomson's Gazelles are small sized antelopes found in Africa. Their males establish dominance (Fig 4). As animals move up in rank, their **readiness** to **attack increases,** particularly towards rivals who have been defeated previously. Although the phenomenon of dominance hierarchy is more pronounced in vertebrates, it also occurs in bumblebees and cricket (**Free,** 1961).

Male mice *Mus musculus* reared in isolation after weaning were less aggressive because they were not subjected to establishment of dominance than those reared in social groups because they had to follow dominance hierarchy. The dominant males in rhesus are more aggressive than subdominants. In a pride of lions, the dominant animals eat first. In a flock of **birds** there is a **peck order.** Birds higher in order are more aggressive. Animal hostility is precipitated by break down of social system, fighting increased in a social group of walrus when the leader was removed.

[VII] Food or feeding aggression

The relation of aggressive behaviour to the food supply and distribution can be seen among a group of animals feeding. Aggression is if the food is

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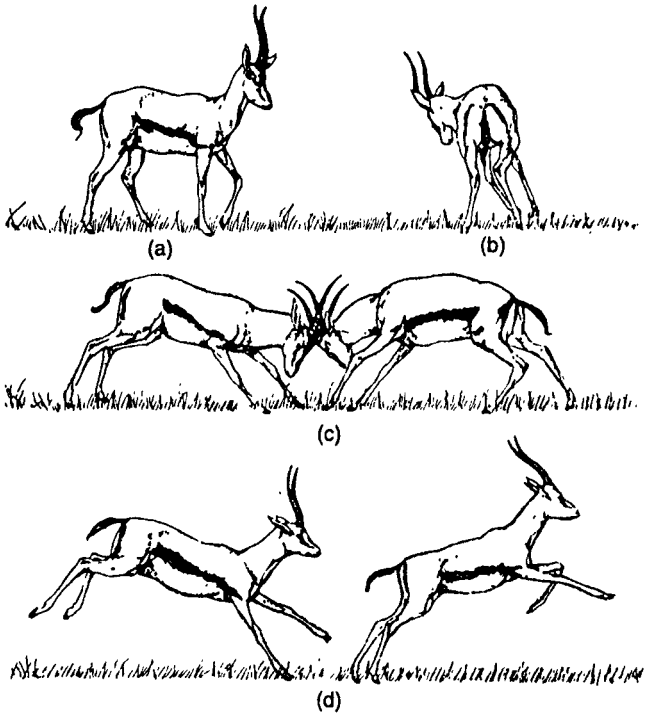

Fig 4. Thomson's gazelles have a ritualized fight Male (a) is threatening male (b) They push each other, (c) to test strength and to decide dominance. One of them decides to run away.

clumped or is in less amount. Food is a common cause for aggression. If there are ten hungry hyenas attempting to feed from a single zebra that offers enough meat for only five, then the hyenas get aggressive and fight for the food; likewise **shortage of food** can cause fights among other animals also. Baboons in Africa and rhesus in India can be seen fighting for food. If the food is **clumped** rather than **homogeneously distributed** the fights are more. **Oceanic birds** such as **puffins, auks, murres, cormorants** and **gulls** fight over clumped food. Aggressive resource competition occurs when the resource is limited in quantity and therefore worth fighting for. Aggressive competition may be strongly seasonal, if the resource itself is seasonal. For example there are frequent fights at the bonanza of fruits and oasis of water.

[VIII] Nest or parental aggression

It can be of two types (i) towards nestlings, (ii) towards intruders. Parents of many birds and mammals direct mild forms of aggression at their offspring (a) to keep them close. (b) or urge them to move, (c) to break up fighting, (d) to terminate suckling. and (e) at the time of weaning.

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Almost all females in the entire animal kingdom become aggressive towards intruders when they become mothers. A mother **rhesus** or **langur** can bite at the **slightest provocation**. The **crocodile** female makes a nest for her eggs and then guards them ferociously. This is an adaptive behaviour with evolutionary significance, because the female invests heavily in terms of time and energy to bring a baby to this world, she has to be aggressively protective. Even your pet bitch does not tolerate your approach towards her pups.

[IX] Instinct or genetic aggression

Is aggression innate or learned? It has both answers yes and no. It is partially determined by heredity as evident from the example given below.

According to **Lorenz**, individuals reared in a non frustrating environment will still be aggressive. Out of the two strains of mice he studied, strain A was aggressive and strain B was not. The puppies of both strains were cross fostered. B puppies were kept with aggressive mothers of A and puppies of strain A were kept with less aggressive mothers of strain B. That means **their environments were changed**. They were given enough shelter, food and water. It was found out that **puppies of aggressive strain remained aggressive in spite of peaceful non aggressive environment** around them. Lorenz said that animals have innate need to behave aggressively. Hermit crabs were kept in isolation away from group, these animals showed aggression. Such individuals that had never been provoked or frustrated by members of their own or other species fought aggressively. On the other hand, this does not mean that social experiences, and early childhood frustrations and traumas have no influence on aggression. It has profound effect.

Aggressive behaviour is **not pathological** or **abnormal** it is very much part of the normal behavioural patterns of almost all animal species. **Darwin** explained that stronger, aggressive and healthier animals are selected for reproduction to produce better progeny. The animals are favoured for aggression.

Aggressive behaviour is essential for animal's survival. Aggression can take numerous forms. It can be **accidental** (a frustrated pet dog can growl at its owner; a person annoyed with some one at office can shout at home at his wife) **or intended** (a hungry feeding pet dog can snap at owners approaching hand; a father can be angry with indisciplined child) **and physical** (through chase, bites, slap) or **mental** (it relates to feelings only e.g. a person could be smiling but may be feeling angry).

Aggression in two strains of male mice (**BALB/c** and **CD-1**) was studied. Aggressive behaviour was estimated by **wound counts**, and level of **testosterone** in blood. Physiological responses to aggression were investigated through urinary **corticosterone** and **adrenal tyrosine-hydroxylase** measurements. Marked differences were found between the two strains.

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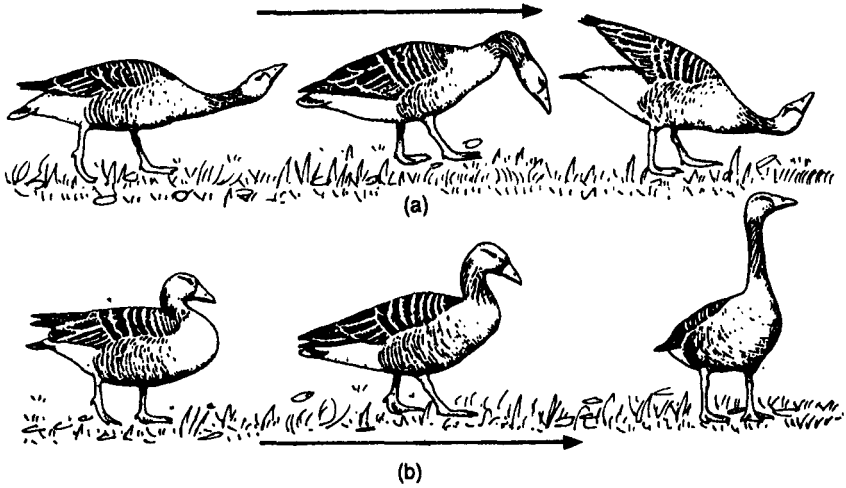

Fig. 5 (a) Increase in Aggression, (b) Rest to alertness.

CD-1 mice were more aggressive, had higher testosterone levels but lower corticosterone levels, and had fewer wounds than BALB/c mice. It seems that housing mice in small, socially stable groups or keeping social disturbances to a minimum considerably regulates aggression in caged male mice. Mice of both strains housed in cages with adequate quantity of nesting material had lower urinary corticosterone levels, lower aggression than standard-housed

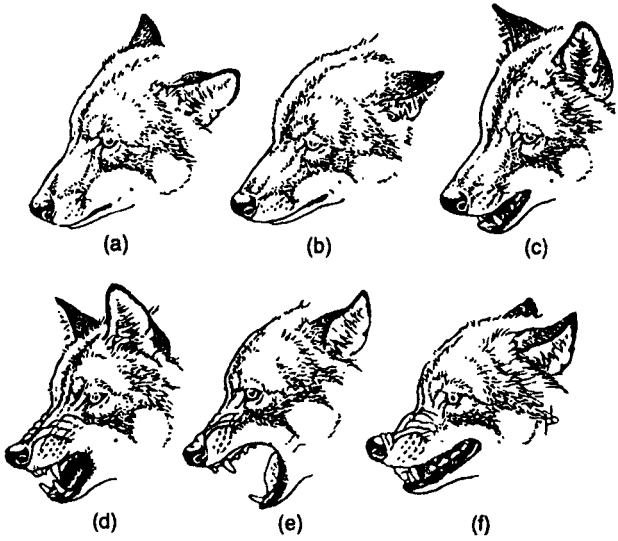

Fig. 6. Facial expression in dog . (a) Friendly, (b) Submissive, (c) Playful, (d) Very offensive, (e) Very defensive, (f) Aggressively defensive

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mice. For scientists working with captive mice it is advisable that animals are provided with sufficient amount of nesting material; this may enhance the welfare of laboratory mice.

Animals display threat and aggression in a stereotype, species specific manner. Graylag goose has been studied extensively by ethologists. Its resting and aggressive displays can be seen in Fig 5. These displays are genetically encoded and are performed in same rigid way by all graylag geese. Similarly aggressive facial expressions in wolves and dogs are shown in Fig. 6. These traits are also genetically determined.

Neural and Hormonal Control

Limbic system

It is a system of nuclei in the brain that maintains our emotional equilibrium. **Amygdala** is a part of limbic system (Fig. 7a). It is a little almond shaped structure, deep inside the antero-inferior region of the **temporal lobe**. It connects with the **hippocampus, uncus, septum pellucidium and the medial dorsal nucleus of the thalamus**. These connections make it possible for the amygdala to play its important role on the mediation and control of activities like friendship, love and affection, on the expression of mood and, mainly, on **fear, rage and aggression**. The amygdala, being the centre for identification of **danger**, is fundamental for self preservation. When triggered, it gives rise to fear and **anxiety** that leads the animal into a stage of **alertness**, getting ready for **flight or fight**. Experimental **destruction** of both amygdalas (there are two of them, one in each hemisphere) **tames** the animal, who becomes sexually non-discriminative, deprived of affection and indifferent to danger. The electrical **stimulus** of these structures elicit **violent** behaviour. **Humans** with marked **lesions** of the **amygdala**, lose the affective meaning of the perception of an outside information, the sight of a well known person does not mean anything to them. The subject knows, exactly, who the person is, but is not capable to decide whether he likes or dislikes him.

Hypothalamus

This structure has ample connections with the other prosencephalic areas and the mesencephalus. The hypothalamus has centre for **expression of emotions and anxiety**. Lesions of the hypothalamic nuclei interfere with several functions and some of the so-called motivated behaviours, like thermal regulation, sexuality, combativeness, hunger and thirst. **Hess** (1953) explored the hypothalamus and found that lateral and **posterior hypothalamus** have centres for **aggression, attack, fight** and **submission**. Destruction of these centres produced unresponsiveness in animals (**Ranson**, 1959). The hypothalamus also plays a role in **emotion**. Specifically, its **lateral parts** are involved with **pleasure and rage**, while the **median part** is involved with **aversion**,

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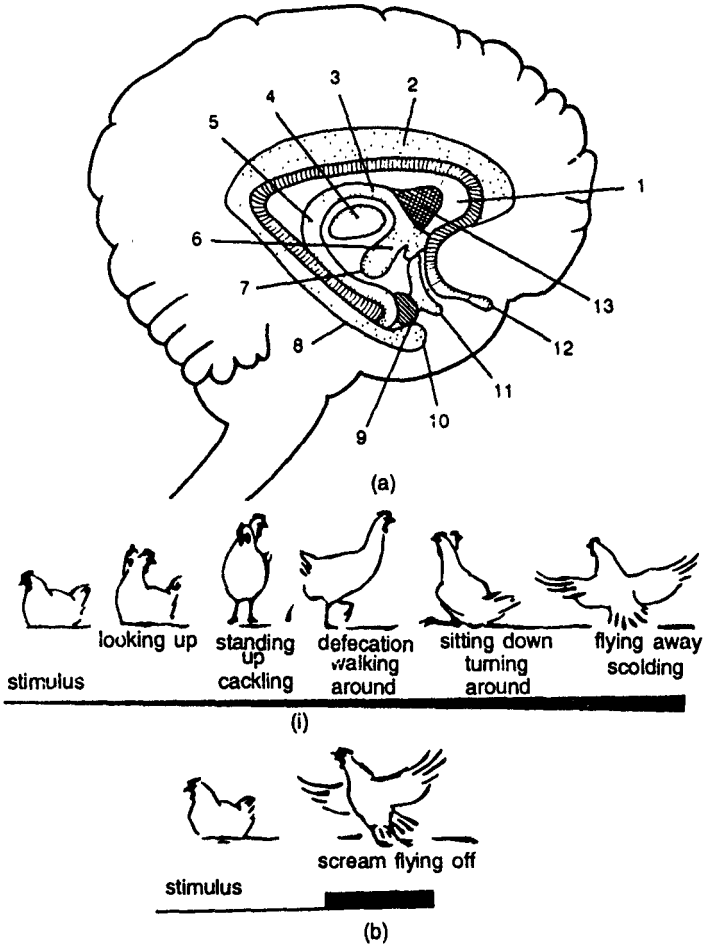

Fig. 7. (a) Limbic system. (1) Corpus callosum, (2) Cingulate gyrus, (3) Body of fornix, (4) Thalamus, (5) Dorsal fornix, (6) Column of fornix, (7) Mamillary body, (8) Hippocampus, (9) Amagdaloid nucleus, (10) Uncus, (11) Optic nerve, (12) Olfactory bulb, (13) Septum pellucidum. 7. (b) (i) Reaction towards slowly increasing stimulation, (ii) Reaction towards sudden, strong stimulus.

displeasure and a tendency to uncontrollable and loud laughing. It has nucleus for fleeing, when an electrical stimulus is given gradually to a cock it shows behaviour sequence of fleeing from looking up and around to standing up and checking to defecation in nervousness to walking around to sitting down and looking around to fly, in comparison to immediately flying away if the stimulus is given in a strong dose (Fig. 7b).

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Hormones and aggression

Among vertebrates it is a generalization that **males** are **more aggressive** than females. **Testosterone** is associated with aggressiveness (**Conner**, 1972). **Castration** causes a dramatic decline in aggression. Another important gland is adrenal, when this is removed, aggressiveness decreases. The aggressive **bulls** are habitually castrated to turn them into docile oxen. In animal kingdom males are more aggressive because they have to compete for females. This is a major selective pressure favouring male aggressiveness.

The function of hormones is to **fine tune** the **aggressive behaviour**. This can be understood in three levels of control :

(1) Preparation to face stress is done by **androgen, estrogen, and leutinizing hormone**, they raise the level of aggressiveness

(2) Quick response towards stress is met by **epinephrine and norepinephrine**. They prepare body physiology for "fight or flight".

(3) Slow and steady response towards stress in done by **adrenal corticosteroids**.

Animal weapons

Hunting can be treated as one of the most common forms of aggression. Animals are equipped with specialized **weapons** for hunting. Snakes have fangs, eagle, falcons and vultures have sharp beak and all the more sharper talons (Fig. 8), bears have non retractile claws, the big and small cats have retractable claws (Fig. 9), the sharks and crocodiles are dreaded for their sharp teeth, walrus have massive canines (Fig. 10 a), the snakes have deadly fangs, the bees, wasps and scorpion have stings (Fig. 10 b). Oryx have sharp horns. Horns of sheep and antlers of kudus of Africa are used as weapons against predators (Fig. 11).

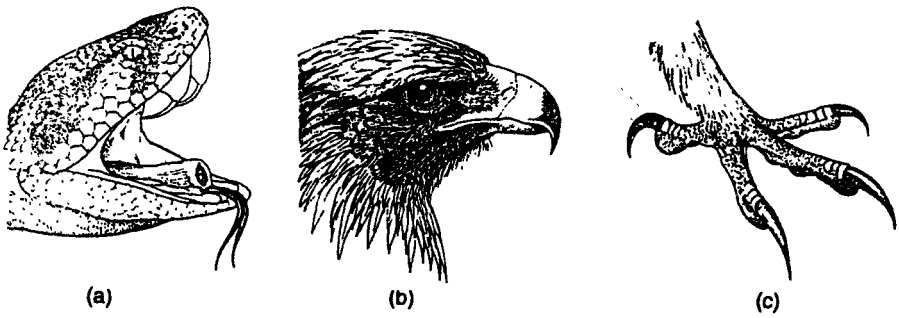

Fig. 8. (a) Snake's fangs, (b) Eagle's sharp beak, (c) Reptor's talon.

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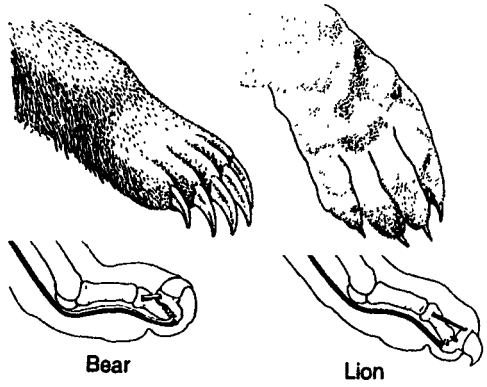

Fig. 9. Non-retractable claws of bear and retractable claws of lion.

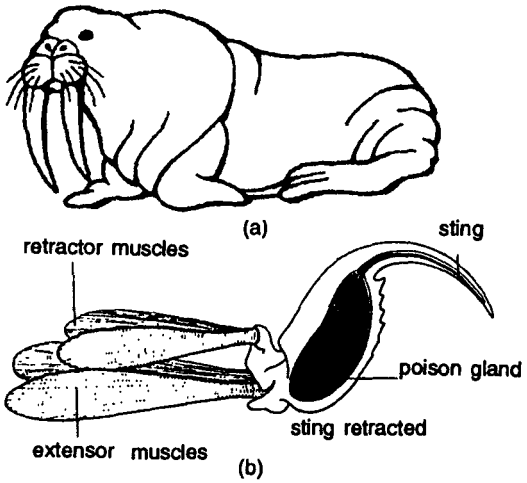

Fig. 10. (a) Long sharp teeth of Walrus, (b) Sting of scorpion.

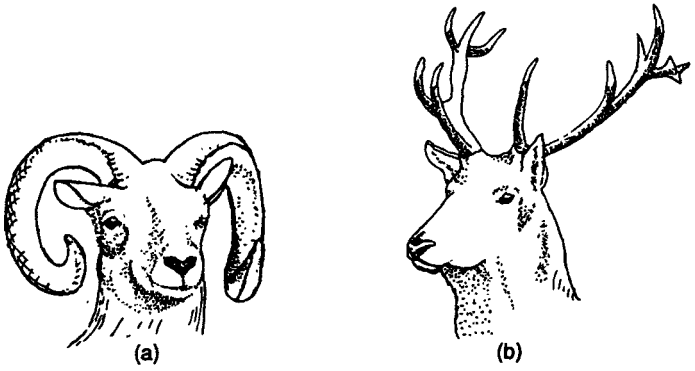

Fig 11. (a) Horn, (b) Antler.

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Aggressive behaviour of pet dogs

Aggression is the most common and a serious behaviour problem in pet dogs. **Dogs** of all breeds show aggressive behaviour at one or the other time. Canine aggression has been classified into different types. It can be expressed in the form of **growl, bark, hair raised, ears erect, chase, snap, showing of teeth** specially canines and bite. Dogs have been reported to inflict more bites to kids because (i) children approach many dogs at their eye level and are apparently viewed by the dogs as invading their private space. (ii) Children may also threaten a dog by direct eye contact, or (iii) by competing with the dog for some resource such as a favourite toy or food, or (iv) even by engaging the dog in rough play that is perceived as threatening. Male children are bitten more frequently than female. Following types of aggressions are generally exhibited by pet dogs :

1. Dominance and aggression. Dominant-aggressive dogs are characterized as **confident**, tail up, with their **ears up** and forward. They carry their **tail high** and **wag it slowly** and stiffly from side to side. They often have their **heads up, staring** looks, and emit a low **growl** with lips stretched and **teeth exposed**. They place a paw on the shoulder of another dog, mount people's legs, and push children aside when going through a door. Dominant-aggressive dogs are demanding of attention. They demand to go outside, demand excessive affection, are **possessive** of their **sleeping areas**, and stop eating when approached. Many of these dogs do not obey commands, especially submissive commands (such as "down" or "wait"). Males lift their legs to **piss** on everything, even in the house, even if their bladder is empty. **Protection of territory** makes a dog aggressive, this may be the dog's home yard or a familiar resting area or even the owners vehicle which the pet dog scent mark as his own.

2. Defense and aggression. Defensive-aggressive dogs are much more **mild** in their behaviour. They display submissive body language (**ears back**, often flat against the head; avoidance of direct eye contact; **lowering of the head** and body; **tucking tail** between the legs; submissive urination) and they **lick hands** and **roll over** to expose their bellies (Fig. 12). They resist handling, hate to have their feet touched, don't like to be groomed, and often shy away from human hands. These are the fear-biters; they may snap if bothered too much. **Protection of pups** by a mother is a very big reason for a female to be highly aggressive. **Self defense** is perhaps the most common cause of a dog attack.

3. Fear and aggression. Fear of a specific situation/person/other animal, or the fear due to incomplete socialization i.e. when you do not allow your puppy to play and roam around freely. It is very necessary to play and spend much time when the puppy is growing into your pet dog so that it does not develop fear from the owner and becomes a friendly dog. The pet dog gets aggressively protective towards the resources and possessions like a special

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Fig. 12. Submissive postures in pet dog : (a) Ears lowered, head lowered, body lowered, tail lowered or tucked between the legs, (b) Lower body, sit and then roll over their back, expose ventral side, all four legs up and flexed, tail lowered.

person, or actual resources like toys, food, food and water bowls, sleeping mattress, and even a ball.

4. Pain, irritation, anger and aggression. A dog who is tired and/or who has physical problems and is in pain can have a much shorter temperament and can be aggressive. Approach your pet dog with caution in such situations. Physical/mental fatigue can also make a dog more irritable than usual. If the dog is hungry or thirsty, or female in heat, a male ready to mate and is prevented to eat, drink or mate can make the dog aggressive.

Preventing aggression in pet dogs

The dogs have evolved from wolves, the wolves live in a group called "**the peck**", the wolves form a **dominance hierarchy** or **peck order** in order to reduce unnecessary fights. The dog has the same tendencies. Therefore, do **not allow** your pet dog to achieve **dominant status over you**. If your pet dog is taught about its rank while it is growing from puppy to dog, it will never challenge people, such dogs will usually be **good family members**. This includes early socialization. (i) Puppies should be handled gently, especially between three and four months of age. (ii) They should be **hand-fed** by children and adults. (iii) They should **not be allowed to chase** children or joggers, jump on people, mount legs, or growl for any reason. (iv) They should never receive or be **part of rough, aggressive play** such as hand-fighting, wrestling. (v) Puppies should never be physically punished for aggressive behaviour, they get scared even by a noise, make a roll of newspaper and bang it on the ground near the puppy, the better way would be deny the rewards such as food or a gentle affectionate pet. (vi) If puppies bite or jump on children, the children should take charge by **screaming "no"** and crossing their arms (to protect hands and arms from being grabbed) and turning away. (vii) Puppies love to play; if **fun is denied** when they get too rough, they will learn to play more calmly. (viii) Puppy should be allowed

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to move freely in an open space, **do not chain** it for long hours. (ix) Puppy should be allowed to play with people other than immediate family members e.g. milkman,. newspaper man, gardner and servants, that will make your dog a nice loving pet.

Food rewards help train young puppies, but as dogs get older, they must receive **praise for good behaviour** and mild discipline for bad behaviour. Dogs should earn everything they receive from their owners. They should sit to receive petting or treats, sit before going out the door, sit before getting in and out of the car, sit to have the leash attached to the collar. These exercises constantly **reinforce** the notion that the owner is the boss.

Dogs should not receive excessive praise (or constant petting), especially for doing nothing. This feature is very common, as the children of owner find **cuddly puppies** irresistible and they keep the pup in arms, take it to bed. Excessive praise and petting **elevates the dog's social status** and sends him mixed signals.. Finally, prevention of aggression requires that the owner win each and every confrontation with the dog. If the dog wins by growling when you try to get him off the sofa or take his toy or approach his food bowl, he receives a signal of dominance and would keep trying it at other times. So do not allow your dog to growl at you, first time when he does, teach him the lesson by saying a firm "no" and deny him rewards e.g. favourite biscuit.

It has been seen that in a family, the dog becomes friendly with one member, plays most with other, and surprisingly will show aggression towards the third family member ! Our first reaction is to minimize contact between an aggressive dog and the person he is most aggressive to. This should not be done as this scheme encourages the dog to become dominant to more and more people and tightens his control on the household. Therefore, the individual who is having the most difficulty with the dog should become the main provider for everything the dog needs food, water, exercise, praise, affection, and other play activities. This person must be able to train the dog to obey basic obedience commands of sit, stay, come, and down. He will probably need a lot of help with the down command (which puts the animal in a submissive position) so he doesn't get bitten. All other family members must totally ignore the dog no play, food, or affection. The dog must look on that one person as its sole provider of everything.

TERRITORIAL BEHAVIOUR

Acquiring space in air, water or land is characteristic of many animals in animal kingdom. This space can be called a "**territory**". Territory ownership occurs in all classes of vertebrates and even in some invertebrates e.g. brittle stars, crabs, spiders, and insects specially crickets, dragon flies, praying mantis, saw flies and wasps. **Territory is a selectively defended area.** It is an area

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in which the simultaneous presence of a same sex adult conspecific or other conspecific rival is excluded by the occupant. Territory enables an animal to become familiar with an area for food, water and escape routes. **Any defended area is territory.**

The boundaries of territories are marked by pheromones or are recognized by edge of the forest, tree trunks, hedges, streams, stones. Animals visit their territories according to a schedule. Animals which are young, large and powerful are more aggressive and defend territory and indulge more in conflicts. Territorial species in mammals perform specific activities in specific locations within the territory. This includes **sleeping area, feeding places, urine marks, dung heaps, drinking** and **bathing places, wallowing, rubbing trees**, look out mounds, escape and hiding places. These fixed points are connected by paths with one another. The most protected point within the territory is where animals make their den. Animals divide geographical area around them into four broad regions :

1. Total range. This includes the entire area covered by an individual or group in life time (**Goin**, 1962). It is large and is visited over the years.

2. Home Range. It is a large area in which animals move through out their adult life. It includes seasonal movements determined by the availability of food. Animals also identify the locations of water, shelter, emergency escape routes. Home range is covered over months. The intruders are tolerated and can be seen roaming. This includes meetings with other groups for mating. The area animal habitually visits, from which the conspecifics are not excluded. It is surveyed for food, it contains familiar land marks, and scent posts.

3. Territory. An area within the home range, therefore, smaller than the home range. Intruders are driven away from a territory by aggressive displays. Territory can be visited in days (Fig. 13).

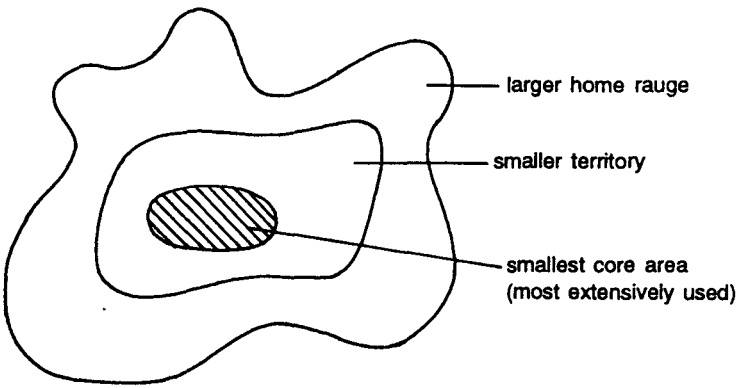

Fig. 13. Home range, territory and core area

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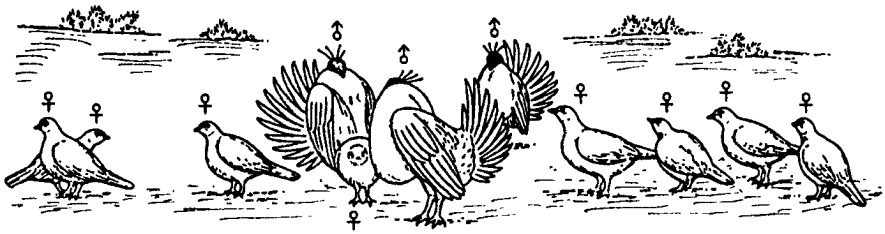

Fig 14. Lek of sage grouse Males are bigger, sexual dimorphism distinct. The males occupy a territory and females visit them.

4. Core area. Within a territory there are much smaller areas called core areas, that are most utilized by the animals, and can be visited all through the day. This includes roosting (Fig. 13).

Meaning of a territory varies from species to species. **Wilson** (1975) classified territories into following categories :

Type A territory. An area for resting, mating, nesting and feeding (e.g. non–human primates).

Type B territory. An area for mating and nesting (e.g. many birds and fishes).

Type C territory. An area for mating (e.g. colonial sea birds, sage grouses (Fig. 14), zebras, wild donkeys, kittiwake, laughing gulls).

Type D territory. An area for resting or roosting (e.g. bats, birds).

Type E territory. An area for feeding (e.g. golden winged sunbirds and humming birds protect flowers with nectar (Fig. 15), shrikes, robins.

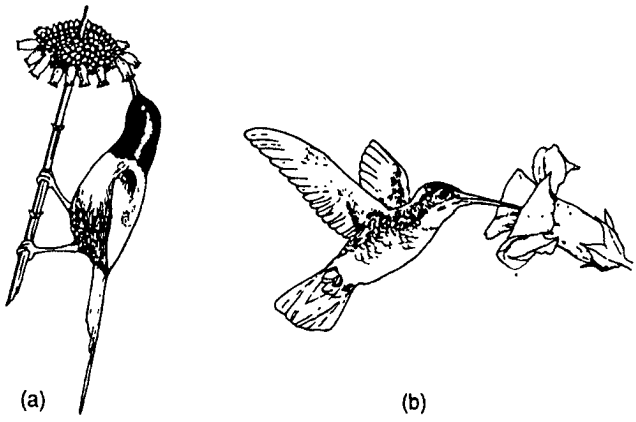

Fig 15 (a) Sunbird, (b) Humming bird both protect nectar producing flowers from intruders.

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The Size of Territories

The **size** of a territory **varies** from **species to species**. It largely depends on the **body size, group size, habitat and food requirements** of the species. Hence breeding and courting territories are smaller than feeding territories. The size of the territory or home range depends on the size and diet of the animal or a group. **Gibbons** are medium sized apes, inhabit thick canopy of rain forest , live in monogamous groups, feed selectively on fruits or insects, they have very small territory, they scent mark it and sing songs to advertise about its occupancy.

Larger species have larger territories e.g. **wildbeest**. Predators have larger territories than plant eaters. The largest territories among herbivores are known in **zebras** and **wild** asses and among predators in **tiger** and **lions**, they may cover an area of several hundred square kilometers (Immelmann,1983). **Jarman** (1974) wrote an excellent paper deriving correlation between diet, body size, mating system and size of territory. According to him small sized animals such as **dik dik** and **duikers** have a small area enough for one pair to live and **large antelopes**, such as **water buck**, **gazelles** and **impalas** move in a very large area. Territories are smaller when the food is found in abundance and the distribution is not spread far. Territorial animals patrol its outer limits. Once the ownership is established and neighbours have been conditioned, then the residents spend less energy inspecting it.

Functions of Territoriality

Allee et al (1949) and **Hinde** (1956) listed the following functions :

(1) Organization of a local population into a well shaped aggregation.
(2) Promotion of parental care by staying in a defined area.
(3) Limitation of the breeding population and hence control over increase in numbers beyond carrying capacity.
(4) Provision of a reserve of unmated males and females, making it possible the prompt replacement of a lost mate in a breeding territory.
(5) Territory ensures adequate food supply for its owner.
(6) Reduction in the rate of contracting parasites or diseases by staying in a safe limited area.
(7) Familiarity with area helps hiding from predators.
(8) Living together sharing the resources provides social stability.
(9) Territory serves as a common meeting place to facilitate pair formation and mating and maintenance of pair bond.
(10) Collective defense of nests and young ones from predators.
(11) After breeding when partners leave for short periods, while looking for food, until the next breeding season, it is easier for the mates to find each other when they have a common meeting place in the form of a territory.

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(12) Territorial behaviour decreases the number of aggressive encounters with conspecifics.

Individual Territories or Individual Distance or Dominance Area

Hedgier (1960) distinguished between two types of animals : (i) **Contact animals** which tolerate body contacts, (ii) **Distance animals** which keep away from each other with respect to the spatial relationship between species members. **Chaffinches** have a personal space of 18 to 25 cm. Higher ranking animals have more individual space than lower ranking. It is an area occupied by one individual for breeding or feeding e.g. humming birds, some coral cichlids. Territory size can vary with age and size of the individual animal. Older and experienced males often have larger territories than younger ones.

Contact animals include **pigs, hippos, porcupines** and **hedgehogs, monkeys, apes, parrots, mouse, birds, turtles, lizards, salamanders, eels; distance animals** are **ruminants, flamingos, gulls, raptors, pike**. Animals maintain a **personal space** that is an area generally carried around each animal. Or it is the minimum distance that an animal maintains from other members of the same species (Fig. 16) Fiddler crabs, Iguanas occupy territory for individual. According to **Hall** (1961) this is found in human beings also. In our day to day life we maintain an unspecified distance from other person. This distance varies from species to species in animals and from culture to culture in human beings. This distance is dynamic, i.e. it is mobile and ever changing. It is linked to the individual rather than to a geographical location. The advantages of having personal space are :

(1) Reduction in chances of getting a disease or parasite from conspecific.
(2) Reduction in chances of getting body friction.
(3) Reduction in chances of interfering during foraging.
(4) Getting space for fleeing.

Inspite of existence of individual distance animals huddle together specially monkeys during rains and cold. Groups or **mats of star fish** and brittle stars are seen gathering around food. Honey bees clump over one another in extreme cold, king crabs make clusters at sea shore. The **migratory** crabs and **snakes** form heaps over each other.

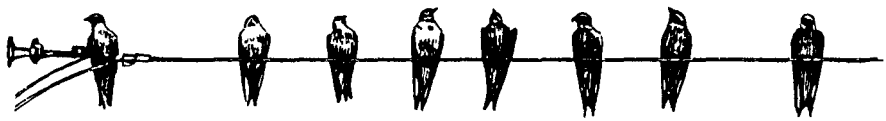

Fig. 16. Individual or personal territory or distance animals maintain.

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Pair territory

An area occupied by a male and female with recent offsprings for all activities e.g. **gibbons, button quail, red tailed hawks**, and all the other monogamous animals.

Group territory

An area occupied by a social group e.g. **monkeys, rodents, hornbills, cuckoos, sea lions, sea cows, walrus.**

Some species are territorial for life e.g. monkeys, sea shore birds, rodents, rabbits, badgers, foxes but some become territorial for short duration either for food or for mates e.g. deer and antelope, and migratory birds.

Animals mark their territories. It has many functions. (i) It repels rivals (ii) It attract mates. (iii) It prevents aggressive encounters. (iv) It conserves time and energy.

Animals can mark their territories in the following ways :

Visual marking of territory. A territory can be recognized by others by the conspicuous display of the owner. Animals "show off" by displaying their beautiful coloured feathers, fins, scales or other secondary sexual characteristics, e.g. **brilliant colours of the dragon fly male** around the borders of their territory, **crab** *Ocypode saratan* **marks its territory** by making a sand pyramid, **bloating of neck feathers and pouches by sage grouse** (Fig. 14), **red belly of sticklebacks.**

Acoustic marking of territory. Animals that can produce sounds use vocalizations to mark their territories. **Frogs, lizards, seals, howlers, gibbons** and **orangutans** produce sound to exhibit the ownership of their territories. The birds sing songs, the gibbons sing songs, Drumming by wood pecker, rattling by rattle snake has the same function.

Olfactory marking of territory. Scent marking has been well studied and documented among animals. **Macrosmatic** (animals with a well developed sense of smell) **mammals** frequently mark their territory with pheromones through urine, faeces, saliva or by special scent marking glands found near eyes, between digits, below the chin, on the neck, below the palms and soles. Hippopotamus marks by splashing of dung. Several marsupials and rodents use saliva; dogs, cats, tiger, lion many monkeys use urine. Details are ahead in this chapter.

Electric marking of territory. African tapir fish uses electric discharge to mark territory from conspecifics.

Interspecific territories. Generally territories are formed to keep away immediate competitors, hence they are defended against conspecifics. However, when two species living in the same area with similar ecological demands come into competition the territories have to be made and defended. Such **interspecific territoriality** are known from **woodpeckers, humming birds, nectar birds, warblers** and **crows.** *(Z–37/Ani. Beh.)*

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Territories of marine invertebrates. Gastropods of rocky shore *Siphonaria jajonica* and *Patelloida saccharina* exhibit territoriality. Limpet *Lottia gigantean* has a territory of about 1000 sq cm in which it feeds on algae (**Stimson**, 1970). The other grazing molluscs are kept out of territory. Similar behaviour has been reported in **Patella** by **Branch** (1975). In annelids **Nereis caudate** (**Evans**, 1973) defends its nest from other polychaetes .

Among crustaceans **lobsters** are known to defend an area around shelter (**Fielder** 1965). **Estuarine Crabs** (*Scopimera globosa* and *Illyoplax pusillus* - **Ono**, 1975) specially males posses territories around their nesting holes, an area with few centimeters around it. The females do not show any such behaviour.

Territories of spiders and insects. Spiders e.g. *Atypus, Lycosa, Menemerus* are known to have defended areas around them (**Kuenzler**, 1958). Jumping spider *Menemerus confures* has a fixed range of movement of 20 cms. **Crickets** and **grass hoppers** and some **butterflies** show beginning of territorial behaviour, that can be seen while they are feeding. **Burrying beetle** male attracts the female by pheromones when he finds a lump of meat that he defends against other males. When the nest is built and parental care by female begins the defense is terminated (**Milne**, 1979). In **crickets** the loud call plays a role of declaring a territory (**Alexander**, 1961).

Large grasshopper *Ligurotettix coquilletti* gives loud calls from a bush and attacks other males coming towards his region (**Otte** and **Joern**, 1975). Male Butterflies viz *Aglais urticae, Inachusio, Lycaena phlaeas* defend a site.

Dragonflies and **Damselflies** have been most studied and documented for their territorial behaviour. **Moore** (1953) recognized territories in seven species of dragonfly *Nannophya, Jagoria, Crocothemis, hemicordulia, Hetaerina, Anax, Macrodiplax*. Males of ***Centris decolorate*** occupy a territory of 1-3 sq mt around its nest and drives other males away (**Raw**, 1975). Among **bees** and **wasps** nests are defended by females (**Yoshikawa**, 1973) *Apis mellifera* is trained with sugar water in a dish kept at a particular point defended the dish from bees of other social group (**Kalmus**, 1941). **Brian** (1955) investigated territories and foraging behaviour of **ants** by distributing honey dishes. He observed that *Formica fusca* had an area of 3·3 mts radius, of which 2.5 mts was defended as territory, *Myrmica rubra and Myrmica scabrinodis* moved in 1·3 mts and defended 1 mts radius.

Territories of fish and amphibians and reptiles. Territoriality has been observed and reported in many species of fish and amphibians. Territoriality is connected to **reproduction, nest building** and **parental care. Medaka, rudder fish, bitterling, stickleback, darters** all are territorial. The interesting part is that in all these cases this role is played by males only. Common freshwater **gobi, parrot gobi, lizard gobi** defend their eggs; they also have feeding territories. **Rainbow salmon, chum salmon**, have territories for breeding.

(Z–37/Ani. Beh.)

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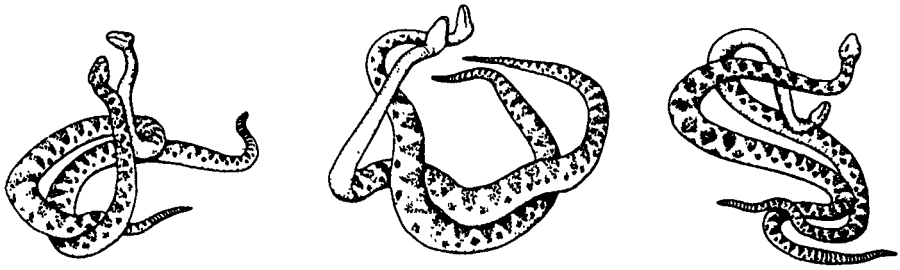

Fig. 17 Fighting snakes

Test (1954) was the first to report territorial behaviour in amphibians. He observed that in *Colostethus trinitatis* male carried the tadpoles in its back. He established a territory along the river bank and prevented invasion by other frogs.Territoriality in **Urodela** is little known (**Porter**, 1972).

Attachment to a site by adult frogs *Rana clamitans* was noticed by **Kikuchi** (1958). The **bull frog** *Rana catesbeiana* chase intruders from a specific area indicating territoriality (**Emlen** 1968).Wilson reported territorial behaviour in most of the members of **families Dendrobatidae, Hylidae, Leptodactylidae, Pipidae** and **Ranidae** in which parental care is known for all species. The **midwife toad** *Alytes* carries eggs in the hind leg of males, from which the hatched larvae are released into the water .The male becomes protective and starts defending an area around him. Male **Japanese tree frog** *Hyla arborea japonica* builds circular nests with mud which are defended from other males. Among other amphibians male of **Pygmy marsupial frog** that carries fertilized eggs under a skin fold; **Darwin's toad male** picks up eggs from the ground and carries them inside the vocal sacs. These species become protective towards their eggs and start chasing animals away-a sign of territoriality.

In reptiles, there are many species of lizards that maintain territories. On the other hand no territories have been found in turtles. In the snakes, the king cobra establishes a territory around its nest. Snakes fight for mates, they do not bite each other but they wrestle and try to pindown each other (Fig 17).

House lizards possess definite areas on walls, intruders are chased away. *Anolis* males show distinct territorial behaviour towards other males by inflating thoracic sac, raising the dorsal skin. **Iguanas** of Galapagos island females remain near the eggs and defend the surrounding area.**Gecko male** *Gehyra variegata* occupies a territory containing several shelters in which females are invited and kept (**Bustard**, 1970). **Crocodiles** occupy a unique position among reptiles. It has become known that all living species build nests and defend an area around the nest (**Pooley** and **Gans**, 1976). During the mating season a pair occupies a territory and the male drives other males from that area. The female digs a hole or builds a mound after mating and defends such a site from other females or predators or approaching human beings.

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Territories in birds. In recent years, field observations of birds have grown enormously. Among birds the species that have **low fecundity** and **high parental care** show **territoriality. Song sparrow, robin, wren, great tit, scrubby jay,** and many other species of **passerines** and **tawny owl, golden eagle** and some more **raptors** all defend areas in which mating, nesting, and food gathering occurs. **Willow warbler** male defends area that inciudes food for himself, his mate and young. **Tree sparrow, gray starling, reed warbler, blue jay, kestrel** have a territory where they defend mating and nesting sites. Territory around breeding site is shown by **colonial breeders** such as **black headed gull,** the **black tailed gull, streaked shearwater, barn swallow, herons** and **egrets.** The **starling** *Sturnus vulgaris* and **long tailed tit** defend only roosting places. **Hummingbirds** defend area around flowers only. The male ostrich and rhea incubate the eggs and defend the nesting area. The pheasants form a harem. Each male has a fixed territory in which he holds five to eight females. The territory may be as large as several hectares in area and feeding occurs within it.

Territoriality in mammals. Among mammals, possession of a large home range is common than a small actively defended territory. Among mammals the territories can be formed.

1. To protect nests. Monotremes, insectivores, rodents and **primitive primates** make nests for young ones. The nest building species would at least defend the area around their nests (Wilson 1975). In mammals, there is mother-infant contact through suckling in all species including egg laying monotremes and marsupials. Because of this bond the existence of nest is not essential as in birds. However, **rabbits, mice, squirrels, guinea pigs, beavers, prairie dogs** do make nests and therefore, have distinct permanent territories to defend.

2. Temporary territories to protect breeding and feeding area. Ungulates produce pheromones to mark outer limits of their territories. In breeding season Impalas are aggressively territorial.

3. Territorial marking in mammals.

Scent Marking in Vertebrates

Many vertebrates produce odours, scents or pheromones to carry out many functions. House shrew, striped hyena and black tailed deer produce scent under stress, other mammals mark territories, mates, pups, and their habitat with scent. The scent is released in many ways viz., along with urine, faeces and saliva, they are also produced through special glands.

[I] Use of urine and faeces

Urine or faeces of many animals have pheromones or scent through which they can communicate with conspecifics. The most common use of urine and faeces is to identify or scent mark **core area** (an area, used extensively and

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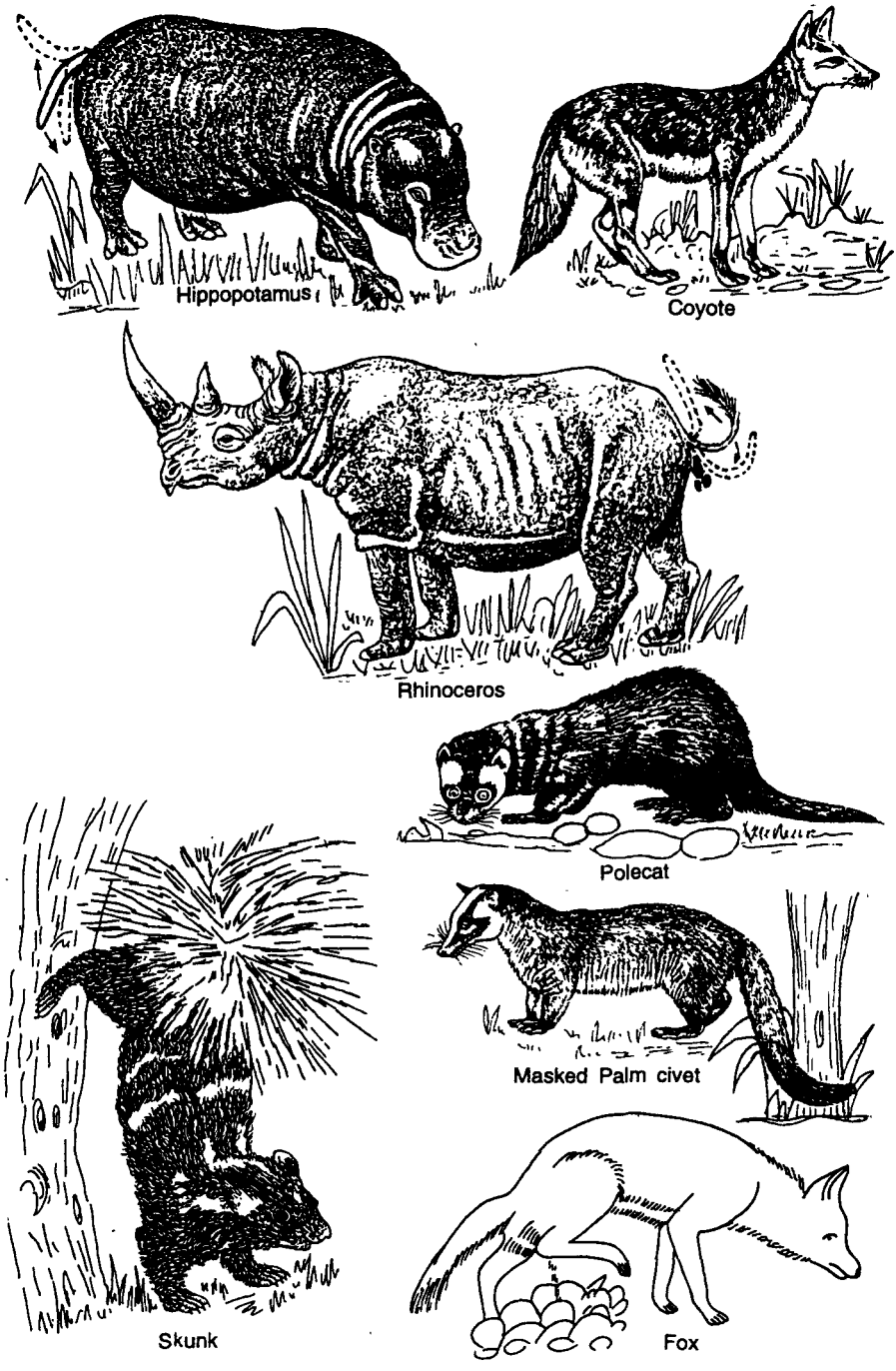

Fig 18 Animals who use urine and faeces for scent marking.

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defended actively), home range (an area around core area, actively used but not defended actively) or **territory** (a bigger area around home range used or exploited but not defended). Some animals use urine and faeces for identifying pathways, resting grounds, feeding grounds and sleeping sites. Some animals urinate or defaecate on rivals, opponents, defeated conspecifics etc. The most interesting and strange example comes from mammals. The male hippopotamus mark their pathway between aquatic resting place and grassy feeding ground, by the deposition of dung at places along the trail, usually close to some conspicuous objects. As hippopotamus defaecates while walking on the trail it keeps moving its tail rapidly from side to side, (Fig. 18) so that the faeces are splashed out and get deposited all over the vegetation above ground level and thus, places it at nose height to make it more noticeable; rhinos mark their pathway by defaecating at prominent land marks and depositing piles of faeces so that it can be both smelt and seen. Tigers select specific places and mark their territories by their droppings. Main land serow of family Bovidae, found in northern India has fixed pathways of movements, initially these pathways are used visually and later the animal marks traditional spots by depositing its droppings there, so that it can just follow the scent and others are kept away. Polecat (a weasel like animal) and civet (Fig. 18) deposit urine and faeces at particular places along their trail too. The male giant rats and skunks have their own style of marking, they place their droppings above ground level by standing on fore limbs and hindlimbs supported against some solid object as they defaecate and urinate (Fig. 18), this is done to mark the area at nose level for easy detection. Dogs, coyote and foxes (Fig. 18) use just the urine to mark their territories, the scent left with urine indicates minute details like individual identity, male or female, dominant or subdominant, adult or subadult and also how long ago that area was marked.

Lions, tigers leopards, and all other big and small male cats mark their home range with pheromone which is passed with urine. The cats select some suitable objects, back up to it, extend the back legs, raise the tail, as the urine is passed, the tip of the penis is curved backward so that the urine is given out as a fine jet between the hind legs (Fig. 19). Bears use two different ways, they first mark a tree by scratching and chewing the bark, and in addition, they frequently urinate on such trees to consolidate the marking. All three species of hyena, striped, brown and spotted (Fig. 19) mark the areas of their movement with urine and faeces, they also have special anal glands for the production of pheromones for the same purpose. Use of pheromones through urine and faeces had its own limitations, that the animal has virtually no control over their production and release and this could have been one of the reasons which led to development of special glands to produce pheromones.

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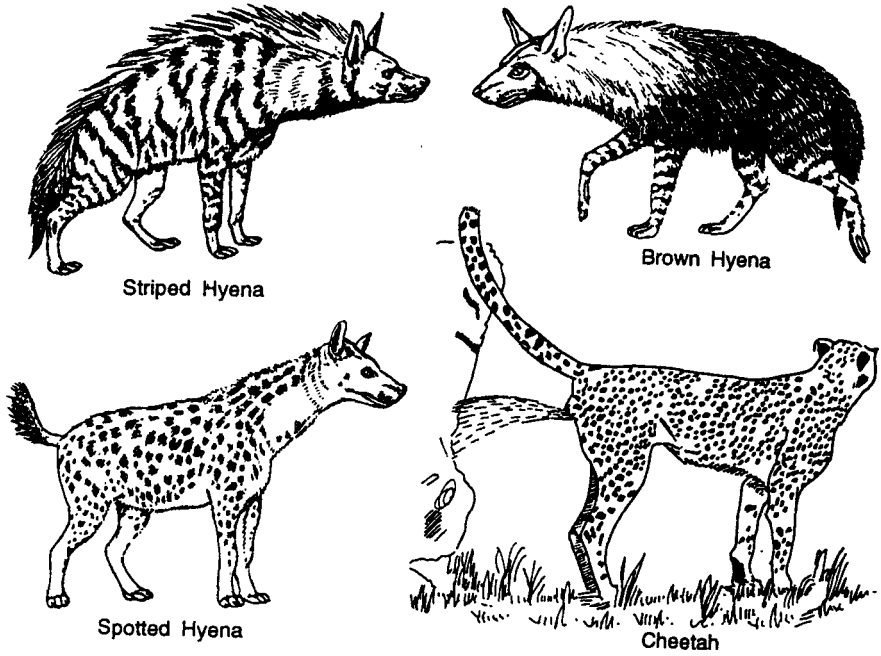

Fig. 19 Animals who use urine and faeces for scent marking

[II] Use of special glands

Many species are not dependent on urine or faeces but have evolved special glands producing the scent, these have the advantage that their use can be restricted to necessity, that the animals could use pheromones as and when needed or production of pheromones remains under control, to prevent its automatic, unwanted release with urine and faeces.

1. Anal gland. The commonest scent producing glands are anal glands. The usual procedure among animals in applying secretions is to evert the anal gland and rub it on the ground or on object to be marked. Marking of this type occurs mainly in Monotremes, Marsupials and in few Placentals.

The male beaver is tenacious about keeping strange beavers out of his neighbourhood, he virtually erects "No Trespassing" signs by pheromones on dams, lodges and feeding trails. He makes mounds by scooping up mud from his pond and on them he squats to deposit a smear from his anal scent gland. Spiny ant eater (Fig. 20) everts the cloaca and rubs it on the ground leaving a smelly mark. The brush tailed opossum and sugar glider (Fig. 20) have two types of cloacal glands with the help of which they mark their nests which is the most precious area for them. In the yellow footed marsupial mouse, cloacal secretions are rubbed on twigs and branches around their small territory. The anal gland of black and red tamarin (Fig. 20) produces

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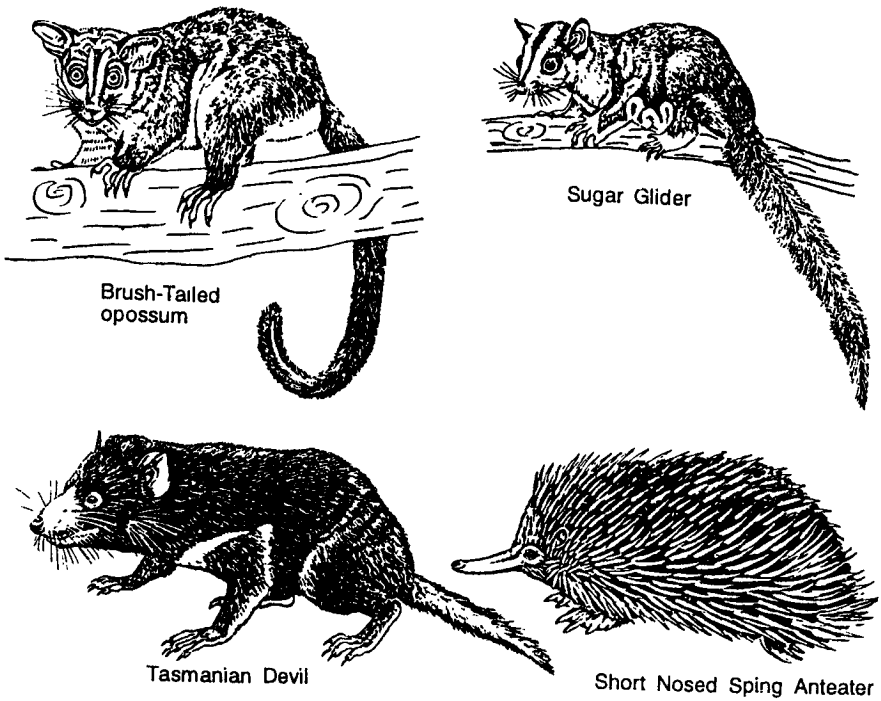

Fig. 20. Animals who use secretions of anal gland for scent marking.

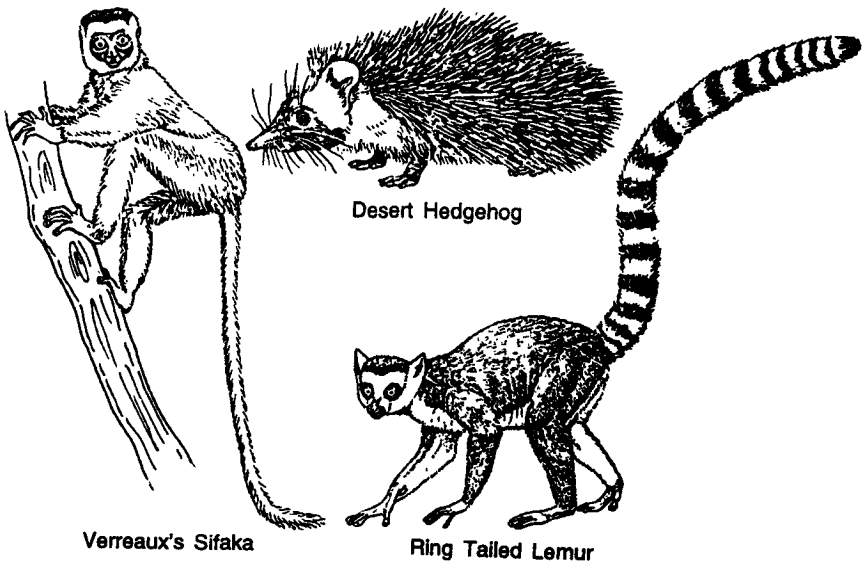

Fig. 21. Animals who use secretions of glands found in forearm, throat and saliva

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a strong smelling secretion which keeps others away. Male tasmanian devil (Fig. 20) has scent glands around its anus which it rubs on objects like stones, branches, ground and grass to protect his female and young ones. In most mammals marking the territory is the job of the male but in few selected ones like, ring tailed lemur (Fig. 21) which are small sized, long tailed primates found in Madagascar, both male and female have scent glands in their fore arms and anus, both rub their glands to mark their territory, however, males have additional scent glands, under chin and by the penis which produce pheromones to attract females. Verreaux's sifakas (Fig. 21) also found in Madagascar mark territories with urine and with secretions of males' throat glands. Brown hare of Europe, normally lives solitary and marks its territory with strong smelling secretions produced from glands situated in its anal region, around its face and inside its cheeks. These secretions are also important in its mating season to attract the mate.

2. Salivary gland. Saliva is a secretion available to all mammals, which has been used as a marking agent by bears, dogs, pigs and a number of other animals. Most marsupials deposit saliva on twigs by chewing them and hence marking the foliage of their territory. Lesser hedgehog (Fig. 21) first salivates on the object to be marked and then scratches it. A female rat licks its nipples to scent mark them so that its blind pups can reach them. A female wildebeest will lick its baby to scent mark it through its saliva for recognition.

IMPORTANT QUESTIONS

➤➤ *Long answer type questions*

1. Define aggression. Describe different types and causes of aggression among animals.
2. Advocate that aggression is controlled genetically. Explain neural and hormonal control over aggression.
3. Describe aggression and prevention in pet dogs.
4. Define home range, territory and core area. Enumerate functions or advantages of holding territory.
5. Give Wilson's classification of territory. Write about factors influencing the size of a territory Differentiate individual, pair and group territories.
6. Write a full note on marking of territory.
7. Write a short note on : (a) scent marking, (b) territories of fish, amphibians amd reptiles, (c) territories of mammals, (d) types and causes of aggression, (e) Limbic system, hypothalamus and aggression, (f) aggression of pet dogs.

➤➤ *Fill in the blanks*

1. Aggression is a part of..... behaviour.
2. Agonistic behaviour includes..... and. .....
3. Aggression towards stranger is called.....
4. Proximate aggression deals with.....
5. Pain increases..... in animals.

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Answers

1 agonistic, 2 aggression, escape, 3. xenophobia, 4. crowding, 5. aggression.

➤➤ ***True or false***

1. Aggression is part of agonistic behaviour
2 Agonistic behaviour includes aggression and flee.
3. Aggression towards strangers is called xenophobia.
4. Proximate aggression deals with crowding.
5. Pain increases aggression in animals.
6. Aggression has no connection with genetics
7. Aggression is purely environmental.
8. Animals never leave territory.
9. Home range is smaller than territory.

Answers

1. True, 2 True, 3. True, 4 True, 5. True, 6. False, 7. False, 8. False 9. False

➤➤ ***Multiple choice questions***

1. Dominant aggressive dogs are characterized by:
   (a) ear down, growl, hanging tail
   (b) ear up, teeth exposed, hanging tail
   (c) ear up, growl, tail up
2 To make a puppy friendly the owner should
   (a) keep it away from strangers, chain it most of the time
   (b) let it play but chain him most of the time
   (c) let it play and chain it moderately
3. A core area is
   (a) smallest, most used within a territory
   (b) bigger, least used within a territory
   (c) larger than the territory, moderately used
4. Type B territory has
   (a) area for resting and mating
   (b) area for nesting and feeding
   (c) area for mating and nesting
5 African tapir fish marks its territory
   (a) with physical clues (b) with chemicals (c) with electricity
6. Control of aggression lies in
   (a) limbic system (b) amydala (c) both
7. Lateral nucleus in hypothalamus is involved with
   (a) pleasure and rage (b) aversion and displeasure (c) none
8. Quick response towards stress in done by
   (a) Androgen (b) Epinephrine (c) Corticosteroids
9 Slow and steady response towards stress is done by
   (a) Androgen (b) Epinephrine (c) Corticosteroids
10. Retractable claws are found in
   (a) Bear (b) Tiger (c) Both
11. Flowers are protected as territories by
   (a) Sunbirds (b) Humming birds (c) Both

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12. Gibbons have
    (a) Small territory (b) Medium territory (c) Large territory
13. Wildebeests have
    (a) Small territory (b) No territory (c) Large territory
14. Dikdik and Duickers have
    (a) Small territory (b) Large terriroty (c) No territory
15. Contact animals are
    (a) Flamingos, gulls, ruminants (b) Hippo, Monkeys, Porcupine
    (c) None of these
16. Distance animals are
    (a) Flamingos, gulls, ruminants (b) Hippo, Monkeys and Porcupine
    (c) All of these
17. Pair territory is formed by
    (a) Button quail (b) Red tailed Hawk (c) Both
18. Limpets have a territory
    (a) 100 sq. cm. (b) 1000 sq cm. (c) None

Answers

1. (c), 2. (c), 3. (a) 4. (c) 5. (c) 6. (c) 7. (a) 8. (b) 9. (c) 10. (b), 11. (c) 12 (a). 13. (c) 14/ (a) 15. (b) 16. (a) 17. (c) 18. (b).

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7

Parental Behaviour

Male-female giving food, shelter and protection to their offspring is parental behaviour. No matter how non-social an animal may be, at least twice in life it has to socially inter-act with conspecifics – **mating** and **parental care** (**PC**). It is defined as-form of parental behaviour that increases the fitness of an offspring . And the Parental Investment (**PI**) is a form of parental behaviour that increases an individual offspring's fitness at the cost of the parent's ability to invest in future offspring (**Trivers**, 1972). Parental care begins very early and can go on for a long time.

Care Before Birth

1. Investment in gamete production. Female **Katydid** eats extra spermatophores provided by male so that she can have larger eggs which survive better in harsh winter. In this case the male is investing in female gametes.

2. Preparation of the housing. Preparation of nests, burrows, or territories (importance of having a place where broods or eggs can be kept-where young can be left while parents forage or ward off predators) e.g. bees make hive, fish and birds make nests.

3. Care of fertilized eggs. Incubation by birds and reptiles, egg guarding by fish, brood carrying by toads, water bugs and seahorses, protection of nest sites or sites where eggs are laid.

Care After Birth

1. Provisioning or protecting young. Provisioning (feeding) by birds, mouth brooding in some fish, lactation in mammals (Fig. 1).

2. Care following nutritional independence. Support during conflicts in social primates. **Royal terns** and **frigate birds** keep feeding their chicks

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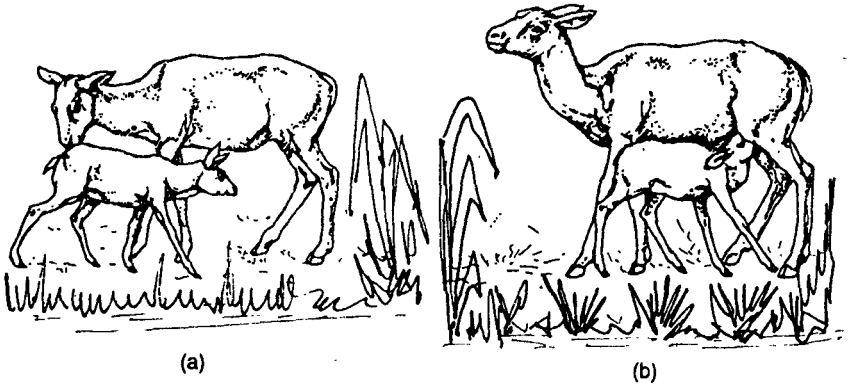

Fig. 1. All mammals feed their babies . (a) Blackbuck mother calls the fawn, sniffs it for recognition, (b) Guides her fawn towards udders and fawn feeds.

even after they have left parents. Parents also provide protection to their babies from predators.

The forms and means of parental care are as varied as species themselves. Some species, such as **salmon** lay millions of eggs but provide no parental care, others, such as **elephant**, gives birth to a single young, shows parental care for many years. There is a great variety of types of parent offspring relationships, **fish** and **amphibians guard** their **eggs**, **bird** and **mammals feed** their young ones. Parental care can be provided in two ways (i) one in which the parents and offspring never come in contact (ii) where parents come in contact with offsprings. How common is parental care and who provides it? In terrestrial Arthropods parental care is not so common, it is shown more by females than males. **Scorpions**, **spiders** carry brood on their back, **bees** and **wasps** provide **shelter** and **food** to their larvae. Among **Reptiles** parental care is uncommon, whatever little care is provided, is rendered by females more than males e.g. Crocodilian females form nest. In **Amphibians**, 18% salamanders and 6% **frogs** and **toads** exhibit some sort of parental care. In this class the parental care is given by males and females in the form of egg attendance and transport, tadpole attendance and transport, tadpole feeding. 25% of **fish** demonstrate parental care like **egg guarding**, **oral brooding**, **cleaning** and fanning of **eggs**. In fish care by male is more common than by female. Most species of birds show **bi-parental** care. Birds are unique, because here father not only looks after the babies but also provides food to his wife. So the care includes provisioning of female by male prior to and during egg laying and incubation, nest building, incubation of eggs, and feeding nestlings. In mammal species, they show 100% care by females (gestation, lactation). Less than 5% show direct male care mostly in monogamous breeders (e.g. tamarins, wolves, naked mole, rats).

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Early Parental Care

(1) Starts before the baby is conceived in the form of gamete production. Eggs are large and rich in nourishment.
(2) Birds provide warmth (incubation) to the egg for the chick to develop and hatch properly.
(3) The construction of nest takes much time and energy of both parents. A pig walks 5-10 kms to look for a safe place to construct a nest and it takes about 10 hours to construct it (**Jensen** 1993).

Most species that provide little to no care are insects, reptiles, and fish as they produce many young. In stable environments when both parents have an equal probability of associating with their offspring then both mother and father provide care; in predictably fluctuating environments when one sex has a higher probability of associating with the young than the other, then that sex provides more care; in fish, it is typically males who defend a nesting territory; in birds, it is typically females except under unusual conditions where females abandon their broods in the care of the fathers and start new broods with additional mates; in mammals, lactation predisposes females to care the most.

Factors Affecting Parental Care

1. Size of the litter of brood. If the size is bigger the parental care decreases; **Lack** (1954) proposed that if there is high fecundity, then there is less parental care, and if there is low fecundity then there is more parental care-known as **Lack's Law. Paradise fishes** lay 20-300 eggs, they show parental behaviour and anabas lays 1000-3000 eggs so they don't. Elephants give birth to one

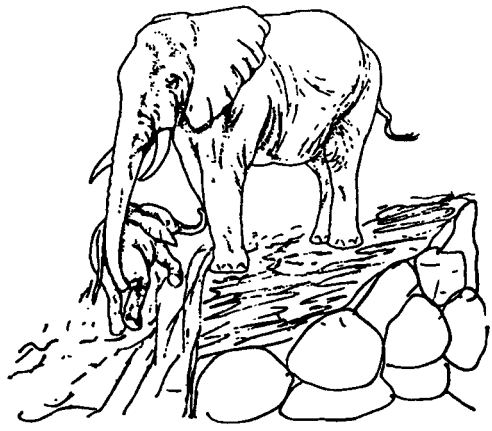

Fig. 2 Elephants provide care to their calves for an long time. Here a mother is helping her baby to climb.

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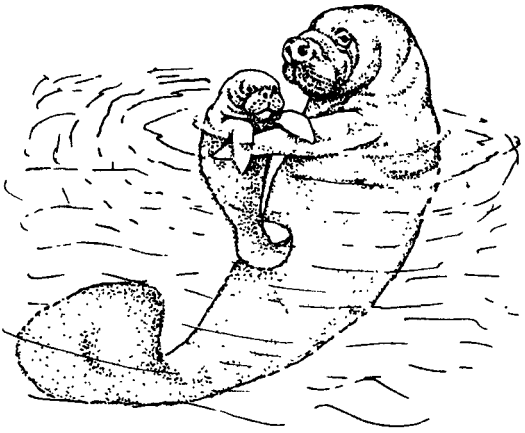

Fig. 3. Mother manatee is supporting her young in water to help him over come the fear for water. She supervises initial swims of her baby.

Fig. 4. Bear cubs are small and helpless They need parental care for many years. The mother has to keep the cub in arms for warmth

baby in few years, therefore, paretnal care or help is extended for a long time (Fig. 2) **Manatees** are also slow breeders, they take their young to water to let them practice swimming and also support them in water (Fig. 3), Grizzly bear gives birth to 1-2 cubs only. The cubs are very small-less than 350 grams, and are quite helpless, they need mother's attention for many years (Fig. 4).

2. Age of offspring. Younger babies get more parental care than older ones. Younger babies are weak. They are vulnerable to disease and predation. They have little muscular coordination leading to injuries. They can not feed on their own.

3. Age of the parent. Younger parents give less care, because they have more reproductive cycles ahead, means they can have more babies and old parents provide more care because they have fewer reproductive cycles (**Clutton –Brock** 1991). Younger parents are less experienced in baby care. Older individuals are better parents.

Types of Parental Care

1. Neither parent is involved in care of young. Promiscuity is associated with no parental care, the mating system that typifies reptiles . Most solitary insects, 100 teleost fish species with external fertilization, some amphibians and reptiles, some birds e.g. cavity-nesting ducks, cuckoos, cowbird show no parental care. There is no example from mammals under this category.

2. Both parents involved in care of young. Monogamy is associated with bi-parental care No insects, reptiles or amphibians are reported in this, a few fish species (e.g. mouth brooding cichlids), many bird species

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e.g. willow ptarmigan; most song-birds; tri-colour black-birds), and few monogamous primate species show this trait. (e.g. gibbons, tamarins marmosets).

3. Mostly females are involved in care of young. Wasps, dung beetle, and **social bees** provision brood cells and defend/protect their larvae, females of about 14 species of teleost fishes with internal fertilization and 24 with external fertilization show parental care; in alligators and crocodiles it is generally the female alone that guards the eggs and babies; bird species in which the male has less investment than the female during brood care are **red-winged blackbirds** and **wrens**. Care by female alone is most widely used in animal kingdom. Why females provide so much care? According to the **investment hypothesis**, the female invests so much energy, it would be risky for her to abandon her offspring without providing care, since offspring may not survive. **The paternity uncertainity hypothesis** says because female is more likely to be parent of offspring than male, male does not really gain from parental care of the offspring. Lastly there is **association hypothesis**, according to this, the females are more likely to be the parent around during egg laying or birth many a times, due to **internal fertilization**–this situation allows males to leave, females have to care for the eggs. Males physically get separated from progeny. Polygamous **mammal** species in which **only females feed** and look after offspring **without** the help of a **male** are **marsupials, rodents, ungulates, felids**, some solitary primates e.g. **orangutan.**

4. Mostly males are involved in care of young. The examples are very few in this category. Male **water bug** carries fertilized eggs, in fishes the

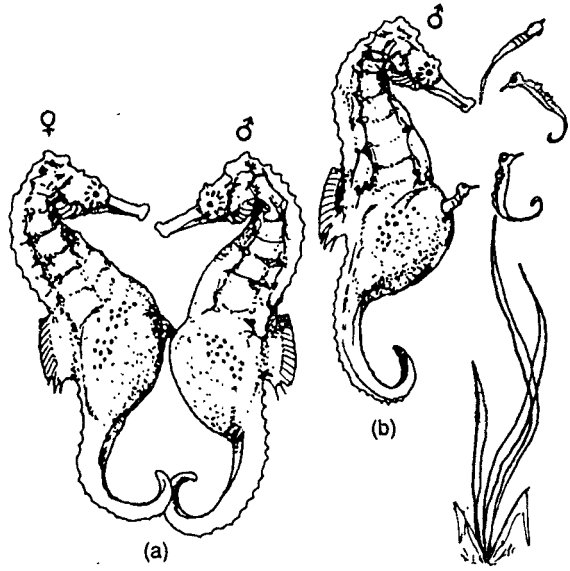

Fig 5. During mating fertilized eggs are . (a) Deposited by female in the brood pouch of male, (b) Male keeps these eggs for 4 to 5 weeks until they hatch The male guards the babies

(Z–37/Ani. Beh.)

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Fig. 6. Male golden lion tamarin carries his baby on his back all through the day.

male usually cares for offspring. Parental care occurs in 28% of fish families and among 61% of these the male takes care of the offspring. In about 63 species of teleost fishes, mostly males defend a nesting territory e.g. **three spined stickle backs**, and **pipe-fish**. In **sea horse**, female places fertilized eggs in male's pouch (Fig. 5). Birds living in flooded marshes e.g. **jacana**, **tinamous** and **moorhens** or migratory birds e.g. **sandpipers** and **phalaropes** and ground nesting ostrich males actively look after their babies. Very few mammals belong, to this category. Males of **Golden lion tamarin** (Fig. 6) of Brazil are world's finest fathers. The female generally gives birth to twins, her job is only to feed babies, the rest is done by father alone. He carries them on his back day and night, protects them from heat, rain and predators.

5. Relatives are involved in care of young/alloparenting. Eusocial insects where sisters (full and partial) care for eggs laid by their sisters (e.g. bees, termites). No fish, amphibians or reptiles have been reported in this category. Among birds **helpers-at-the-nest** are found in e.g. **Florida Scrub Jay, green wood hoopoes, white-fronted bee-eaters, babblers** and **Mexican Scrub Jay**. In **elephants, wolves, dwarf mongoose, monkeys, lions** the related females, called **aunts** help in feeding the baby. Related elephants help each other in acts like while mother drinks at a water hole, the aunt guards the young (Fig. 7). White-footed deer mouse, prairie dogs, banded mongoose, spotted hyena show communal denning, where related females help making a den and also look after the babies in the den. Thief or sneaked suckling is reported in elephant seals.

(Z–37/Ani. Beh.)

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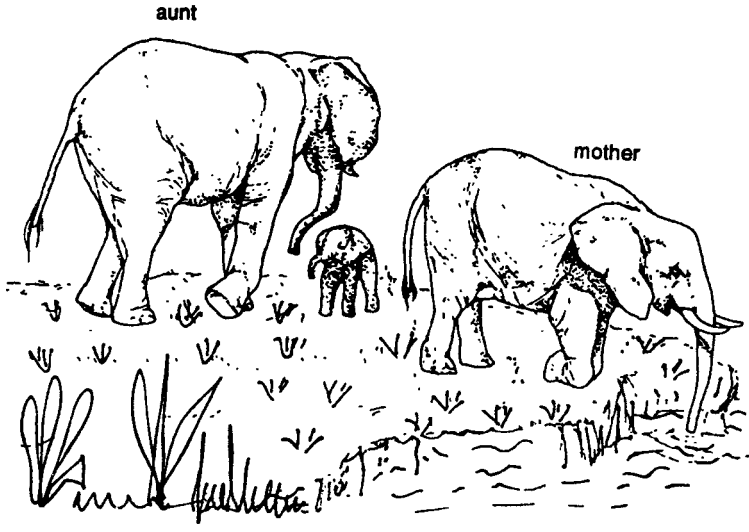

Fig. 7. The mother elephant drinks water from a pond and the baby elephant is looked after/guarded by an aunt

Care and Attachment

Parental care in parents and development of **attachment** in babies have evolved **simultaneously** thus giving the individuals having those genes a survival advantage. Suppose an adult individual delivers parental care to a **detached** offspring, who is constantly straying and is eventually lost, thus losing representation in the next generation. Parents that produce detached offspring would have no survival edge and would eventually become **extinct**. Conversely, if the offspring is born with a bias to **attachment** but is rejected by the parent, it becomes easy prey for predators and strangers. Rejecting parents have then the same fate as detached offspring: Natural Selection will **eliminate** them. Parental Care carries several distinct benefits, and it is strange why it is not commonly found in the entire animal kingdom. An organism that gives its offspring a tender care would be at a tremendous advantage over another that provides less parental care.

All animals have to face the decision of whether to invest time and energy looking after their offspring or not because the **benefit** is that young are often helpless and vulnerable to starvation, predation and harsh climatic conditions. Their survival and fitness rely on parents to assess their needs. If the baby survives, the fitness of parent increases and the **costs** are that parents get less time to find food for themselves and get less time to find additional mates. The parents have to put in lots of efforts e.g. a male **mallee fowl** invests **5 hours a day for 6 months** of each year to build a huge compost *(Z-37/Ani. Beh.)*

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nest of sand and organic material. Each time his mate lays an egg he digs a deep pit to receive the egg and then covers it up, shifting about 85kg of compost and sand. The mound keeps the egg protected from predators and at a constant temperature. The females show more parental behaviour because (i) their investment is much higher in terms of time and energy (ii) they are sure the offsprings are in fact their own, whereas, males can not be so sure.

Parent-offspring Conflict

Freudian theories and theories about socialization of infants (it says humans are born savage and greedy and the parents' job is to teach them to leave their selfish drives and to become a part of society). However, **parent-offspring conflict** is not specifically human- it's very widespread in the animal kingdom. Anyone who has looked at parents and offspring in primates has reported parent-offspring conflict of some sort or another.

Trivers (1974) noticed, that the mother, nursing her young, better uses her energy for the production of new offspring, rather than continuing to nurse offspring that are at least partly able to live independently. The offspring, however, does not want to be weaned as it regards its own interests as more important than those of its future brothers and sisters and protests against weaning. In the **carrion crow** (*Corvus corone*), for example, conflicts between parents and offspring increase when the juveniles grow up and the parents want to breed again. Then the parents become more aggressive toward their offspring, causing their offsprings' final independence. Other species, for example **the spectacled parrot** (Forpus conspicillatus), solve the problem by putting their young in a **crèche** i.e. they start leaving their babies in some other parrots nest. Trivers suggested that evolutionary interests of parents and their young are not same, therefore, cause **parent offspring conflicts**. The theory has been analysed in several mathematical models and has been found logical. **Offsprings** are expected to **gain fitness** by demanding more care than the parents are willing to give. So there will always be conflict.

Weaning conflict

Think about how in the first stage, the mother maintains proximity to her offspring, following the baby, restraining it from leaving her, and initiating most nursing bouts. In the second stage, the infant becomes more independent and initiates most nursing. In the last stage, the mother trails off efforts to maintain contact, and she stops wanting to nurse. In this later stage, the mother will begin rejecting the infant, gently at first and then more strongly. The infant spends a lot of time shouting and crying (Fig. 8). And the conflict about weaning is by no means the only type of parent–offspring conflict

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Fig. 8. Babies show weaning tantrums. A mother koala gently hits her baby to keep it under control.

Carrying conflict

Another conflict that is common is for **riding over the mother or carried by the mother** (Fig. 9). It is pretty similar to weaning conflict; the mother does everything at first, then less, and the infant gets upset about it. So the parent doesn't want to carry it and the baby still wants to ride. The young

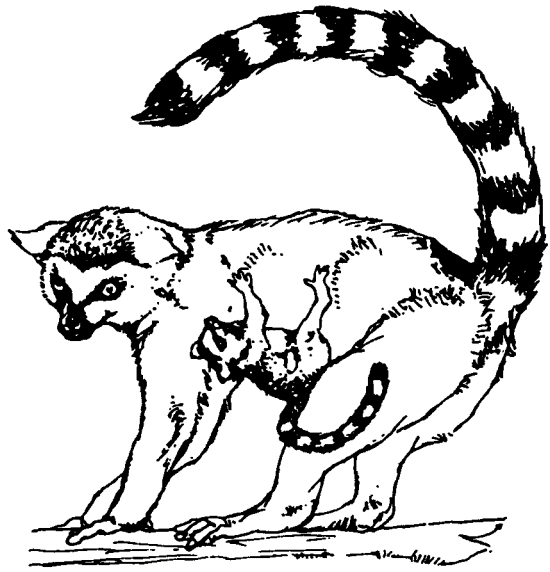

Fig. 9. Parents carry their babies from one safe place to another Mother ring tailed Lemur carries her baby on her under side.

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obviously need to learn to walk for themselves. Carrying is best seen in non-human primates. Many a times even juveniles try to climb on their mothers !

Temper tantrums

Another manifestation of conflict is **temper tantrums**. As babies get older and the mother begins rejecting the baby, baby begins throwing tantrums-clinging to arms, pulling her hair screaming and yelling. A Koala mother literally slaps her baby for throwing tantrums (Fig. 8). Tantrums are seen in orangutans, and in many other primates such as chimps, and humans, especially at the height of weaning. There are a few different ways that the young use to **manipulate** their parents. In one study Jane Goodall observed that in chimps, the tantrums made the mother tense and nervous and when the infant began throwing a tantrum, she ran to comfort it and then started to nurse. So tantrum some times bring good to the baby.

An infant who has been rejected will begin to act more young and helpless than it really is. Since younger infants need more investment, the baby might trick its parent into giving it more.

Parental care in animals

The word **parental care** is generally used for **higher animals**, for **lower animals** more appropriate term is **brood care**. Social insects show some degree of brood care, specially members of phylum arthropoda, that too in insects. It is worth noting that arthropods care about their babies in many ways : (i) they can lay eggs near future food of larvae (ii) they can lay eggs inside the future food of larvae (iii) they can carry them on their own body, (iv) they can construct special chambers or nests for their larvae. Nests are important as they keep eggs and hatchlings warm and provide protection from predators and the climate. They are a safe, warm place where the female lays eggs and she or her mate can protect them. Animals spend days or weeks building a nest, while others simply scrape a small depression in the soil, cr pile a few twigs together. Others lay their eggs in the nests of others or take over abandoned nests. In birds different nest structures include — domed, suspended, cup, hole, cavity, burrow, mud, saliva and debris. These nests can be found in rocks or buildings, in water or nearby, open ground, growing herbage, under trees or shrubs, in a crevice or hole in the tree or on a branch.

The nests formed by animals specially insects, fishes and birds are so varied that a full length separate chapter can be written on their different forms and structures. **Dystrophaptic** insects lay their eggs on the larval food, **eutrophaptic** insects like butterflies lay eggs near leaves on which their larvae feed, some supply eggs with protective covering, some remain with eggs and larvae, some build nests and put their larvae inside with food. Leaf rolling

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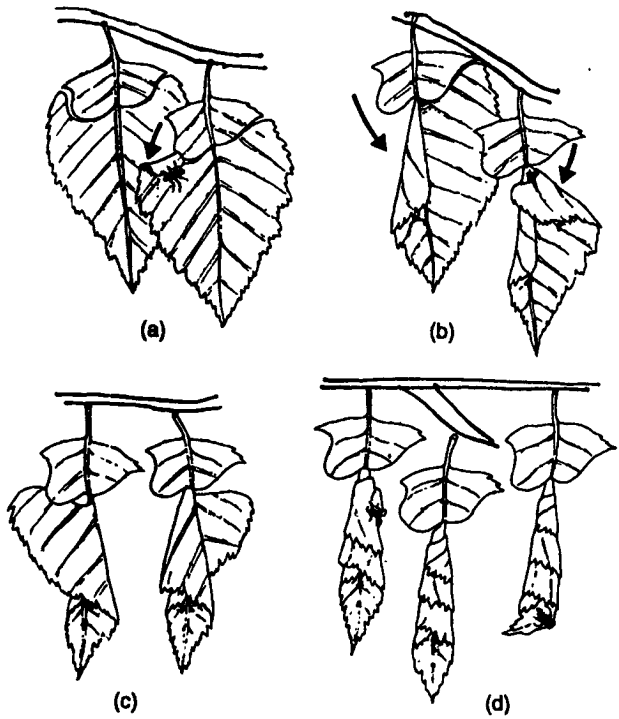

Fig. 10. Leaf rolling weevil female lays her eggs on a leaf, cuts the leaf and start rolling it inwards. The finished structure is 3 mm thick but provides enough food and shelter to growing larvae.

weevils **Byctiscus betulae** make cigar shaped nests **by rolling the leaves** (Fig. 10), **some hydrophylidae** build small floats in which the eggs are embedded to float, **Trissolcus basalis** use its sting to drill a hole in a living host (eggs of shield bug) and then deposits the eggs (Fig. 11), sand wasps make underground nests, then catch the food, put it in the nest, lay eggs and seal the nest for protection. Spiders regurgitate food, cockroaches feed their young, whip scorpion females carry their young, Male water bug carries fertilized eggs on his back. Many beetles excavate underground chambers to store and protect the resource and the larvae developing within it from predators. This intensive processing requires the collaboration of both parents. A number of insect species show parental sharing in brood care. *Cryptocercus* roaches pair for life. The adults (many parents) chew a series of galleries (passages) interspersed with large rearing chambers (for all babies) in rotting logs. **Young nymphs** require the transmission of **intestinal flagellates** through **proctodeal trophallaxis** from their parents. Nymphal growth is slow, and the nymphs' diet is supplemented in the early stages with parental hindgut fluids and fecal pellets. Salid beetles are also monogamous, and cooperate in

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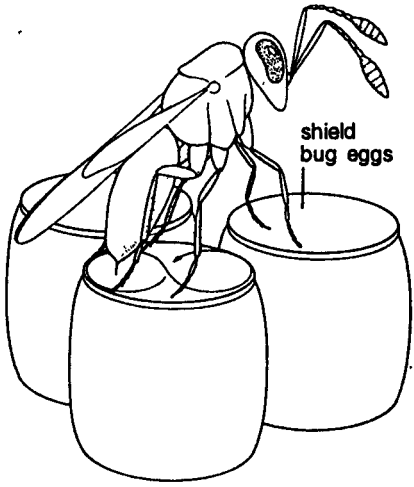

Fig. 11. Parasitoid hymenopteran *Trissolcus basilis* lays its eggs in the eggs of shield bugs

construction and defense of interconnected galleries in rotting wood. Larvae of different species have differing abilities to chew and process wood for food. Colonies generally have overlapping generations and cooperative brood care. Colonizing adults share galleries with offspring in all stages of development. In some cases, young adults assist parents in the construction and repair of sibling pupal cases and other tasks.

Cooperation in excavation of brood galleries and rearing young is also known in the *Minarthrum* **bark beetles**, and other **scolytids**. Complex cooperation between the sexes, with division of labour, occurs in many species of **scarabaeine dung beetles**. Females in the genus *Copris* and many *Ontophagus* species **dig tunnels** and **brood chambers** under dung, pushing dirt up to males higher in the tunnel, who in turn push it out. When excavation is complete, males transfer dung from the surface to the female in the tunnel and she constructs the brood ball. Typically the male remains with the female for most of this process, but disappears from the nest soon after eggs are laid in the dung (**Halffter** and **Edmonds**, 1982). Some *Cephalodesmius* **dung beetles** pair for life and cooperate extensively while rearing larvae (**Monteith** and **Storey** 1981). The female excavates the brood chamber while the male stands guard at the entrance. The male then forages for leaves, flowers, and fruits, which he passes to the female. She adds dung and shapes the material into a ball, which is allowed to ferment for a week. The female then divides the ball into smaller sections for each larva. While the larvae are growing, the male continues to provision the nest. When the young approach pupation, both parents seal themselves inside the chamber with the larvae.

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Parental care occurs in 28% of fish families and among 61% of these the **male** takes care of the offspring. In **fish** the fertilization is **usually external.** This means the males and females have the same costs of deserting a clutch of eggs. Parental care in fish includes : **making a nest, burrying eggs, chasing predators, oxygenating, cleaning, carrying eggs,** and **oral brooding** e.g. **yellow head jaw fish** that actually guards the eggs by holding them in his mouth. Males are territorial, females mate with males on the male's territory, fertilization is external, the eggs are deposited on the substrate, and females leave. Males then tend to have a closer association to the nest. Site for nests could be hard substrate, weeds, algae, and shells. Fish have come up with three modes of reproduction depending on the method they care for their eggs :

Oviparity. A phenomenon where undeveloped eggs are layed, 90% of bony fish have external fertilization, so they fall in this category, **cat sharks, ground sharks, carpet sharks** and **nurse sharks** though have internal fertilization but are oviparous. In fishes, oviparity is most common; the eggs are inexpensive to produce, and as eggs are in the water, they do not dry out (oxygen, nutrients are not scarce). The adult can produce many offspring. The survival of individual eggs is very low, so millions of eggs must be produced in order to successfully produce offspring. **Bowfin** males prepare a pit nest, invite a female, fertilization takes place, male guards the eggs, hatchlings keep moving under father's protection (Fig 12).

The other modes have their advantages, the eggs are much less prone to predation when carried within the mother, and the young are born fully

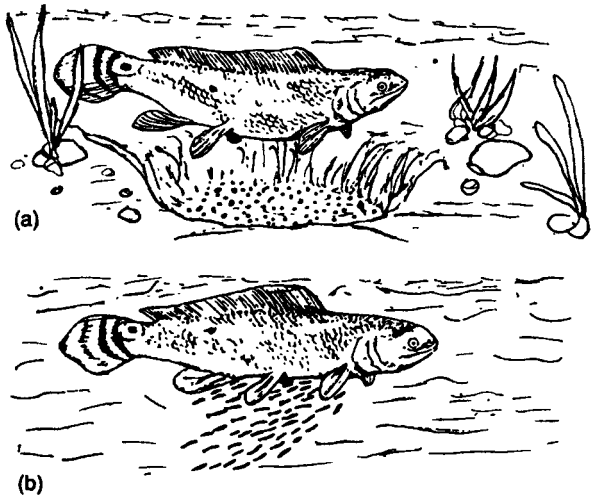

Fig. 12. (a) **Bowfin** males prepare a pit nest, invite female. she spawns, **male** fertilizes the eggs, then guards them, (b) After hatching his babies keeps swimming around him. He protects them from predators.

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advanced and ready to deal with the environment as miniature adults. The adult must supply nutrients to its offspring and can only produce a few eggs at a time.

Ovoviviparity. In this type the eggs hatch inside the body of the female, there is little internal development without direct maternal nourishment and babies are born after few days (e.g. **most sharks** and **rays**). Very rarely a larva or less developed baby is born, a mother helps it feeding e.g. **rockfish.**

Viviparity. Internal fertilization leading to internal development. In this situation the baby derives direct nourishment from mother Fully advanced baby is born (**hammer headed sharks and surf perches**).

Many fish species build nest in one form or another, whether it is a simple **pit** dug into the gravel or the elaborate **bubble** nest. No special breeding set-up is needed, when ready to spawn the fish construct a nest by blowing bubbles, often using vegetation to anchor the nest. The **Gouramis, Anabantids** and some **catfish** are the most common nest builders. Some lay eggs on a flat surface, like a stone or plant leaf or even individually placed among fine leaved plants like Java moss. The parents usually form pairs and guard the eggs. The **Cichlids** are the best known species for this. Some **Catfish** and **Rainbow fish** are egg attenders.

In **mouth breeders** the females lay their eggs on a flat surface where they are then fertilized by the male. After fertilization the male picks up the eggs and incubates them in his mouth. Even after hatching the fry will return to the safety of their father's mouth if danger is near. Brood numbers are usually small, since by the time the fry are released they are well formed. The well known mouthbreeders are the **African lake Cichlids.** The other mouth breeders are catfish, anabantids, killifish. Fish with internal fertilization do not lay eggs at all, they are fertilized internally and grow inside the mother's body. The broods are small and the fry are well developed when born. The **Guppy swordtail** and **Platy** are the best known members of this group.

In **amphibians** most common form of parental care is in the form of **guarding of eggs** by one or both parents. **Salamanders** and **caecilians** protect their eggs, **sticky caecilian** female of Sri Lanka makes a cluster of her eggs and then she protects them by coiling around them until they hatch (Fig. 13). 10% of **anurans** exhibit parental care, mostly in the form of egg attendance by males, some attend to offsprings also. In **Dendrobates, hylids** females attend to tadpoles and provide them unfertilized eggs to eat for nourishment. **Pyxicephalus** and **leptodactylus** frogs look after their tadpoles. Many species carry eggs on their backs e.g. **midwife toad** (Fig. 14), **gasthrotheca, hemiphractus,** and **felctonotus. Rhinoderma darwini** males carry eggs in vocal pouches. **Rheobatrachus** are gastric brooding frogs. Females swallow fertilized eggs, they develop in stomach and are spitted back through mouth as froglets.

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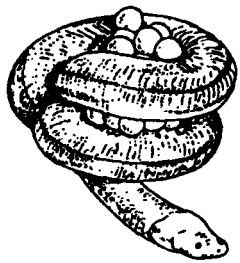

Fig. 13. An apodan – Sticky caecilian found in Sri Lanka. Its female protects her eggs by coiling around them until they hatch.

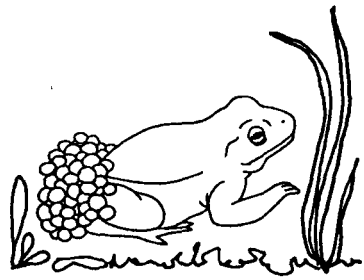

Fig. 14. The male midwife toad sticks the fertilized eggs on his back and carries them till they hatch.

The young of most egg-laying reptiles hatch long after the parents have abandoned the eggs; a few **lizards** and **snakes** guard them, and **pythons** incubate their eggs for a while. In **reptiles** parental care is less common, it is almost non existent in **turtles**, except for that female turtles dig holes to lay eggs, bury them and leave. **Crocodilians** appear to be the most social reptiles, and parental care for young after hatching is probably universal among them (**Lang, 1987**). All 21 living species **build nests** and **defend an area** around nest (**Pooley** and **Gans** 1976). **Females guard** the nests. Young crocodiles call from inside the egg shells when nearing hatching. The female hearing the calls, digs the eggs out and carries all young in her mouth and takes them to water (Fig 15). The female **King cobra** makes and guards a nest ferociously. Parental care is shown by **Iguanas** of Galapagos-the females

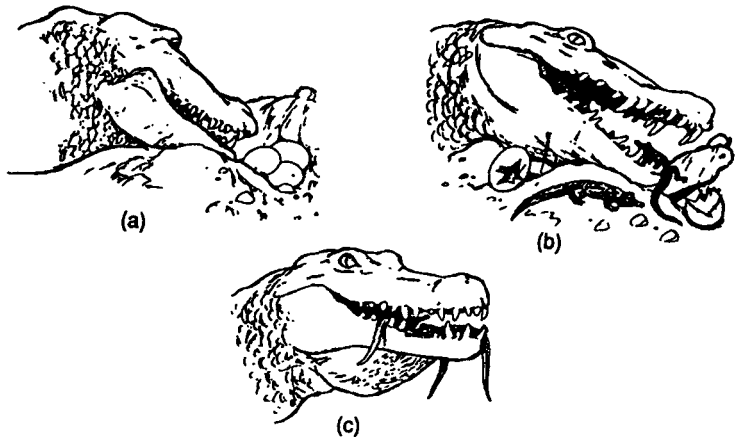

Fig. 15. Female crocodile burries her eggs into a nest, (a) In response to the calls of her unhatched young from inside the eggs, she uncovers them, (b) Mother helps young to come out of their shells, (c) She picks them in her mouth and carries them to water

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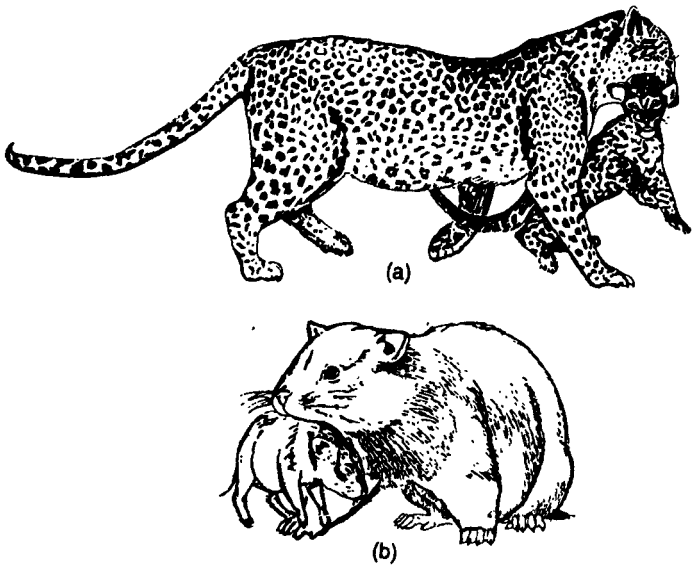

Fig. 16. Shifting of pups to a safe place is a common feature in parental care, (a) A leopard shifts its baby holding between her teeth but never hurts the cub, (b) a hamster carries its cub to a safe place.

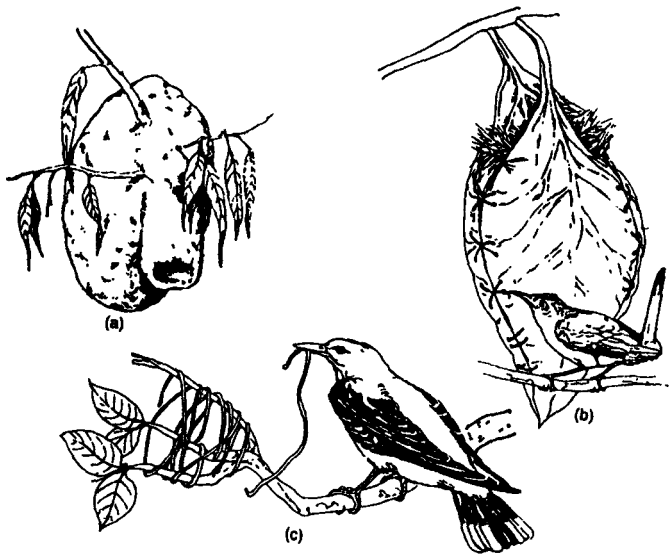

Fig. 17. Nest building is an important parental behaviour Birds are master builders, (a) Weaver bird's nest, (b) Golden oriole making a nest, (c) Tailor bird is sitting next to her nest.

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remain near the eggs and defend the surrounding area. Shifting of young ones from one place to another is seen in many animals (Fig. 16).

Nest building is very typical of birds. There is a great variety of nests. (Fig. 17 a, b, c) Both male and female **swallows** participate in making a nest, but later it's the mother who looks after the nestlings (Fig. 18). Among birds, some chicks, at hatching are entirely dependant on their parents, while others are able to leave the nest and begin finding their own food within hours of hatching. Based on such differences, young birds are generally categorized as either altricial or precocial. Because of variation within these two broad categories, ornithologists more precisely classify young birds into six categories (**Gill**, 1995) :

1. Superprecocial. Young are completely independent at hatching; no parental care e.g. **megapodes.**

2. Precocial. Young leave the nest soon after hatching and follow parents, young can feed themselves almost immediately e.g. waterfowl, shorebirds, and gallinaceous birds.

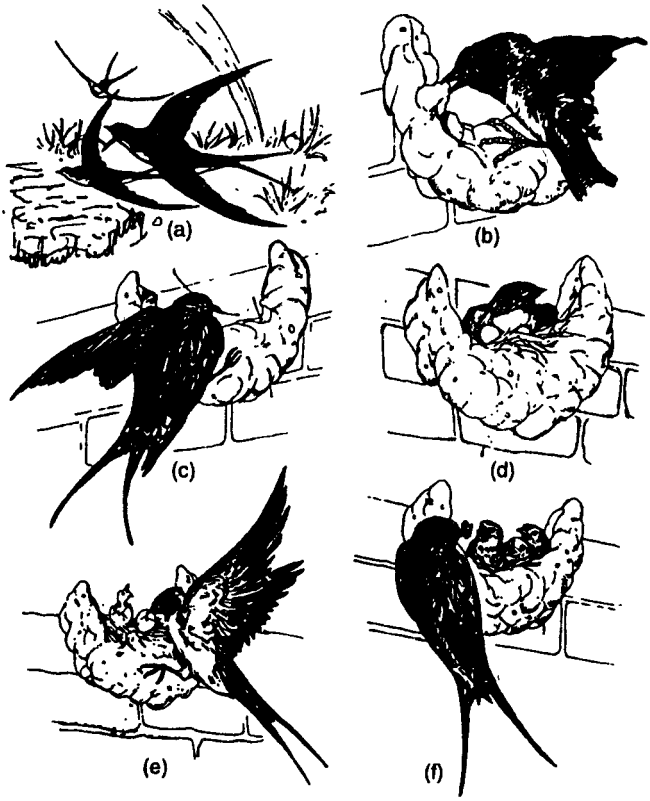

Fig. 18 (a) Swallow's bring mud, (b)–(c) to build their nest, lines it with grass and feathers, (d) Female lays eggs, (e–f) Feeds the chicks.

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3. subprecocial. Young leave the nest at hatching and follow parents,young are fed by parents (or at least shown where food is located by parents), e.g. rails, grebes, and loons.

4. Semiprecocial. Young are somewhat mobile at hatching but remain and are fed by their parents e.g. gulls and terns.

5. Semialtricial. Young not mobile at hatching and are fed and brooded by parents, eyes of young open at hatching (semialtricial 1) or within a few days (semialtricial 2), e.g. screech-owls, herons and hawks.

6. Altricial. Young are naked, blind (eyes closed), and helpless at hatching, e.g. songbirds, woodpeckers, hummingbirds and pigeons

After hatching, avian parental care may involve **brooding** and **feeding** nestlings as well as **protecting young** from predators. Only a few species (brood parasites and the mound builders or megapodes) exhibit no post-hatching parental care. For those that provide care: bi-parental care is predominant, female-care only has been described in about 85 species (those with lek polygyny mating systems plus promiscuous species like humming birds), male-care only has been described in about 30 species (polyandrous species).

The food given to young birds contains all the moisture they need, and parents do not bring them **water to drink** (**Skutch** 1976). Notable exceptions are the **sand grouse** (e.g., the Black-bellied Sand grouse to the right) — parents (particularly males) have specially modified abdominal feathers with great water holding capacity. In fact, these feathers have structural modifications (the barbules are not hooked together) that make them three to four times more absorbent than synthetic sponges (**del Hoyo** 1987). Adults may travel great distances to soak up the water in the abdominal feathers, then fly back to the nest so their young can drink the water from their plumage (**Skutch** 1976).

Predators of various types prey on nestlings, and adults in most species exhibit some form of defence when potential predators approach a nest. Defence may involve calling, approaching the predator, or, in some cases, even striking the potential predator. **Pheasants, hens, and ducks** do not feed young, instead, they give parental care in a different way. They guide them to food, chase the predators away. **Song birds** and flycatchers (Fig. 19) carry flies, caterpillars and earthworms for babies. Female **earwig** keep a close look at eggs, if they start drying she carries them individually to a damper place. The **giant penguins** of Antarctica take particular care to protect eggs and young from snow and cold by keeping them warm in a special abdominal fold.

In most birds the bond is established through **imprinting** during a limited **ontogenetic phase (sensitive period)**. There are two types of young **altricial and precocial**. Some birds, rodents and mammals have altricial young. These babies are born helpless, nude, deaf and blind, do not move, whereas, babies

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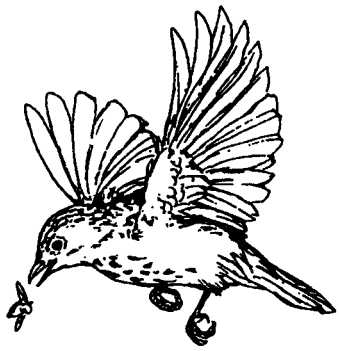

Fig. 19. Fly catcher bird catches insects and feeds them to her babies.

of precocial babies move soon after they are born, they can see and hear, social interactions begin very early. Altricial young are typical among **carnivores**, the helpless cubs stay back in den, while parents go hunting. A young active baby born to meat eating animals would have hampered the hunting. On the contrary, this baby would fall an easy prey. As against this, species of ungulates are precocial, it helps them run away from predators, soon after they are born. A general rule is that species with one or two young (**oligotocous**) e.g. cattle and primates are precocial and species with larger litter size (**polytocous**) e.g. pigs are altricial.

Food supply or **provisioning** forms the largest part of parental care. Many birds feed their young specially insectivorous and carnivorous birds. The food is caught by parent and brought to the young. The babies **beg** for food either through vocalization or by tapping, nudging. it is either fed directly into the beak of nestling or is torn into small pieces (**Hamer** and **Hill** 1994). Among altricial (and semi- and sub precocial) species of birds, one or both adults begin to feed young (or show young where food can be obtained) soon after hatching. Birds carry food from long distances, from sea, lake of forest. This food is provided to the young in partly digested condition, parents eat the food, store it in the stomach, it is partly digested. It has been well documented in **Sea gulls** by **Tinbergen** (1950). As the parent arrives, a slight jerk on nest acts as a stimulus for fledglings to open their mouths, the sight of that stimulates **regurgitation** in parents. In most socially monogamous species plus some polygynous species, both sexes help provision the young. Among birds that deliver food to young, food may be transferred from adult to young in several different ways (**Pettingill** 1985) :

(1) Food is carried in the bill and placed in the open mouths of the young (**most passerines**). Kingfisher feeds its chick in the nest (Fig. 20).
(2) Food is swallowed by adults and later delivered to the young by :

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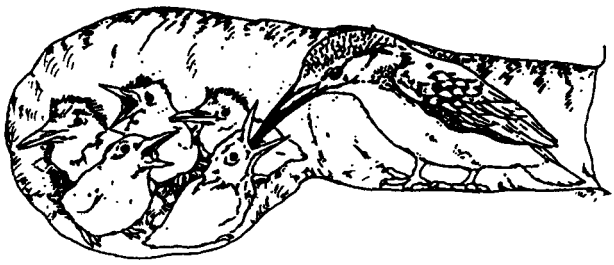

Fig. 20. Kingfisher female can have 5-6 chicks. She brings them food and regurgitate it straight into their hungry mouths

(i) regurgitating the food into the mouth or throat of the young (e.g., **waxwings, hummingbirds, and herons**).
(ii) Regurgitating the food into the nest or somewhere nearby where young can pick it up (e.g., **gulls**)
(iii) opening the mouth and letting young reach in and retrieve the food (e.g., **pelicans and cormorants**).

(3) Food consists of 'milk' (produced in the crop) that is regurgitated into the mouths of the young (e.g., **pigeons and doves**).
(4) Food is carried in the talons to the nest and then either torn into smaller pieces and fed to the young (e.g., raptors with young nestlings) or given to the young whole (e.g., **raptors with older nestlings**).

After feeding nestlings, adults often pick up fecal sacs (packages of excrement surrounded by a gelatinous membrane that may be eaten (particularly when nestlings are very young) or carried from the nest for disposal.

Among **mammals** the parent- infant communication begins through chemicals, followed by hearing and sight (**Romeyer**, 1993). Licking plays an important role (**Alexander** 1986), it cleans the baby and through saliva scent marks the baby. Mother gets the ready nourishment and hormones from foetal fluids. All marsupials are unique for having a pouch to keep the baby. In kangaroos the offspring stay close to mother until they are sexually mature- even babies 18 months to 3 years old get inside the mothers pouch (Fig. 21). Among ungulates **hider species** (pigs, cattle) are those where the young remain at or near the birth site for some time after parturition. In **follower species** (deer, antelope) offspring start moving around with mother. Under both circumstances the mother has to form a strong bond to motivate leaving the grazing areas and return to baby. Shifting of babies to a safer place is a common sight in most mammals specially rodents, cats and dogs. They use teeth to get the hold over the lose skin of baby, pick up and take it to a safe place.

All mammals provide milk to their babies produced by mammary glands. Many **carnivores** show regurgitation. In wolves and dogs, it is common to feed 3-4 week old pups (**Malm** 1995). **Female wild boar** forms a mound of

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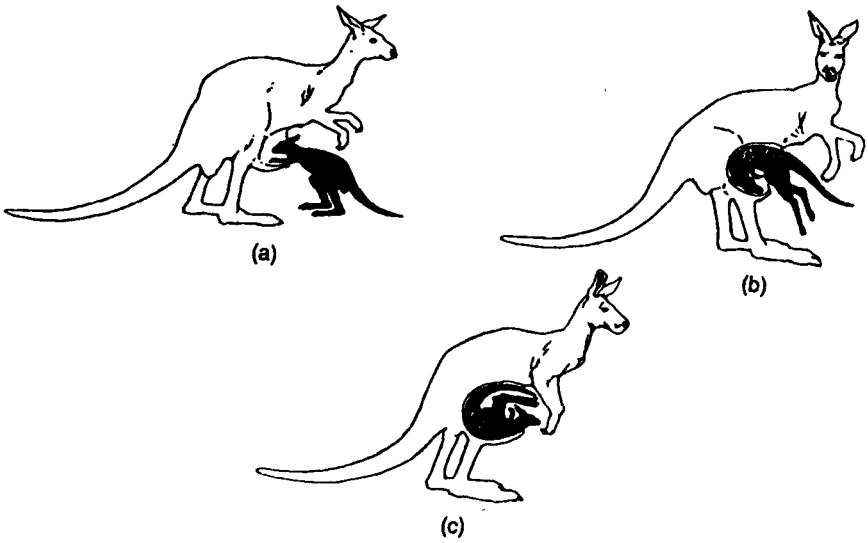

Fig. 21. (a) A Kangaroo female carries its baby for several months. Offsprings from about 18 months to three years old. stay close to their mothers until they are sexually strong (b) The baby first inserts its head and forearms,(c) Then turns around and protrudes its head outside the pouch.

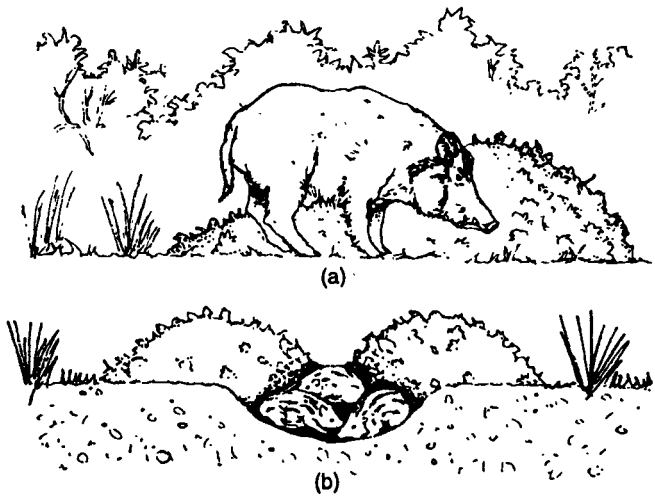

Fig. 22. (a) Before giving birth a female wild boar digs a den and covers it with branches and fallen leaves, (b) She keeps her babies safe in that den.

branches, plants or leaves to protect the nest and young ones inside (Fig. 22). Female of **garden dormice** doesn't want to lose her babies going from one place to another, she orders her babies to hold on to her tail, the babies literally climb on their mother (Fig. 23). As already mentioned **Kingfisher** makes an unlined nest, when the eggs hatch both parents bring food to feed *(Z–37/Ani. Beh.)*

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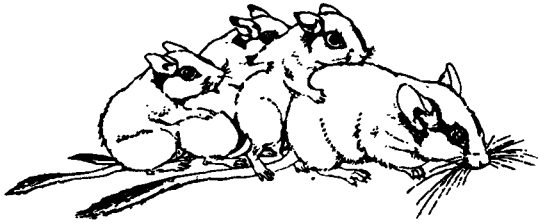

Fig 23 Dormice pups keep very close to their mother for safety.

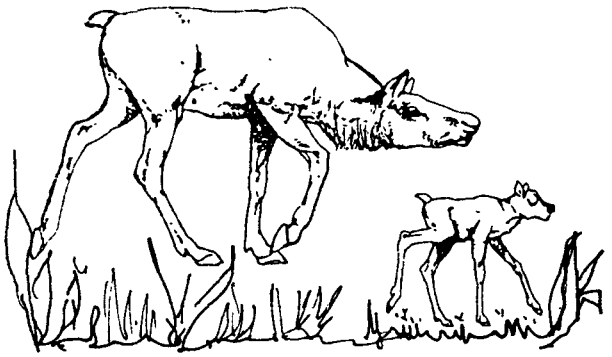

Fig. 24. Mother reindeer lowers her head and gently guides her calf

them through the process of regurgitation (Fig. 20). Parents give extra care to their babies. They help them stand, feed and guide them to move e.g. reindeer (Fig. 24).

In **non-human primates** the parental care is important and extensive, the early development of social behaviour occurs during interaction with the mother. As the infant matures it interacts to a considerable extent with its peers, but these interactions are largely controlled by the mother. These include rooting, grasping, clinging, finding the nipple, gesturing, vocalizations and other social signs. **Monkeys** spend most of their early months, and apes most of their early years, clinging to their mothers in a ventro-ventral position or riding on their backs, and when moving about most mothers give little support to their infants. It is thus essential for the infant to be able to cling to his mother as she runs or leaps about (Fig. 9). The infant's ability to cling depends on basic reflex patterns. This response is still present in the human baby as the **MORO reflex**, given on stimulation of the vestibular organs or the muscles of the neck. In addition to clinging with hands and feet, an infant monkey also holds on to its mother's nipple with its mouth. (Fig. 25). The nipple thus provides an additional point of support in baby **gorillas** (**Fossey** 1975). Sucking has a soothing effect on the baby, even though it obtains no milk thereby and even if it has never previously been fed from

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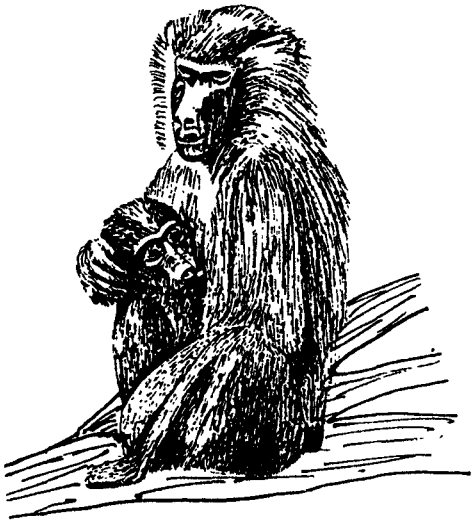

Fig 25. Holding mother's nipple by the baby is very common. It gives them support and security.

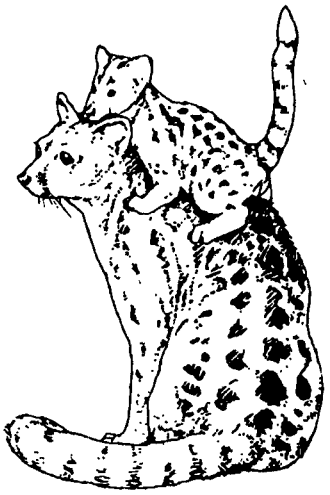

Fig 26. Kittens cling to their mothers back for transportation

breast or bottle. Riding on mother is not exceptional to monkeys, riding on the dorsal side of mother is seen in some cats also (Fig. 26).

All tamarins and marmosets show parental care. **Golden Lion tamarins** (Fig. 6) are small-bodied new world primates (family Callitrichidae; tamarins and marmosets). They show a great deal of parental care by both sexes. In many mammals, usually the female takes care. But in marmosets and tamarins even the males indulge in infant care. Tamarins are arboreal and very mobile during the day. They have territories (40-200 hectare depending on the species) that they actively defend by travelling and patrolling. One of the principle forms of parental investment is infant carrying. Although the body size in lion tamarins is small, females generally produce twins. Females are about 600 g and give birth to infants that are collectively 120g. Therefore they need help in caring for the young. The reproductive female carries offspring on her back for the first several days, nursing them every two hours or so. After approximately a week the male starts carrying the offspring.

Harlow (Harlow and **Suomi**, 1959) provided rhesus monkey infants with two **surrogate mothers** one mother consisting of a hard wire framework with a nipple providing milk and another mother had soft cosy body and no nipple and milk. When rhesus monkey infants were left with these artificial mothers, they spent nearly all their time on the **soft, cosy mother** even though they could obtain no milk from her. The babies jumped to the wired mother to drink milk and quickly returned to soft mother. (Fig. 27). **Textural stimuli** are important in determining an infant's **clinging preferences.** *(Z-37/Ani. Beh.)*

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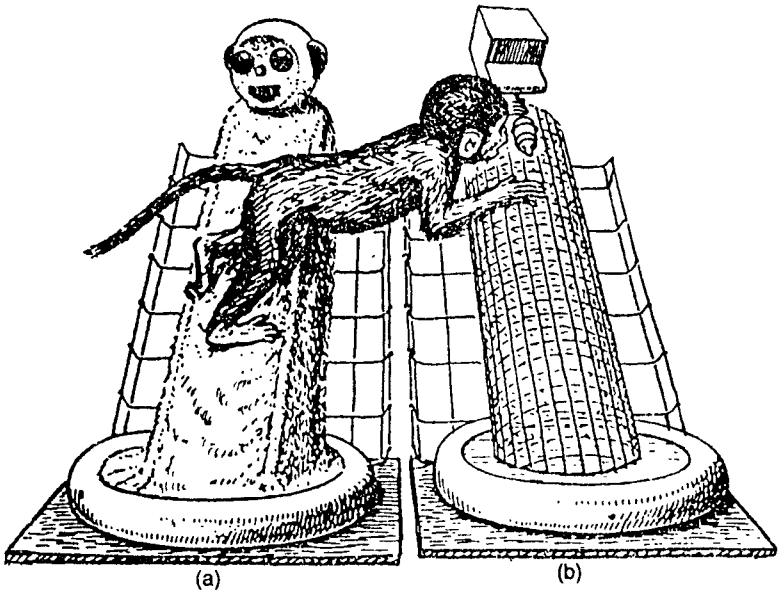

Fig 27. Rhesus infant was offered two mothers (a) was covered with soft material and (b) was made with wire, (a) was not provided with milk bottle, while (b) was provided with milk bottle The infant spent most of its time with soft mother, (a) and went to mother, (b) for a very short time. Attachment between mother and infant does not depend on food alone but also, on comfort (Harlow, 1958).

How do parents ensure that their own offspring receive their parental care? Can animals recognize their own offspring? **Mexican free-tailed bats** live in cave colonies that contain millions of individuals. Females give birth to a single offspring which they leave in the cave when they go to forage. The female returns to the spot where she last nursed the pup but is **misled** by babies next to her own offspring. Given that there were so many pups so closely packed, it was thought that feeding must be indiscriminate. Blood samples of mothers and nursing pups demonstrated that females nurse their own pups at least 80% of the time. They probably do this by a combination of smell and sound.

Two **swallows** that nest in burrows in clay banks are the **bank swallow (colonial nester)** and the **rough-winged swallow (solitary nester)**. Bank swallow young have diverse vocalizations and parents rarely make a mistake despite the high densities in which they are found. Rough-winged swallows however, readily accept the offspring of distantly related individuals and even feed the offspring of bank swallows.

Siblicide/infanticide

In some birds it is common for **siblings (brothers** and **sisters)** to compete for food and space vigorously and even **kill each other** e.g. **blue footed**

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booby and **black eagle** siblings kill a weaker sibling. The parents are generally indifferent to this behaviour. This might be explained, not just as the result of the offspring's **selfish genetic** tendencies, but also as part of a **parental strategy** to identify the **best offspring** and to concentrate resources where they will do most benefit. Various species of **pelicans, eagles and magpies show** this behaviour. Siblings have an interest in small broods because that way each sibling gets a greater share of food, more space in the nest. If a mother has a choice of saving lives of two of her offspring of different ages, the one she neglects is bound to die, in this case she would save the older and let the younger die because according to **Dawkins** (1976) she has already invested higher proportions of her life's investments in the older baby.

It has been observed that bird parents kill their weak baby in the nest, a phenomenon now widely observed in other animal species also called **infanticide**. Infanticide, is associated with the killing of offspring after birth. This is found in many mammalian species. **Syrian hamsters**, for example, **cannibalise** their young when the external circumstances become too unfavourable. **Male cats of all kinds** (including the domestic cat) kill a female's offspring to make her stop nursing and return to fertility, so that they can fertilize her to have their own babies. **Mice, horses and zebras** and many **primates** such as **langurs, baboons** and even **chimpanzees**, all engage in infanticide. In all cases, infanticide can be regarded as part of a male reproductive strategy – albeit an unconscious one. Infanticide in Langurs has been studied and documented by **Mohnot** (1981) and **Mathur** (1986). Langurs maintain unimale bisexual groups. Males from different groups join to form all male groups. After an aggressive encounter, new male from all male group takes possession of females, older male is thrown away by this new male. He tries to kill those young babies who are fed by mothers. When a female is lactating, she is not ovulating. If the male kills the baby, female will stop lactating and start ovulating. This new male can sire his own baby through her.

There are two more unusual behaviours worth mentioning, one **nest parasitism** and other **maltreatment**. **Cuckoo parents** do not perform real brood care, their females deposit eggs into a suitable nest belonging to another species. Young cuckoos hatch earlier than the offsprings of host, they throw the hosts young out of the nest, and keep eating from the host adults. This phenomenon is called **nest parasitism**. **Maltreatment** by mother and aunt have been reported in various animals. The babies can be pulled, pushed, slapped (Fig. 8), carried clumsily. Among langurs and rhesus inexperienced mothers have been seen sitting over their babies ignoring their distress cries. Harlow named this "**deprivation syndrome**" due to the absence of proper parental care.

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IMPORTANT QUESTIONS

➤➤ ***Long answer type questions***

1. Define parental behaviour, parental care and parental investment write factors affecting parental care.
2. What is parent-offspring conflict? Write a note on early parental care
3. Write an essay on parental care

➤➤ ***Write short note on the following***

(i) Early parental care, (ii) Factors affecting parental care, (iii) Types of parental care, (iv) Care and attachment, (v) Parent offspring conflict, (vi) Siblicide, infanticide and maltreatment, (vii) Harlow's experiment and parental care in golden lion tamarin

➤➤ ***Write very briefly on the following***

(i) Parental care in reptiles, (ii) Parental care in amphibians, (iii) Parental care in fish, (iv) Examples of no parental care, (v) Examples of bi parental care, (vi) Examples of male parental care, (vii) Examples of only female parental care, (viii) Examples of relative giving parental care, (ix) Weaning conflict, (x) Ovoviviparity, (xi) Superprecocial, (xii) Precocial, (xiii) Subprecocial, (xiv) Semiprecocial, (xv) Semialtricial, (xvi) Altricial, (xvii) MORO reflex, (xviii) Siblicide, (xix) Infanticide, (xx) Nest parasitism, (xxi) Lack's law.

➤➤ ***Fill in the blanks***

1. Behaviour that increases the fitness of an offspring is called .. . . care
2. Behaviour that increases the fitness of an offspring at the cost of the parent is called ....
3. Female.....eats the spermatophore provided by the male.
4. Cuckoos are known for ..... .
5. Killing own brother or sister is called. .....
6. Golden lion tamarin males are known for their.... ....
7. Some birds feed their young ones.....milk.
8. In amphibians.....% salamanders and ....% frogs and toads show parental care
9. Scorpions carry their babies on their..... .
10 Paradise fish lays about.....eggs.
11. Anabas lays about ....eggs.
12 Younger parents give..... care to their babies
13. Older parents give.....care to their babies.
14. Florida scrub jay is known for its..... .....
15. Infanticide has been well documented in Indian monkey . . ..
16. .. ..insects lay their eggs on the larval food
17. .... insects lay eggs near the larval food.
18. Bycticscus betulae makes a . ...shaped nest
19. Male water bug carries fertilized eggs on .. . .
20. African lake cichlids are .....breeders.
21. Eggs are carried in vocal sac by..... .
22 Gastric brooding frog is ....
23. Python ....their eggs.
24. King cobra makes a ... ...for eggs
25. Megapode chicks are ....

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26. Waterfowls and shore bird chicks are.....
27. Hummingbird chicks are. ....
28. Giant penguins keep their brood in a special .....
29 Species with one or two young are .....
30. Species with larger litter size is.....

Answers

1. Parental, 2 Parental investment, 3 Katydids, 4. nest parasitism, 5. siblicide, 6. parental investment, 7. crop, 8 18% and 6%, 9. back, 10. 20-300, 11. 1000-3000 12. less, 13. more, 14. helper in the nest, 15 langur, 16 dystrophaptic, 17. eutrophaptic, 18. cigar, 19. its back, 20. mouth, 21 Rhinoderma darwini, 22 Rheobatrachus, 23. incubate, 24. nest, 25. supercocial, 26. precocial, 27 altricial, 28. abdominal fold, 29. oligotocous, 30. polytocous.

➤➤ ***True and false***

1 Behaviour that increases the fitness of an offspring is called Parental care..... .....
2. Behaviour that increases the fitness of an offspring at the cost of the parent is called Parental investment..... ..... .
3 Female Katydid eats the spermatophore provided by the male .....
4 Cuckoos are known for nest parasitism .....
5. Killing own brother or sister is called siblicide.....
6. Golden lion tamarin males are known for their parental investment.....
7. Some birds feed their young ones crop milk.....
8. In amphibians 18% salamanders and 6% frogs and toads show parental care .....
9. Scorpions carry their babies on their back.....
10. Paradise fish lays about 20-300 eggs .....
11 Anabas lays about 1000-3000 eggs.....
12 Younger parents give less care to their babies.....
13. Older parents give more care to their babies.....
14. Florida scrub jay is known for its helper in the nest.....
15. Infanticide has been well documented in Indian monkey langur.....
16. Dystrophaptic insects lay their eggs on the larval food.. .....
17. Eutrophaptic insects lay eggs near the larval food .....
18. Bycticus betulae makes a cigar shaped nest .....
19. Male water bug carries fertilized eggs on its back.....
20. African lake cichlids are mouth breeders.....
21. Eggs are carried in vocal sac by Rhinoderma darwini.....
22 Gastric brooding frog is Rheobatrachus.....
23. Pythons incubate their eggs.... .....
24. King cobra makes a nest for eggs.....
25 Megapod chicks are supercocial.....
26. Waterfowls and shore bird chicks are precocial.....
27. Hummingbird chicks are altricial.....
28. Giant penguins keep their brood in a special abdominal fold.....
29. Species with one or two young are oligotocous.....
30 Species with larger litter size is polytocous.....

Answers

1 True, 2 True, 3. True, 4. True, 5. True, 6. True, 7. True, 8. True, 9. True, 10. True, 11. True, 12. True, 13. True, 14. True, 15. True, 16. True, 17. True, 18. True, 19. True, 20. True, 21. True, 22. True, 23. True, 24. True, 25. True, 26. True, 27. True, 28. True, 29. True, 30. True.

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➤➤ ***Multiple choice questions***

1. Least parental care is provided by
   (a) Mammals (b) Reptiles (c) Birds
2. Factors that affect parental care are
   (a) Size of the litter (b) Age of parent (c) Both
3. No parental care is provided by
   (a) Cowbird (b) Cichlids (c) Songbirds
4. Both parents provide parental care
   (a) Gibbon (b) Crocodile (c) Langur
5. Relatives provide parental care
   (a) Golden lion tamarin (b) Elephants (c) Sea horse
6. Cigar shaped nest is made by
   (a) Bycticus betulae (b) Water bug (c) Trissolcus
7. Mouth breeding is seen in
   (a) Sword tail (b) Platy (c) Cichlids
8. Megapodes are
   (a) Subprecocial (b) Precocial (c) Supercocial
9. Female Katydid eats
   (a) Mating male (b) Spermatophore (c) Both
10. Cuckoos are known for
    (a) Nest parasitism (b) Helper at the nest (c) Siblicide
11. Golden lion tamarin males are known for their
    (a) Twins (b) Male parental investment (c) Both
12. Younger parents give
    (a) Less care to their babies (b) More care to their babies
    (c) Do not care for their babies
13. Older parents give
    (a) Less care to their babies (b) More care to their babies
    (c) Do not care for their babies
14. Infanticide has been noted in
    (a) Langurs (b) Lions (c) Both
15. African lake cichlids are
    (a) Surface breeder (b) Mouth breeders (c) None
16. Eggs are carried in vocal sac by
    (a) Rhinoderma darwini (b) Rheobatrachus (c) None
17. Gastric brooding frog is
    (a) Rhinoderma darwini (b) Rheobatrachus (c) None
18. Species with one or two young are
    (a) Oligotocous (b) Polytocous (c) Both
19. Species with larger litter size is
    (a) Polytocous (b) Oligotocous (c) None
20. Deprivation syndrome was studied by
    (a) Tinbergen (b) Harlow (c) Lorenz

Answers

1. (b), 2. (c), 3. (a), 4. (a), 5. (b), 6. (a), 7. (c), 8. (a), 9. (b), 10. (a), 11. (c), 12. (a), 13. (b), 14. (c), 15. (b), 16. (a), 17. (b), 18. (a), 19. (a), 20. (b).

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8

Behavioural Genetics

Introduction

All behavioural patterns are either learned or genetic. There is no third category. If animals are arranged from simple to complex on one axis of a graph and on the other axis we put percent contribution (learned or genetic) and plot a graph (Fig. 1) it reveals that lower animals rely more on genetics as compared to higher animals. Reverse is true for learned behaviour.

It has been known since long that **intelligence** runs in the family. Many relatives are found equally intelligent in families. That means intelligence is somehow transferred from parents to offspring. The scientific pioneer in this field was a cousin of Charles Darwin - **Francis Galton** he published a book in 1869 "***Heredity Genius***". He examined 300 families. His results showed that eminent social status such as judges, poets, musicians, painters appeared more in close relatives and as degree of relatedness fell the likelihood of eminence decreased. **Galton** eliminated the possibility of effect of environment as individuals belonging to such families when reared away in different environments still showed that **intelligence**. Studies of related individuals has been a very popular technique to establish genetic control over behaviour. **Galton** had further noticed that Individuals with **schizophrenic** parents had very high chances of having this mental illness even if they were separated from them in their early childhood.

Galton's studies were based on human beings and had many assumptions. The field of **behavioural genetics** became firmly established by 1960 when **Fuller** and **Thompson** published their book "Behaviour Genetics". Discovery of genetic control over bahaviour added substance to the concept of fixed action (instinctive or inborn behaviour).

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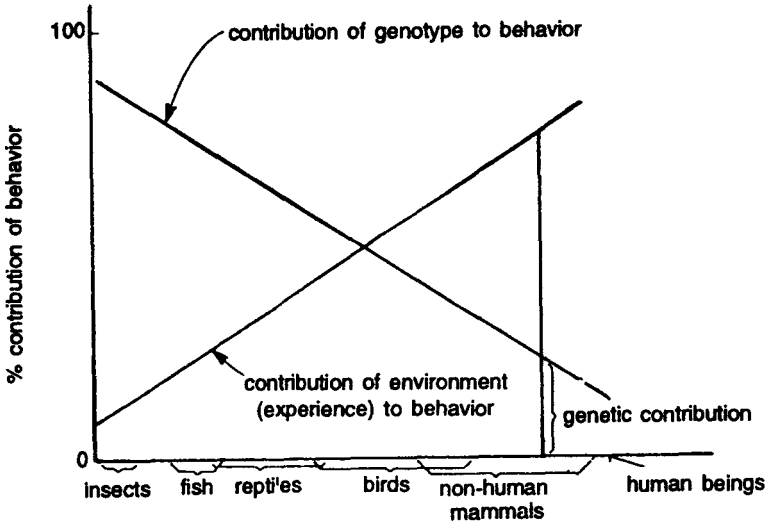

Fig. 1. Percent contribution of genotype is higher in lower animals and contribution of environment/ experience/learning is higher in higher animals.

The pathways from genes to behaviour represent extremely complex routes of biochemical and physiological activity. In 1974, **Gould** published a book on "***Molecular Ethology***". This specialized area linked genotype with behaviour. Genes regulate behaviour indirectly through hormones by changing sensitivity of receptors, through central nervous system, by altering morphological and physiological characteristics.

The involvement of genes can be simplified by following sequence : Genotype → regulates production and activities of enzymes → this in turn regulates biochemical reactions → regulates functioning of nervous and muscular, endocrine systems → and subsequently regulates behaviour.

It has been difficult to study relationship between genes and behaviour. Ethological approach to behavioural genetics is only through **simple crossing over** experiments. These investigations are limited to :

(1) the species that can be kept under laboratory conditions.
(2) these species must be able to reproduce in a relatively short time and
(3) these species should possess easily recognizable and measurable differences in their behaviour and lastly.
(4) resulting hybrids should produce fertile young to study further generations.

This is necessary as by additional back or self cross studies with species hybrid one can examine whether a behaviour pattern is controlled by only **one single** set of **alleles** or whether **several sets of alleles** are involved ? It is known well in genetics that single gene and its one or two alleles produce 1-2 kinds of single traits, whereas, multiple genes with respective alleles produce a variety of traits.

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Study of behavioural genetics is basically organized to find answers to following questions (**Thiesch** 1972; **Dewsbury** 1978).

(1) If behaviour is influenced by genes ,then how many genes operate to regulate one trait ?
(2) How do genes and environment interact to produce behaviour?
(3) If there are differences in behavioural traits in different species then is it attributed to variation in genotype?
(4) What proportion of the measured variability in behaviour is attributed to genetic and to environmental factors respectively?
(5) Behaviour helps the animal in survival. Is it adaptive (evolutionary) ?

Methods of Studying Relationship between Genotype and Behaviour

(A) Studying Genetically Uniform Populations

A widely used method has been to create **genetically uniform populations** of lab animals through **inbreeding** procedures. All the members of a given strain have the same genotype and will behave similarly if reared in the same environment. However, if two groups of **different strains** are raised together under exactly the same environmental conditions, the two lines will usually **differ behaviourally** on almost any test. Mice with **different genotypes** differ in speed with which they learn to avoid an electric shock and in their ability to retain learned information, because their genotype is different, therefore, their **behaviour is different**. This indicates behaviour is regulated by genes (**Bovt.** 1969). Different genotypes when subjected to identical environments, the behavioural differences among strains result from genetic not environmental factors.

Geneticists have performed carefully controlled experiments in which they have deliberately attempted to select for or against a particular behavioural trait. **Tryon** conducted a long series of selection experiments on rats. First, he tested a diverse population of rats and let them run the maze and he later divided these rats into three groups on the basis of their performance in a maze :

(1) **Bright rats**-those that learned maze quickly.
(2) **Dull rats**-those that made many errors and learned the maze slowly.
(3) **Intermediate rats**–those that performed between the two categories This group was discarded.

Tryon permitted only **bright males** to **breed** with **bright females** and dull **males** to **dull females**. Tryon repeated the procedure for **seven generations**. By interbreeding the very best of the bright line and the very dullest of the dull line (Fig. 2) he was able to produce **brighter** and **brighter** rats as well as **duller** and **dullest** ones. His breeding programme led to concentration of

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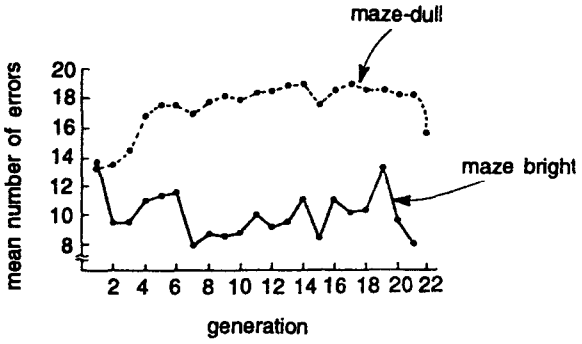

Fig. 2 The results of selection for Maze-Bright and Maze-Dull rats. (Modified from Mc Clearn, 1963).

genes that underline maze running ability in the two groups. There are other examples indicating direct involvement of genotype with animal behaviour.

1. Alcohol preference in mice. Rogers and **McClean** (1961) compared four strains of inbred mice kept in the same environment for generations. Each strain was presented with vessels containing either pure water or alcohol varying in strength from 2.5 to 15%. Daily consumption was measured. The data indicated that the strain **C57BL** and **C3H/2** exhibited a **preference** for **alcohol**, while **BALB/c** and **A/3** demonstrated an **aversion** to it, this preference differences are attributed to the genotype of each strain.

2. Open-field behaviour in mice. Open field test was designed to study **exploratory** and **emotional** behavior in mice. When placed in a new environment, mice normally explore the surroundings, but they are a bit cautious or "nervous" about the new setting. This is evidenced by their elevated rate of **defecation** and **urination**. To study this in lab, an enclosed, brightly illuminated box was devised with the **floor marked** with **squares**. Exploration is measured by counting the number of squares entered in a given standard time. Emotions are measured by counting the number of defecations. Different inbred strains of mice have been shown to vary significantly in their response to the open field setting, **BALB** demonstrated **low exploratory activity** and was very **emotional**, while **C57** was **field active** and **non-emotional**.

3. Baboon Mate Selection. *P. hamadryas* has a social system that includes **harem**. P. anubis are **promiscuous** (mate indiscriminately) which is controlled by dominance ranking of males. In the overlapping range hamadryas males have been observed to **kidnap** juvenile anubis females. These females learned to cooperate with the **herding behaviour** of males in **harem life**. **Hybrid males** resulting from such mating were not so efficient in herding females as the pure hamadryas. Since both hamadryas and hybrid males appear to have the same opportunity to learn the herding behaviour, it can be concluded that herding behaviour is genetically determined.

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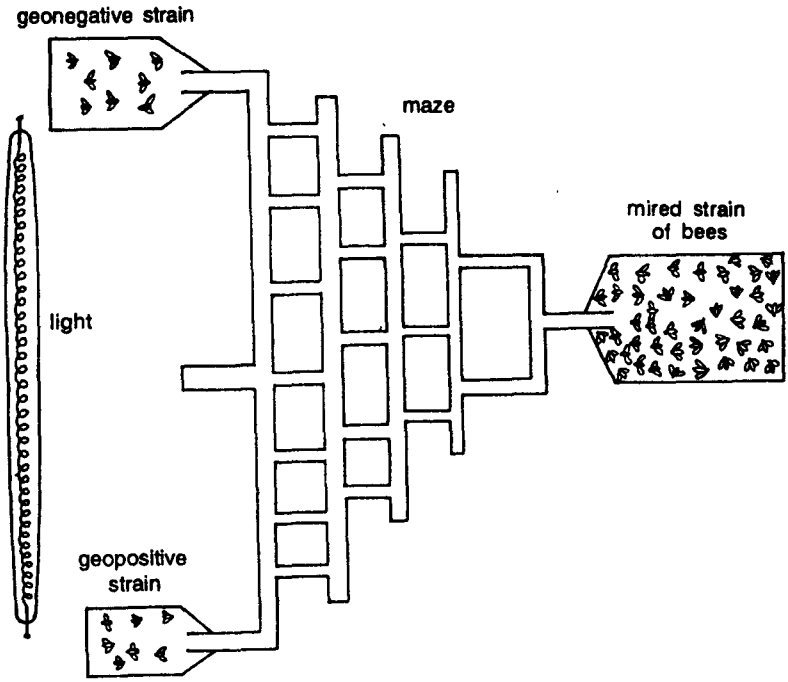

Fig. 3. Two strains of bees were mixed and were allowed to go through a maze Geopositive strain got collected in the chamber closer to ground and geonegative collected away from ground

4. Geotaxis in *Drosophila*. Hirsch (1963) and his colleagues designed a mass **screening device** which allowed **200 flies** (of two strains) to run in a maze (zig zag path). The **maze** was placed vertically, a fluorescent light illuminated the side opposite to the starting point (Fig. 3). Those flies that continued to turn up **(against gravity)** at each junction finally arrived in the **top tubes**; those that **always turned down (towards gravity)** arrived in the **bottom tubes**. It was found that two strains of flies could be sorted out for both **positive** and **negative geotropism**, establishing the genetic influence on this behavioural response. Further experimentation led Hirsch and his colleagues to conclude that geotaxis was under **polygenic** control and responsible genes were distributed on all three **major chromosomes (X, 2 and 3)** in *Drosophila.*

5. Roamers and sitters in Drosophila. In another study two strains of *Drosophila.* One whose larvae covered a lot of distance **(roamers)** in search of food while other whose larvae did not **(sitters)**. These larvae were reared under identical conditions. **Roamers** travelled about **four times farther** on an **yeast coated petri dish** during **one minute** test than **sitters**. When adults of the two strains were permitted to reproduce they created offsprings all of which were **roamers** during the larval phase. They grew and produced next generation (F2) with a ratio of 3 : 1 of **roamers** and **sitters**. According to

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Mendel these results indicate that roamers carried one or two copies of the dominant gene affecting foraging behaviour of larva whereas, sitters had two copies of the recessive genes. Here is an example where difference between two behaviours is due to a single gene. **A single gene affects** maternal behaviour in laboratory mouse. Females with one mutant gene **fosB** do not protect and feed their young ones. In another experiment **Manning** (1961) could separate two types of *Drosophila* on the basis of their two different **mating speeds. Cade** (1981) selected **male crickets** that called very frequently and those that hardly called at all. Such experiments invariably imply that there is genetic mechanisms underlying behaviour.

The recent improvements in genetic techniques has led to further studies that attempt to identify the genetic basis of individual differences in behaviours, such as homosexuality and aggression.

(B) Simple Crossing Over Experiments

Another way of studying genes and their influence on behaviour is **hybrid study**. The behaviour of hybrids has been studied in a large number of species from various animal groups - especially **ducks** and **geese, pigeons, parrots, finches**, and several species of **fish** and **insects**. The behaviour of hybrid is usually **intermediate** between the respective parents. (i) male hybrids from the cross of a **ring necked pheasant** and a **domestic chicken**, show a posture when crowing that is exactly **intermediate** between those of the parent species (Fig. 4). (ii) hybrids between **Waxbills** that drink by immersing their entire beak into the water, and those that drink by dipping their beaks, show an intermediate depth in the degree to which they immerse their beaks in the water.

If two parent species **differ qualitatively**, i.e. if one **possesses** a behaviour that is **absent** in the other, then it is **either present** or **absent in the hybrids**, depending on whether or not it is dominant. In complex behaviour patterns,

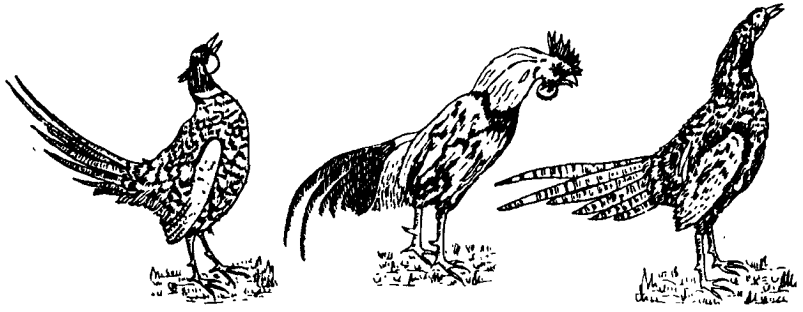

Fig. 4. The crowing posture of the ring-necked pheasant (left), a domestic rooster (right), and a hybrid of both species (center) (Stadie 1968).

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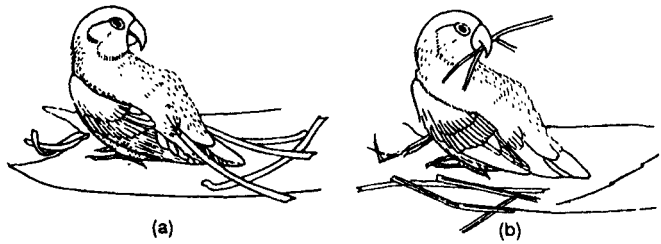

Fig. 5 Transportation of nesting material in love-birds of genus Agapornis

hybrids may show a **mixture of behaviour** elements derived from each parental species. A cross between fish **Tholloni-a substrate breeder** and **Nilocita**–is a **mouth breeder**. Hybrids show **random oscillation** of the behaviour patterns of both parents : they glue the eggs to the substrate, fan them, pick up a few of eggs, spit the eggs and so forth.

Very informative results were obtained in crosses of two species of African lovebirds **-A. Roseicollis**, have a peculiar method of transporting nesting material to the nest cavity; they cut and place strips of leaves or paper, between the rump feathers on their backs, where they adhere to small hooks on the underside of the feathers. Other species, A. fisherei, transport the nest material in their beaks (Fig. 5). Hybrids between these two species at first try to carry the nest material between their rump feathers, but in this, they fail ,then ultimately they carry strips in beaks.

The above mentioned examples indicate involvement of genes in behaviour, when these genes are mixed in a hybrid they show a mixed and intermediate behaviour of parent species. Unfortunately in most cases the individuals of F_1 generation remain sterile therefore, next generations are not available to carry out further experiments.

(C) Geographically Distinct Populations

Geographically distinct populations often have different morphology and behaviour, reflecting adaptation to the existing ecological conditions in their respective habitats.

Arnold (1981) observed two populations of Garter snakes (*Thamnophis egans*). **Inland Population**-which was very aquatic. Fed mainly on frogs, fish and leeches. **Coastal Population**-Terrestrial, Fed mainly on slugs. Arnold found that interbred forms demonstrated an intermediate preference for slug eating. The other common research methodologies are family studies and twin studies. **Family Studies**-Children share 50% of their genes with each parent. Therefore, influential genes must run in families. Obviously, a trait that is environmentally transmitted rather than inherited. For example, last names tend to run in families, but no one would claim that last names are genetic.

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Twin Studies- Monozygotic (MZ, identical) twins share 100% of their genes, while dizygotic (DZ, fraternal) twins share only 50% of their genes (the same percentage as non-twin siblings). Identical twins provide a unique opportunity to study "nature-nurture" interaction.

Single or multiple gene effect

Pleiotropy. A **single gene** that has an effect on the expression of two or more **phenotypic** traits, it is said to have a **pleiotropic effect** on the traits. For example, testosterone controls the development of what are referred to as **secondary sexual characters** (e.g., lion's mane), but testosterone also relates to behavioural traits like aggression.

Polygenic. If **two or more genes** are responsible for a **single trait**, the phenotypic trait is said to be governed by **polygenic factors**. For example, **growth rate** is undoubtedly caused by a number of genes that act in a complex cascade. Thus **body size** which is the result of a large number of genes is **polygenically determined**. Genes that control growth hormone have a large effect on body size. Likewise, genes that control sex steroids like testosterone also control body size to some degree, especially during the maturation phase body size. Undoubtedly, many genes that influence metabolism have some small, but measureable effect on body size. Body size, is thus governed by many genes of large and small effect. There is a gene responsible for head shaking and rapid circling in "**waltzer**" **mice**. **Inbred strains** are created by mating brother to sister for at least **20 generations**. This severe inbreeding eliminates **heterozygosity** and results in animals that are **virtually indentical genetically**. Behavioural differences between inbred strains reared under the same laboratory are then due to environment.

It is important to note that there is no single gene for intelligence, personality traits, behaviour, or even height. Rather, such **complex characteristics are polygenic**, i.e., they are influenced by **multiple genes**. If gene alleles occur in just a dominant— recessive gene relationship, only two phenotypes are possible (**single gene** effect) when there is a lack of dominance, **three phenotypes are possible**. Other genetic relationships such as **multiple alleles produce wider range of phenotype (multiple gene effect)**. All the experiments mentioned so far went no further than the F_1 generation because the **hybrids** are generally **sterile** (a hybrid between horse and donkey is mule. The mules are sterile). The few instances in which experiments were carried into F_2 generation yielded further understanding about the inheritance of behaviour pattern. If one crosses two subspecies of **phoretic (carrying of one organism by another without parasitism) thread worms**, Rhabditis inerims, a nematode of which larva of one species makes **undulating movement** (Fig. 6) with the anterior part of its body, increasing its chances of contact with an insect on which it will be carried away - then only undulating hybrids will be obtained in F_1 generation. In a back cross one

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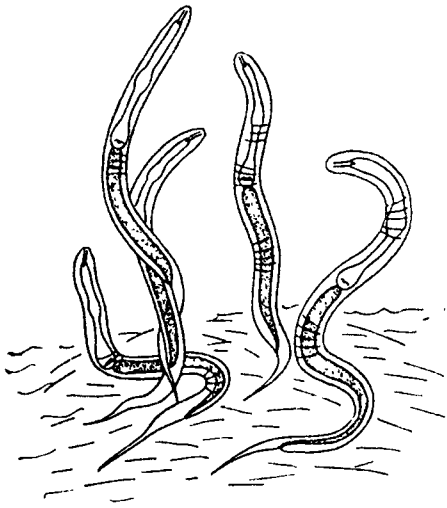

Fig 6. Larvae of the threadworm Rhabditis inermis perform undulating movements with the anterior parts of their bodies, which are raised above the substrate (after Osche 1966)

obtains **undulating** and **non undulating** nematodes in a ratio of 3:1. This shows that character undulating is dominant and is determined by a **single gene**.

The *Drosophila*, which is better known genetically than any other animal, provides good examples of the various ways in which genes can affect behaviour. Many hundreds of mutant genes are known in Drosophila and their position on chromosomes has been mapped.

Name of the Gene		Trait
Bar and White	:	Reduces the number of facets in compound eyes. Reduces pigmentation in the eyes. Affects vision and then behaviour, these flies cannot locate mates
Forked and Hairy	:	Bristles are sensory structures Flies with this gene have defective tactile sense Unable to locate mate.
Vestigial and Dumpy	:	Alters wing structure .These will have grossly malformed wings which can not be vibrated properly and they too have poor mating success.
Yellow and Black	:	Affects general body pigmentation. Flies with these genes take longer to mate.
Stuck		Males fail to dismount
Coitus interrupts	:	Males dismount early.
TKO	:	Mutant fly gets a jerk, falls, twitches, goes into coma, recovers.

By screening large number of Paramecia scientists have found some mutant individuals of various sorts. Single gene alters the behaviour.

(Z–37/Ani. Beh.)

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Sluggish	:	Slow swimmers
Fast	:	Rapid swimmers
Paranoiac	:	Swims backwards
Pawn	:	Cannot swim backwards

The appropriate set of genetic crosses revealed that each of these behavioural mutants was linked to its single gene mutation. It is striking that single gene can so severely disturb the development of normal behaviour. There are over **150 metabolic disorders** in **humans** caused by **single gene defects**. The behaviour of these humans is certainly affected because metabolic disturbances cause menal retardation.

The environment also determines the phenotype. For example, food availability determines body weight. The environment is anything external to the genetic material. In animals that lay eggs without parental care, the eggs are subjected to environmental variation in the form of **temperature**, **hydration**, or perhaps **salinity**. In animals that lay eggs and have extended parental care in a **nest**, the environment is a function of the parents and the siblings in the nest. In animals with internal fertilization and some kind of gestation, the mother's physiology becomes an important component of the offspring's environment.

How genes control an innate behaviour

An adult *Aplysia* in largely occupied with **feeding** and **reproduction**. Aspects of the snail's reproductive behaviour are highly **ritualistic** involving a coordinated series of **stereotype** patterns that accomplish **courtship**, **mating** and **deposition** of **fertilized** eggs. In *Aplysia* fertilization is **cross** and fertilized eggs are laid in an elaborate, stereotyped array of **coordinated behaviours**. The eggs are laid in **long strings** of more than million eggs. As the string of eggs is expelled by contraction of the reproductive duct muscles, the snail stops moving, it stops eating. The snail **grasps the egg** string in its mouth with a series of characteristic **head waving movements**, it helps to extract the string from the duct and winds the string into an irregular mass. A small gland in the mouth secretes a sticky mucoid substance that becomes attached to the mass. Then, with one forceful wave of head, the **animal fixes** the entire mass of eggs to a **solid support**. A number of behavioural acts have come together in a rigid coordinated sequence to serve a common function of egg laying. **Does *Aplysia* learn this** ? Or what genes encode these activities?

Kandel and Irving Kupfermann (1989) identified two clusters of neurons, the **bag cells**, at the top of Aplysia's **abdominal ganglion**. When an extract of these cells was injected into live snails, it elicited the full repertoire of behaviour associated with egg laying even though the animals had not mated and had no eggs to deposit. In subsequent studies **Arch** and **Strumwasser** (1990) isolated one of the active bag cell factors and identified it as a

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peptide consisting of **36 amino acids**. They found that when the peptide was administered to snails, it elicited some but not all of the egg laying behaviours suggesting it was one of several factors controlling the total egg laying behavioral repertoire. This peptide was designated as **Egg Laying Hormone** (ELH). Later, a group of scientists namely **McAllister, Jackson, Schwartz, Kandel, Schaller** and **Axel** isolated the gene encoding ELH in 1992. They concluded from their studies that there is a single gene which encodes a long protein chain, this chain has number of small, biologically active peptides, these different peptides bring about different actions in egg laying.

A number of **phenotypes** in **humans** have been demonstrated to be controlled by **single gene**. Many forms of **mental retardation** including **phenyelketoneuria, Gargoylism** (Gargoylism : sex linked inheritance, congenital mucopolysaccharide disorders of metabolism characterized by skeletal abnormalities, coarse features, enlarged liver and spleen, mental subnormality and abnormal behaviour) and **Wilson's disease** (hepaticolenticular degeneration due to disturbance of copper metabolism, mental subnormality, abnormal behaviour) are controlled by **single recessive genes.**

One very interesting "**single gene and behaviour**" example comes from **honeybees. Rothen Buhler** (1964) carried out a cross between two strains of bees :

Unhygienic strain
Dominant genes
U = do not uncap the cell
R = do not remove dead from the cell
Hygienic strain
Recessive genes
u = uncap the cell
r = remove dead from the cell

In nature, these strains do not breed but in experimental conditions they breed giving following progeny :

UURR × uurr (parents)
= UuRr (offspring; phenotypically unhygienic and genotypically carrier)
If a **test cross** is done then following results were obtained :
UuRr × uurr

Gametes	UR	Ur	uR	ur
ur	UuRr(1)	Uurr(2)	uuRr(3)	uurr(4)

(1) Unhygienic.
(2) Will not uncap the cell but if experimenter uncaps the cell the bees remove dead larvae.
(3) Uncap the cell but do not remove the dead larvae.
(4) Hygienic.

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Single gene control on behaviour are also known in humans. An example is the **lactase deficiency** found in certain racial groups. Lactase production is controlled by **one gene** along with **its two alleles** :

L, L_1 and L_2 both L_1 and L_2 are recessive to L and L_2 is recessive to L_1. Individuals with :

LL or LL_1 or LL_2 - Genotype produce lactase both as adults and as children. Those with L_1L_1 or L_1 L_2 do not produce lactase as adults but produce lactase as children and those with L_2 L_2 can not produce lactase all their lives.

It is interesting to note that more examples are available from single gene control on behaviour. Whereas, most of the behavioural traits are controlled by **many genes**. The study of involvement of many genes is hard to trace. For this a long multi generation test has to be applied. If a behavioural trait is due to a **number of genes** it can be expected to produce **many phenotypes** continuously within a population. To study multi gene effect fertile offsprings are needed which are found rarely.

All courtship displays, nest building, parental behaviours, birds songs are controlled by many genes. Hybrids of two species of **swordtail fish**, *Xiphophorus helleri* and *E. montezumae*, show that even simple behavioural differences in courtship behaviour can be **polygenic**. Digler (1990) proposed that the nest building characteristics are under **polygenic** control.

Variation in **genotype** profoundly influences **behaviour**. It is apparent that all the members of same species do not look alike or do not behave alike. You do not look exactly like your brother or sister. We can also tell our dogs apart, individual pigeons are often easily distinguished. Furthermore, we don't always react to a situation in the same way as our brother or sister might. Animals of same group also show strong behavioural differences. The point is, members of populations even closely related may differ strongly in both appearance and behaviour. Human populations show maximum variation. We come in a variety of shapes, sizes, colours and we differ in our behaviour, culture and abilities.

Jane Goodall has been carrying out research on the Chimpanzees of Gombe National Park (Tanzania) since 1953. She identifies all the chimps not only by their faces but also due to differences in their behaviours. Though all of them are chimps, for a layman all of them should behave similarly. A common man would not identify a variety of different behaviours executed by different chimps. But since Jane Goodall has devoted her 50 years studying them, she identifies great variance in behavioural acts among the individuals of different groups. She has maintained geneological records of each and every chimpanzee.

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IMPORTANT QUESTIONS

➤➤ *Long answer type questions*

1. Describe methods of studying behavioural genetics.
2. Explain with examples single and multiple gene effect on behaviour.

➤➤ *Multiple choice questions*

1. 7 generations of mice were studied in maze by
   (a) Galton (b) Darwin (c) Tryon
2. Alcohol preference in mice is shown by strain
   (a) C57 BL (b) BALB/c (c) A/3
3. Hirsch and his colleagues conducted experiment
   (a) Phototas in *Tribolium* (b) Geotaxis in *Drosophila* (c) Kinesis in *Planaria*
4. Book "Heredity Genius" was written by
   (a) Darwin (b) Hirsch (c) Galton
5. Book "Molecular Ethology" was written by
   (a) Gould (b) Galton (c) Lorenz
6. Alcohol aversion is shown by mice
   (a) C3H/2 (b) C57/BL (c) A/3
7. *P hamadryas* are
   (a) Monkeys (b) Rabbits (c) Cats
8. Geotaxis in *Drosophila* is
   (a) Single gene effect (b) Multiple gene effect (c) None

Answers

1. (c), 2 (a) 3. (b) 4. (c) 5. (a) 6. (c) 7. (a) 8. (b)

➤➤ *Fill in the blanks*

1. Jane Goodall has been studying . . ... .of.. ... National Park.
2. Genotype L_2L_2 will cause ..... .deficiency
3. Unhygienic and hygienic strains of bees were studied by... .....
4. The full form of ELH is.....

Answers

1. chimpanzee, Gombe National Park, 2. Lactase, 3. Rothen Buhler, 4. Egg Laying Hormone.

➤➤ *Match the following*

1. Bright and dull rats	(a) Loger and McClean
2. Alcohol preference	(b) P. hamadryas
3. Herding behaviour	(c) Arnold
4. Garter snakes	(d) Tryon

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