Shinde Rajesh

Deepika Dhoble yedkar

* Parental care in Amphibians / higher animals
* Nesting behaviour in fishes / Aves

TO THE FIRST EDITION

luction to the science of Animal Behaviour erably within the past few years. In the midst tions, new information, was gathered in the r which has heartened us to compile this e form of a book. The purpose of this book is ciples of Animal Behaviour and is intended Post-graduate students of different Indian Behaviour is being taught as a subject. Our k which can enrich the knowledge of students

pters on stereotyped, acquired and motivated s in behaviour, pheromones, courtship and tion and mimicry, sociobiology, biological fish and bird migrations, behaviour genetics These chapters contain recent information

with thanks the valuable suggestions given , Department of Zoology, Banaras Hindu viding necessary information regarding the viour of *Drosophila*. The suggestions of Dr. Psychology, Banaras Hindu University were so thank Sanjay Anand for providing practical nimals. The authors extend their thanks to d all other well wishers who have extended anuscript.

able suggestions from the readers of this book ay be made in the next edition.

Authors

Harjinder Singh

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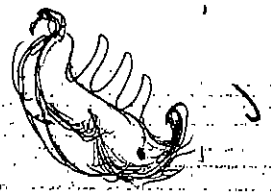

ETHOLOGY — INTRODUCTION

The study of the animal behaviour is called Ethology which originates from two Greek words "Ethos" meaning "Character" or "Habit" or "custom" and "logos" meaning "study". Ethology literally means "character study" which was used earlier to interpret character through the study of body gesture or it may be called as descriptive study of the "habits of animals". Animal behaviour is the study of motor activities of an organism interacting with the environment. The word "behaviour" signifies motor activities patterns as observed in the activity of rat when it will be exposed to a strange environment (motor activity). The feeding response of rat signifies specific activity pattern. In a "behaviour" of an organism, a number of specific behaviours combine with each other. Behaviour includes all those processes by which an animal senses the external world and the internal states of its bodies and responds to changes which it perceives. Ethology deals with the study of animal behaviour in its natural habitat. The display of specific behaviour pattern of an organism is dependent on its genetic make up and the environment in which it inhabits. The behavioural science or Ethology developed from the works of A. Vesalius (1543) and Darwin and Wallaces' theory of evolution. Instead of dealing with behaviour, A. Vesalius (1543) gave the structural details of human brain in his work "De Humani Corporis Fabrica" which has provided first insight of the nervous system (Grier 1984). Neurobiology, physiology and psychology are the backbones of behavioural studies of animals. Herbert Spencer (1855) in his book "Principles of Psychology" dealt with the mental continuity in the psychology of lower animals to that of higher animals and supported the theory of inheritance of acquired characteristics proposed by Lamarck. This was expanded further in 1896 from reflex behaviour to choice or free will behaviour. This was found to be of quantitative nature than qualitative and showed gradation from one organism to another. Darwin (Plate-I (1)) published his book "The Origin of Species" in 1859 in which he made significant contribution about the general principles of evolution. In this book, he has brought forward the idea that nature selects the fit individuals by weeding out unfit individuals. Here he has not focused much as behaviour of animals but in his later publications like "The Descent of Man" (1871) and "Expression of the Emotions in Men and Animals" (1873) he made significant contribution on behaviour of animals and provided evolutionary approach to behaviour and

other biological traits taking out many significant results relating to the internal mechanism of behaviour. For example, his idea of "Principles of serviceable associated habits" is close to the modern idea of Associated learning. In "Principles of antithesis" he has described about animal's outward expressions of their internal emotions. He supported the idea of behaviour in his work "Principles of the direct action of the excited nervous system of the body, independently of the will and support of Habit." In 1884 George John Ramanes published a paper on "Mental evolution in Man" where he has explained about the feeling of animal or human being in a particular situation. For example, in a state of fear or danger organisms react to either avoid or face the situation.

Further researches from 1890 to 1910 dealt with the mechanism of internal control of behaviour. Such works developed independently to each other and provided basis for establishing new branches like ethology, neurobiology and comparative psychology. Beer (1975) compared ethology to a "broad river, fed by numerous tributaries, and braided in its lower reaches through the division and shifting of its channels in the loose gravel that is its bed" but is "a single fluvial system that is separated from others flowing in its vicinity and through similar terrain" (Grier 1984). In seventeenth century, the word Ethology (Greek ethos meaning habit) was used in human ethics and by middle of nineteenth century this term was used to living organisms in the ecological sense rather than behavioural sense (Grier 1984). In 1940's the term ethology was widely used in the study of animal behaviour. Ethology deals with the study of species-specific patterns of animal behaviour under natural conditions with little emphasis on learning. On the other hand, Comparative psychologists have paid much attention on the principles of associated learning under laboratory conditions using certain experimental designs and biostatistical methods. They have concentrated more on the learning behaviour of humans and other vertebrates like pigeons, rats, dogs, rodents etc. Parallel to this, neurobiologists provided understanding of the functional units of behaviour by making observations on proximate mechanism of nervous system. The causes of behaviour were explained by physiological psychologists. Maier and Schmeirla (1935) published a book on "principles of Animal Psychology and ethology". Schmeirla found that maze-learning behaviour in ants and rats are quite different. Ethologists and psychologists (Lehrman 1953, Lockard 1971) confronted each other but now a merger is seen on the thought and results because behaviour may be defined as the observable act of animals (Grier 1984) which is dependent ... and sociobiology on one hand and neurobiology on the other. ... to Kendel (1976) behaviour can be defined "as all observable ...etory responses to changes in an animal's internally or ... It includes muscular contraction, secretions, courtship ... not be sensed directly but it takes one far below ... udes five parameters which are patterns, stimuli, ... sequences. Pattern is a behavioural unit which

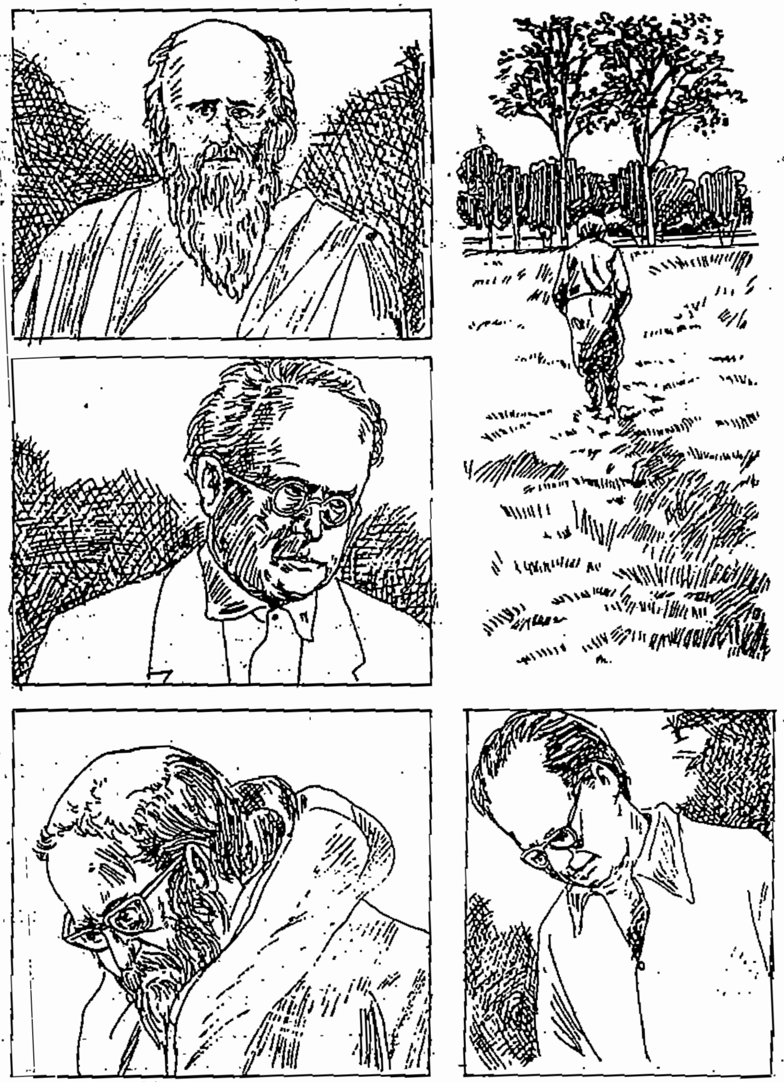

PLATE-I. Explanation of Photographs

1. Charles Darwin (From the Betimann Archive, Inc.)
2. Konard Lorenz (Thomas Mc Avoy, Life Magazine, c, 1955 Time, Inc.)
3. Karl Von Frisch (Photo by W.S. Hoar)
4. Niko Tinbergen (Photo by W. S. Hoar)
5. B.F. Skinner (From Nina-Leen Life Magazine ...

occurs after a stimulus. The stimulus may be any information, which an organism collects by its sensory organs, interpreting it in the nervous system and reacting to it. Only specific informations are interpreted and used in motor activity which is known as behavioural stimulus. A stimulus may be useful at one time but becomes useless on another occasion. The physiological mechanism of an organism is responsible for triggering or eliciting a stimulus. In the mechanisms of behaviour, perceptual, neuroendocrinological locomotor activities and different systems working in relation to it came under this. Any pattern of stimulus may be elicited, if any organism is not physiologically ready to accept it. For example, outside the breeding season animals will not mate and they will not respond to sexual signal because they are physiologically not fit to accept the sexual signal. But in breeding season they will mate due to action of many mechanisms in the body which will help in mating. The level or quantity of behaviour will depend on the nature of the stimulus.

Finally one must observe the consequences of performing an act. The consequence may be of short term effect, a neighbour, or long term like survival act and increased fitness. In behavioural study, one must consider teleological and anthropomorphic approach. In teleological approach, a state of confusion may be created in the function of a pattern with its cause as seen in eating behaviour of animals. Eating is important for survival of an organism. In anthropomorphic approach, the organism possesses sensitiveness to respond to a particular situation as humans do. Animals generally eat because of hunger but mate because of the pleasure it gets during mating.

Charles Whitman of the University of Chicago and Oskar and Heinroth of the Berlin aquarium are the two naturalists who are the founders of the modern discipline of Ethology (Kandel, 1976; Lorenz; 1981) Whitman studied the reproductive behaviour of closely related species of pigeons whereas Hienroth carried out research on the duck behaviour. One of the students of Whitman called Wallace Craig studied complex behaviour patterns and said that there are two components of complex behaviours which are appetitive and consummatory components. In appetitive behaviours, the animal actively searches and orients itself to external stimuli. It is highly variable, whereas the consummatory portion is more fixed and stereotyped in action. In the field of ethology, many naturalists like Konrad Lorenz, Karl Von Fresch and Niko Tinbergen published his research in different scientific journals and a concise account of this has been published in 1951 in his book "The study of Instinct". From their observations and many other naturalists it has been observed that under identical circumstances in the same age groups or sexes, animals show a stereotyped behaviour. This has led Lorenz to formulate fixed action pattern (FAP) but now with the current researches it has been found that behaviour is of variable nature. The concept of FAP was further elaborated by Schleidt (1974). Barlow (1968, 1977) has elaborated the concept of model action pattern (MAP) about a stereotype behaviour. Many ethologists have reported that the

stimulus for response may be very simple as seen in the fighting response of Sticklebacks, begging responses of newly hatched gulls, escape responses of birds to coloured cardboard models of hawks, territorial threat responses of European robins, such simulations of whole patterns of complex behaviour by dummy pieces [illegible] cardboard models are called sign stimuli which are used [illegible] by a species and are called as releasers. The releaser [illegible] synonym with sign stimulus. In vacuum behaviour FAPs are seen in absence of a stimulus eg. many insectivorous birds even in the absence of prey insects fly and exhibit all sorts of catching, killing and eating behaviour little stimulus is found as reported in the case of rats who use their tails to make their nest in absence of building materials (see Eibl-Eibes feldt, 1958 reported in Lorenz, 1981). Sometimes a stimulus may be a super normal releaser as found in the case of some birds which incubate a larger than normal egg in preference to their own (Grier, 1984). In 1981 Lorenz described the concept of innate releasing mechanism (IRM) by keeping the sign stimulus and FAP together which may be represented as follows: Sign stimulus—IRM—FAP, where IRM is not a true neurobiological nature known to Lorenz but he compared the process to the filling of reservoir in his famous hydraulic (or Flush Toilet) model. He modified the version and postulated an action specific energy (ASE) building up motivation for particular behaviour. According to Dewesbury (1978), "The term FAP cannot presently be used in effective scientific communication".

Beach (1955) reviewed the instinct or innate concept in greater details. Cassidy (1979) wrote a review on the concept of instinct. Grier (1984) was of the opinion that stimulus response relationships are learnt but many of the others do not show learning behaviour. Occasionally simple cues trigger learned responses in animals. When two stimuli occur simultaneously the effect of one will be more than other but if the two stimuli are of equal nature, they produce conflict behaviour, seen in the fighting of males at a territorial border where impulse to flee is balanced by the impulse to stay and fight (Grier, 1984). conflict behaviour may be categorized in the following two types:

(1) Redirected behaviour: Here response is directed to different objects like that seen in pecking the ground in place of opponent.
(2) Displacement activity: Here irrelevant response is given suddenly like eating instead of fighting.

According to Hinde (1970) there are some other be[illegible] seen in the conflict situation which are immobility, compr[illegible] (1951) (Plate-I (4))came forward with hierarchical orga[illegible] the complex behaviour which show higher and lo[illegible] seen in the reproductive behaviour where l[illegible] building and mating and higher level by c[illegible] threatening etc. In the reproductive behavi[illegible] centers and IRM functions as center of inh[illegible]

releases lower centers (Grier, 1984). In the study of instinct stimulus, filtering occurs at sense level rather than in the central nervous system and according William James (1890) instincts are the bundle of reflexes which were not invariable as reported in his book, "Principles of Psychology". Instinct is a ndency to act in a way of which the average is constant but which may not be mathematically true.

In 1894 C.L. Morgan published a book "Introduction to Comparative Psychology" in which he said "In no case may we interpret an action as the come of the exercise of one which stands lower in the psychological scale." (Morgan's Canon). From his idea "Cognitive theories" originated which refers internal mental processes that may exist apart from immediate external stimuli (Grier 1984). As seen in the maze experiment, where an animal learns to get food a definite place because in this case learning depends on a cognitive map of the maze design in the animal's head. Reinforcement theory also developed m the Morgan's research. Thorndike paid attention on this line. He kept animals in a problem box and recorded performance over subsequent trials. He posed "Law of Exercise and Effect" based on these experiments which say that performance of behaviour improves with practice (law of exercise) and the mulus strength to produce a response increases with the pleasant consequences and decreases with unpleasant ones (the law of Effect). From ies on sparrows, rats and monkeys it can be concluded that learning is milar in all the species (Grier, 1984). Pavlov's (1906) experiment on dog vation, supports this idea where salivation response is due to stimulus of nging bell and not the sighting of food.

After Thorndike, the idea of "Behaviourism" was proposed by J.B. Watson (1913-1930) and he said about human behaviour "as collection of mulus—responds reactions" (Grier, 1984). The behaviour of an animal can studied by observing outward behaviour (public events) and inward viour (private events).

In 1938, B.F. Skinner (Plate-I(5)) published a book on "The Behaviour of anism" where main emphasis were made on psychology and learning ies. He put the idea of operant conditioning or instrumental learning. He Skinner boxes and demonstrated responses of animals which may be ntrolled. In instrumental learning, the pattern of response is modified as ers the classical conditioning when focus is made on different stimuli. The ard and punishment may shape the condition responses (Grier, 1984). The nal response may be altered by reinforcement and on the nature of Many other studies were made on other aspects of learning like and imprinting. The psychologists have paid attention to the studies abilities, emotions, memory traits etc. (psychological behaviours) ethologists have concentrated more about "Species-specific r". In 1904, Cajal published a book on neurobiology "Histologie du Nerveux de l'homme *et* des Vertebres" where he could show that

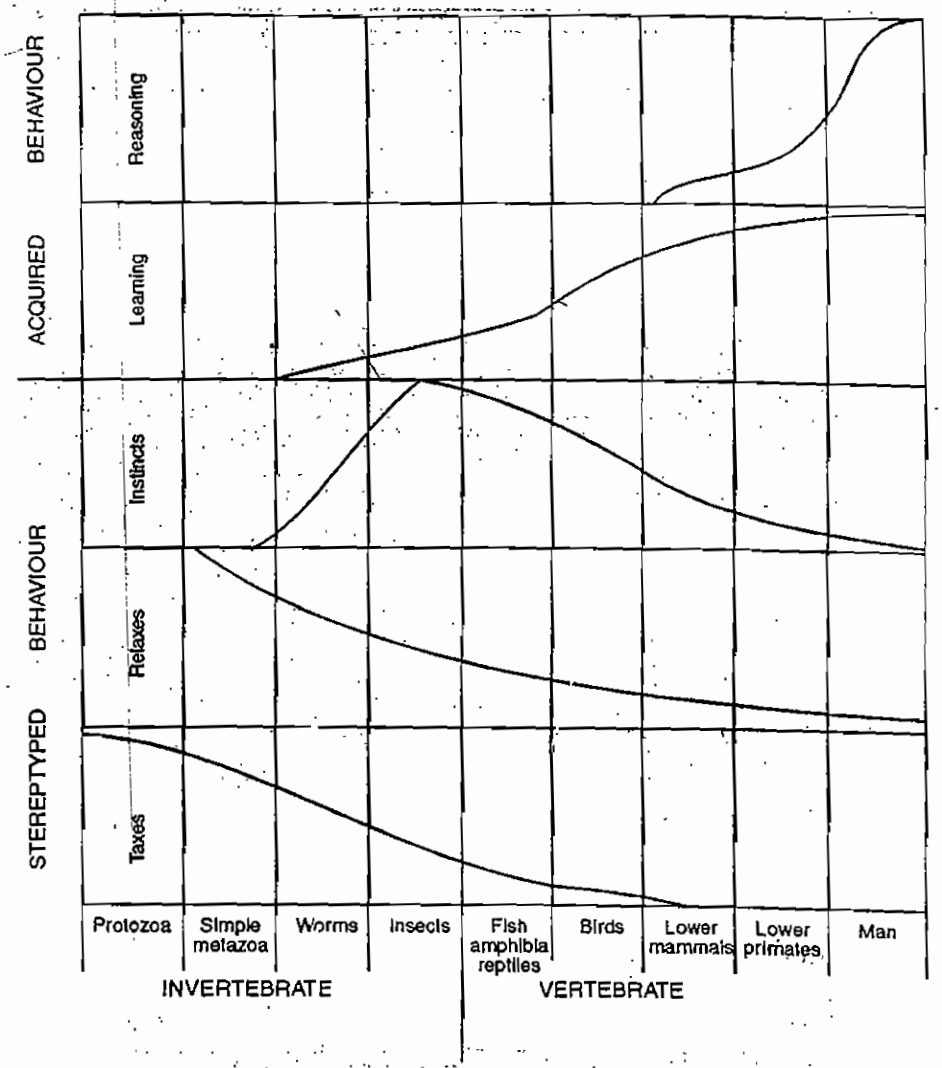

Fig. 1. Major mode of adaptive behaviour in phylogeny of animals.

central nervous system plays an important role in bahaviour. Now it is possible too stain neurons with different staining techniques and to see its role in behaviour. Invertebrates are easy to study than vertebrates. The behaviour of pigeons and doves was studied by Charls O Whitman (1998). He wrote a book on the animal behaviour mentioning his observations. After his death one of his students, O Riddle published his remaining work. Konrad Lorenz (1903-1989) (Plate-I(2)) founder of Ethology who was lecturer in Animal Psychology at the University of Vienna, Austria studied the imprinting behaviour in young ones and wrote books "King Solomon's Ring" (1952), 'Man Meets Dog" (1954) and "On Agression" (1962). Karl Von Frisch (1986-1982) (Plate-I(3)) studied the behaviour of honey bee and proposed the communication system of bees in the form of honey bee dances for which he was awarded the Nobel prize. Niko Tinbergen (1907) (Plate-I(4)) studied the behaviour of animals like butterflies, three spined sticklebacks and gulls in their natural habitat. He wrote books on "The Study Of Instincts", "Social Behaviour In Animals" (1965) and "The Animal In Its World" (1972). Ethologists are concerned with experimental aspects of behavioural study whereas neurobiologists are able to show internal mechanisms of an organism's behaviour and psychologists have taken into consideration evolutionary changes in animals.

BRANCHES OF ETHOLOGY

Ethophysiology—Deals with the physiological aspects of behaviour which can be further classified into following categories:

(a) **Ethoendocrinology** which deals with the relations between hormones and behaviour of animals (b) **Neuroethology** deals with the relationship between sensory processes and nervous system with a particular act of behaviour of animal.

Ethogenetics or Behaviour Genetics—Here genetic basis of behaviour is studied because the genetic makeup of an individual influences the behaviour pattern of an organism.

Ecoethology—Here environmental influences on a species and its behavioural changes are studied which may be considered on two things one on the habitat and another on groups of species. How different species adapt themselves to different habitats and why different species differ from each other is being considered. Different species living in the same habitat show similar behavioural adaptations, whereas other living in different habitats show change in their behavioural adaptations. It is interesting to note that behaviour of a single species may be different from that of a group i.e. when a member of a species lives individually it behaves differently than that when it lives in groups. Time is also an important factor, influencing behaviour of an organism.

Human Ethology—This is the recent branch of a ethology dealing with the human behaviour. The variability of human behaviour has occurred in evolutionary time, which has passed from generation to generation through their genes.

Sociobiology—This is a fascinating branch of ethology standing between ethology and population biology where social behaviour of an organism studied.

PHYLOGENY OF BEHAVIOURAL PATTERNS

Phylogeny and Ontogeny of behaviour are two different things. Phylogeny of behaviour traces the origin and development of behavioural characteristics in a species in evolutionary time whereas ontogeny of behaviour forms the study of development pattern of behaviour of species. The highest evolved, man shows dominant mode of adaptation in the form of reasoning and learning. There is very little in the way of instinct or even in reflex which is not greatly modified by experience and taxes are essentially non-existent. In a simple mammal like a rat, reasoning is virtually non-existent but learning is well developed. Here, instincts are clearly seen and important but they may be modified with the experience. Some taxes are present but only in the earlier ontogenic developmental stages. The insects learn poorly and are dominated by unchangeable instincts and show taxes quite clearly. Learning is not clearly recognizable below the level of worms and may not be a property of an organism. The instinctive patterns are still simpler and poorly developed and the organism is dominated by taxes and reflexes (Fig. 1).

REVISION QUESTIONS

1. What is Ethology ? Describe its history of development.
2. Write short notes on the following:
   (*a*) Behaviour
   (*b*) Sign stimuli
   (*c*) Conflict Behaviour
   (*d*) Law of Exercise.

orientation of body with respect to the source of stimulation.

1 STEREOTYPED AND ACQUIRED ANIMAL BEHAVIOUR

Behaviour may be broadly classified into two types (1) Stereotyped (2) Acquired animal behaviour.

STEREOTYPED ANIMAL BEHAVIOUR (Innate, Inborn, Inherent behav)

In the case of stereotyped behaviour, organism is to a large extent stimulus *bound*, where a pattern of stimuli trigger a sequence of responses. Since this kind of behaviour is essentially the outcome of inherited properties of the nervous system of the organism, it is also known as *innate* or *inborn* or *inherent behaviour*. Stereotyped behaviour is of three types (1) Taxis (2) Reflexes (3) Instincts.

TAXIS (Behaviour guided by external stimulus)

It is one of three types of stereotyped behaviours. Taxis means the orientation of the body with respect to the source of stimulation. It is a simple movement influenced by the direction of the stimulus. In taxis, animal's body takes up a particular direction which may be combined with locomotion so that the animal moves towards, away from or at a fixed angle to the source.

The simplest form of adaptive behaviour is the orientation of the organism in respect to some aspect of its environment. It may also be seen that in taxis the orientation of body may also involve movement in respect the stimulus. But all the orientations are not taxis. In a very simple case the orientation may be nothing more than a series of random movements coupled with occasional avoidance or approach movements in response to a specific stimulus. For example, *Paramacia* will congregate in regions of low Carbon dioxide whenever random movement brings them in the bubble where Carbon dioxide level is high, they swim backwards and turn and then swim forward again, away from the bubble. This action is repeated over and over with the result that most of the members of a group are situated at some distance from the bubble at any one instant. But this kind of orientation is not taxis because its direction is not continuously guided by a specific stimulus. Therefore, an example of taxis would be the case in which an organism orients itself in

such a way so as to maintain equal stimulation of two bilaterally symmetrical receptors or in which by alternate left and right movements it equalizes stimulation at successive intervals of time. For example, an organism may orient towards a light source so that both eyes receive equal stimulation. If the source is moved laterally, the orientation will change because one eye is now receiving more illumination than the other. If one eye of organism is removed or painted, the organism will move continuously in circle as though "trying" to equalize the light on the two eyes. Such orientation continuously and specifically guided by external stimuli is called taxis.

In the simplest cases, a taxis may amount to a forced orientation or movement in which the organism's adaptation is simple, automatic and innate pattern of response to sensory stimulation. However, in other cases,

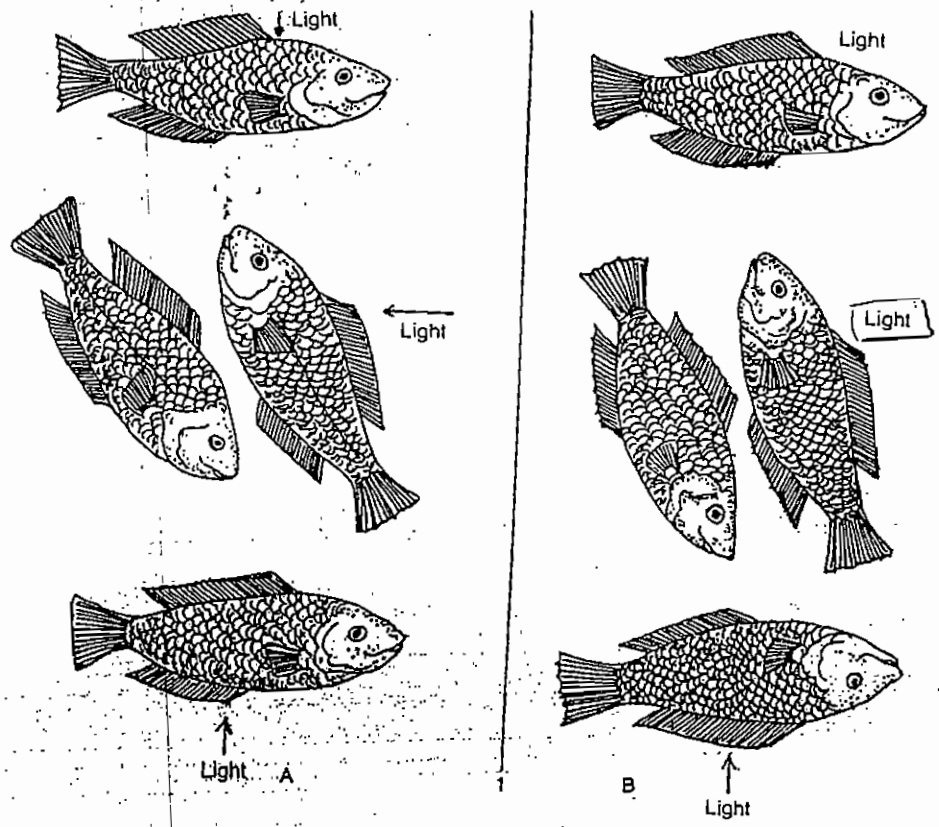

Fig. 1. Diagram showing upright orientation of fish, *Crenilabrus rostratus* towards light stimulus.
A. Orientation of normal fish.
B. Orientation of fish in which labyrinth of the inner ear is destroyed.

a taxis may be embedded in a complex instinctive act. For example, the upright orientation of fish (*Crenilabrus rostratus*) with ventral surface down may depend upon both photic and gravitational taxis (Fig. 1. A,B). If light comes in from the side rather than from above, certain fishes may orient at an angle upward or downward. If the effects of gravity are removed by destroying the labyrinth of the inner ear, the fish will orient perpendicularly with light from the side and even with ventral side up if light comes from below (Fig. 1.B).

The taxis may be of following types:

1. Klinotaxis. In this case, receptor is not capable of discriminating the source of stimulation. The animal can compare the intensities of stimulation on the two sides of its body by turning the receptor first in one way and then in the other. This comparison is successive and enables the organism to turn until both sides are stimulated equally. Such type of taxis is seen in the response of maggots of common flies like *Musca sp., Calliphora sp., Lucilia sp. etc.* to light during the period preceeding pupation. Frankel and Gunn (1940) showed that under condi-tions of dim. diffuse light, the maggot's turning, depends on successive compari-sons between the stimuli on both sides of the body. As the maggot turned its head to the left side, a second light hanging centrally above the animal was switched on momentarily. This was repeated, every time the head moved to the left, but not when it moved to the right. As a result, animal circled towards the light. If the second light was switched on momentarily when the head was to the right, the circling was to the left. Thus orientation in a horizontal beam is not due to a direct response to the direction of the beam, but to successive responses whose strength varies with intensities of the incidence light (Fig. 2).

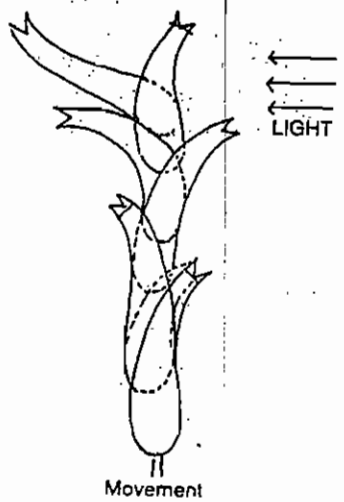

Fig. 2. Diagram to show klino-taxis in the maggot of flies (After Mast 1911)

2. Tropotaxis. In this type of taxis, the comparison of stimulation is simultaneous. It depends on bilaterally symmetrical receptors arranged in such a way that they are stimulated unequally when the animal is not oriented towards or away from the source of stimulation. This simultaneous comparison makes possible [illegible] from a localised source without the lateral swing[illegible] necessary in klinotaxis.

Cases of pure tropotaxis are not easy to find because it is often combined with telotatic responses. Both klinotaxis and tropotaxis depend on balance *i.e.* the animal orients itself by equalizing the intensity of stimulation on the both sides of the body.

"The dorsal light reaction" shown by many aquatic and aerial animals (keeping the dorsal or ventral sides uppermost), was distinguished from tropotaxis by Frankel and Gunn (1940). In this reaction, animals move in a plane at right angle to the source of stimulation rather than towards or away from the stimulation.

3. Telotaxis. This type of taxis does not depend on simple balance as in case of klino-and tropotaxis. If there are two sources of stimulation operating through the same modality, the animal orients towards one or the other and not in an intermediate direction. This suggests that the influence of one of the stimuli must be inhibited *i.e.* animal orients towards or away from the source of stimulation. Examples of telotaxis are seen in the orientation of a dragonfly towards its prey (Kiinn, 1919), orientation of hermit crab towards one source or the other. Bees behave similarly if blinded unilaterally, they first show circular movement but then orient towards light source due to adaptation.

Grayling butterfly (*Eumenis semele*) flies towards the sun to escape from its predators. If one eye is blinded, its escape reaction consist of flying in circles which shows dependence on bilateral optic stimulation. To explain that not all taxes depend on equal bilateral stimulation, the same butterfly will continue to pursue the female in a straight path after unilateral blinding.

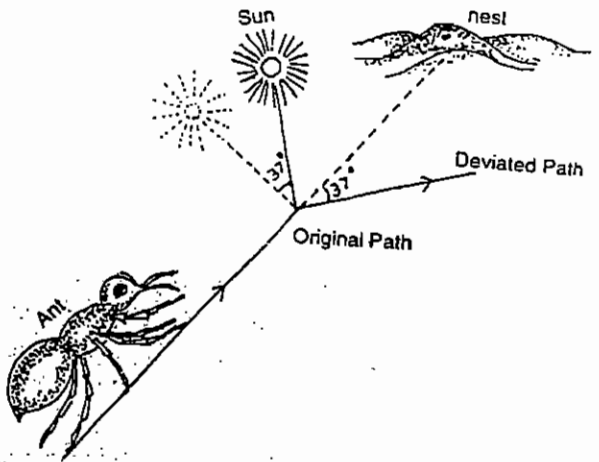

Fig. 3. Diagram showing sun-compass orientation in ant.

4. Menotaxis or light compass response. It involves orientation at a constant angle to the direction of source of stimulation. Schneirla (1933) studied that the path of a homing ant is guided, in part, by the direction of the sun; if the apparent direction of the sun slowly changed by the use of mirror, the ant changes its course accordingly. Homing ants maintain orientation towards nest by progressing at right angles to the sun while captured and held at point end. When the sun moves at 37 degrees their path continues at right angles to the sun and then ants deviate from their path to the nest by 37 degrees (Fig. 3).

The example of Menotaxis is the light compass reaction of ants and bees. It is a taxis that can also occur with only one eye. In this case, the orientation is not simply towards or away from the stimulus source but rather, the organism orients and moves at some angle to the source of light. The homing ants change their direction in accordance with the change of position of the sun even when they are captured and kept in dark boxes and even if the sun is invisible, these ants are sensitive to the plane of polarization of light from the sky.

5. Mnemotaxis. Frankel and Gunn (1940) classified certain cases which did not involve configurational stimuli. In invertebrates, however, some orientation responses depend on complex stimulus situations. Van Beusekom (1948) studied that the hunting wasp, *Philantus triangulum* which uses a number of land marks simultaneously when returning to its nest. Tinbergen and Kruyt (1938) carried out an extensive series of experiments and came to the conclusion that the insects return were guided by the relation of the nest entrance to the whole configuration of land marks and did not depend on stimulation of special parts of retina by particular land marks. Such cases were distinguished as mnemotaxis, in which configurational nature of stimuli was involved. It involved basic learning also.

On the basis orientation and movement towards or away from the source of stimulation, the taxes are of two types: (1) Positive (2) Negative.

1. *Positive taxis* : If the orientation and the movements are towards the source of stimulation, it is called positive taxis.
2. *Negative taxis* : When the orientation and movements are away from the source of stimulation, it is known as negative taxis.

Types of stimulus bound taxes

1. Phototaxis. Oriented locomotory movement caused by the light either towards source or away from it is called Phototaxis. *e.g. Euglena,*

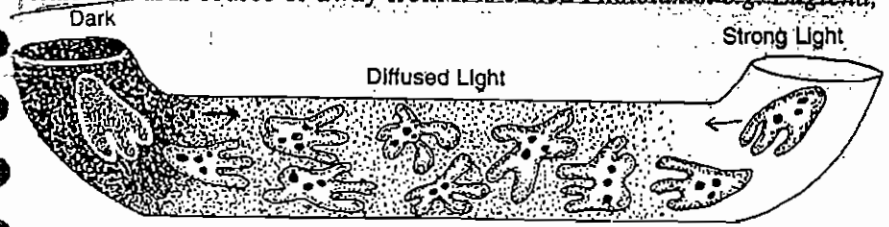

Fig. 4. Diagram showing phototactic behaviour of *Amoeba.*

Ranatra etc. move towards the source of light (positive Phototaxes) while *Planarians*, Earthworms, Slugs, Copepodes, Siphonophores etc move away from the source of light (Negative Phototaxis). *Amoeba* (Fig. 4) *and Paramecium* avoid both direct sun-light and total darkness. They respond positively to normal or weak light. The housefly *Musca domestica* show

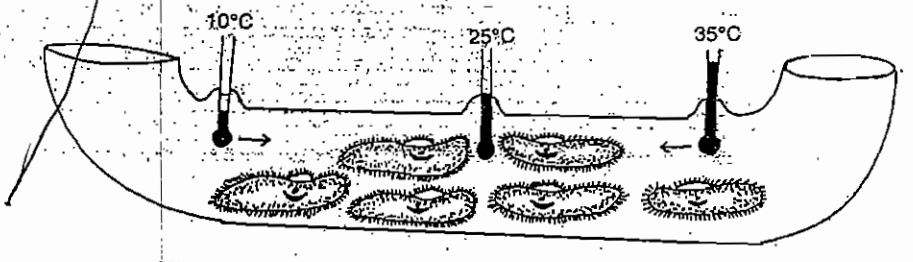

Fig. 5. Diagram showing thermotactic behaviour of *Paramecium.*

positive response to the light while mosquito exhibit the negative response to it. Bed bugs display negative response to light whereas *Hydra* show positive phototropism.

2. Thermotaxis. Response to temperature is known as Thermotaxis. Animals strive to remain in a different temperature range *e.g. Paramecium* lies between 24 degree C and 28 degree C, which is temperature optimum for them (Fig. 5). They avoid temperatures higher and lower than this. Animals thrives best at the optimum temperature e.g. the optimum temperature for *Amoeba* lies between 20 degree C and 25 degree C. An avoiding reaction is given to the temperatures higher and lower than this.

3. Chemotaxis. Response of animals to the chemical substances is called Chemotaxis. It is negative in most of the cases e.g. *Amoeba* is negatively chemotactic to strong solutions of alkalis and to sugars (Fig. 6).

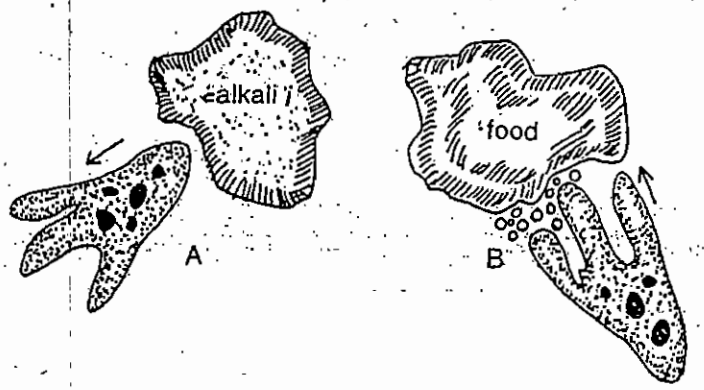

Fig. 6. Diagram showing chemotactic behaviour of *Amoeba.*
A. Negative chemotaxis B. Positive chemotaxis to sugar (food).

It also avoids substances unsuitable for it. *Paramecium* shows avoiding

reaction to the salt solution, however, a positive response occurs with a drop of weak acid solution.

4. Geotaxis. Animal's response to gravity is known as geotaxis. Some of the animals show negative response to the gravity while others show positive response, *eg. Amoebae* exhibit mostly positive response as it drops to the bottom of the container filled with water (Fig. 7) *Paramecium*

Fig. 7. Diagram showing geotactic behaviour of *Amoeba*. A. Suspended *Amoeba* in water B. Positive geotactic behaviour of *Amoeba*.

are generally negative geotactic in a culture containing in a test tube, they gather close to the surface film with their anterior end pointed upwards. House fly *Musca domestica* also show negative response to the gravity. The fruit fly *Drosophila* when placed in a vertical glass tube, moves upwards in the tube showing negative response to gravity.

5. Rheotaxis. Response to current of air or water is called Rheotaxis. Most of the animals prefer to be drifted along the flowing water or air. *Amoeba* show negative response, while *Paramecia* show positive rheotaxis orienting themselves with their anterior ends upstream and swimming against the current. Some of the fishes are also positively Rheotactic. According to Dembowaski, trouts living in stream, toil day and night in order not to be swept away by the current. In winds, birds and insects mostly fly upwind although they may go in any direction.

6. Thigmotaxis. Response to contact is called Thigmotaxis. *Paramecium* when slowly moves, comes in contact with any object like an algae or a plant stem, becomes quiet but an avoiding reaction is seen when its anterior end is strongly touched with a solid object.

7. Galvanotaxis. A positive or negative response is seen in animals towards electric current. In positive galvanotaxis, animals move towards the negative pole or cathode when a weak electric current is given. Such a behaviour is seen in *Paramecium* when they are exposed to weak electric current. *Paramecium* move backwards towards anode when a strong electric current is given.

REFLEXES

Reflexes are very similar to taxes because they are relatively stereotyped and they may fit into the definition of innate behaviour in the sense they are outcome of inherited neural mechanism. Occasionally it is difficult to differentiate between taxes and reflexes. Taxis involved orientation of

the whole body which may involve a number of specific reflex responses whereas reflexes involve all or most of the body like the flexion of leg in response to painful stimuli or the pupil constriction to intense light. Such reflexes are adaptive and are irreversible. There are two classes of reflexes which are as follow :

(*a*) Tonic reflexes
(*b*) Phasic reflexes

Tonic Reflexes : They are slow, long lasting adjustments which maintain muscular tone, posture and equilibrium.

Phasic reflexes : They are rapid short lived adjustments as seen in the flexure response.

Reflexes may be organised at various levels of the nervous system and occur in varying degrees of complexities. Usually those with greater complexities, depend on the higher areas of the nervous system. In the animal kingdom, the reflex response is one of the major modes of adaptation. During evolution, however, reflexes become less prominent features of behaviour because they become more variable and subject to modifying influences of the higher neural mechanism and hence, are overshadowed by the other modes of adaptations.

INSTINCTS

Instincts are the more complex and fascinating of the stereotyped or innate behaviour. In the past, the term instinct was used for some mysterious, vitalistic force that compels the organism for action and direct its course with the infallible "wisdom of nature" but today we know that no special energy is released in instinctive behaviour beyond the energy from the metabolic mechanisms that lie behind all the cellular activity involved in behaviour. It is also known that in many cases, instinctive behaviour is not an infallibly accurate "fixed pattern" of response because there is too much variability in the behaviour of even in simple organism and behaviour of higher organism is constantly being modified and shaped by individual experience and learning.

It was shown that in instinctive behaviour three parameters of behaviour are to be considered. These are 1. Unlearnt 2. Character of the species 3. Adaptive nature. However, it is very difficult to apply this criteria to prove the instinct. It is already established that adaptive value is not a feature distinguishing instinct from other behaviour. In the higher animals, the first two criteria are even more difficult because it is not easy to control individuals life experiences to the point where we can be sure that learning has not contributed to a pattern of behaviour. For example, cat killing a mice was presumed to be instinctive behaviour but all cats do not kill mice. It is because, kittens often see adult cats killing mice before they do so themselves but when kittens are reared with mice they rarely become

mouse killers. Similarly if the *Chaffinch* is reared in isolation from its kinds, it sings much simpler songs than chaffinches reared with adult birds and they may never be able to learn the full song of species, if they are kept isolated from their kind before one breeding season.

The original concept of instinct says that it is an inherited pattern of fixed responses which are independent of environment and learning. The fact that each species shows a particular behaviour like building a particular web, nest or singing a particular song support the view that instinct is a predetermined behaviour, but there are certain instances which contradict this concept e.g. older Robin birds are found to build superior nest than young Robin birds and many species of bird reared with other species sing the song of other species and not of their old species. Therefore, it can be said that instinct mainly depend on the innate organ system of the individual but its pattern is not totally independent of environmental factors and learning processes of the animals. Tinbergen and Lorenz (1937) propounded a simple theory to explain the mechanism of operation of instinctive behaviour according to which the urge to perform instinctive

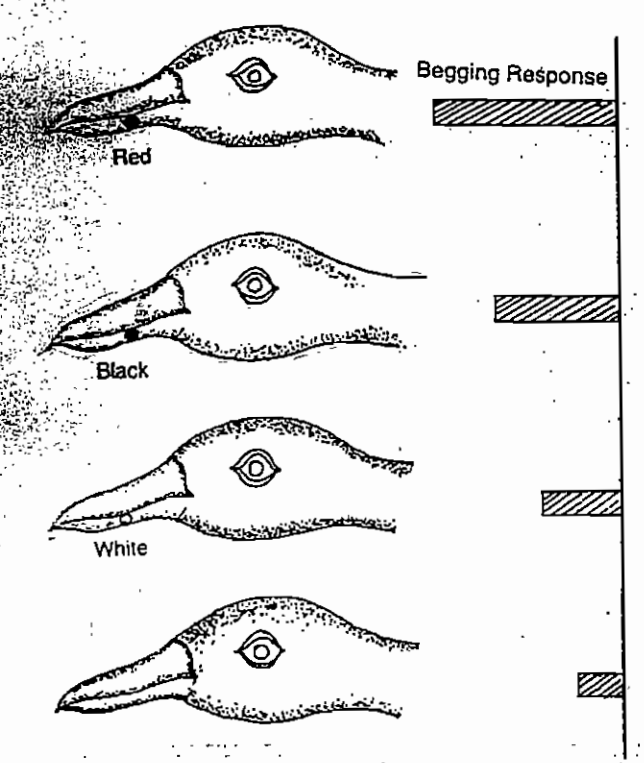

Fig. 8. Diagram to show begging response in herring gulls.

and acts grows during the appetitive phase because of some inhibitory factor. Such factors are lost in the innate releasing phase so that the instinctive act will be performed during consummatory phase. This theory, whether right or wrong, reveals that although instinct is predetermined, it requires triggering of some external and internal factors which act to inhibit the instinctive behaviour. Sign stimuli are the example of such external factors, for instance the red breast of Robin bird acts as sign stimuli for fighting instinct in the males. Similarly, the red spot on the beak of herring gull acts as a trigger for the food begging instincts in the young gulls. (Fig. 8).

Helman (1967-1969) published two papers on instinctive behavioural patterns on the pecking preferences in young herring gull. The title of the paper "The Ontogeny of an Instinct ...." and "How an Instinct is learned." Young herring gulls are fed by parents who regurgitates partially digested food for them. Parents lower its head in its return journey to nest in front of the gull chick. This chick if not fed earlier, will peck at the parents bill and grasping and stroking. The parent now regurgitates the food and suppose chick does eat food immediately, parent and chick show a complex interplay alluring the chick to eat. Afterwards it has been seen that innate releasing mechanism (IRM) remains operational which activated by highly specific stimuli (Tinbergen and Perdeck 1950). They found that models with red spots on the head received fewer pecks than on the bill. In his experiment, Helman used three models instead of two used by Tinbergen and Perdeck. Out of three models, two were identical to that of Tinbergen and Perdeck models whereas the third one had a spot on the forehead and a longer handle so that the movement of the spot on the head was equivalent to that on the bill of the other model. It has been observed that newly hatched chicks made pecks to the new model in the same manner as with the older one. It seems that relatively simple stimuli controls pecking of newly hatched chicks. The pecking response and its control by rapid moving spots, require experience. The pecking accuracy and identification of parents, were under the influence of the environment. Pecking behaviour of gulls is an "Instinct" with an interesting ontogeny. Eibl-Eibes Feldt (1963) studied the nut cracking of European red squirrel. Squirrels were reared under such conditions so as to gnaw to develop jaw muscles but were not allowed to open nuts. It has been observed that they made furrows but with random orientation until the nut was broken down. Nuts were broken only when there were gnawed furrows in proper orientation. Slowly Squirrels learn to break open nuts by making furrows parallel to the grain of the nut, concentrating more on its broader side. This art was learnt by them according to Eibl-Eibesfeldt. The movement patterns of gnawing was designated as "innate" where as orientation into a complete functional pattern was called as "learned" Ewer (1971) defined the Term "Innate" as "Simple behaviour that appears in its typical adapted form, the first time an animal of suitable age is phased with the correct situation". Alcock (1975) defined it as " species-specific behaviour emerging in a reasonably complete

form the first time an animal of a certain age and motivational state encounters a particular stimulus. Fentress (1972-73) studied stereotyped movement patterns in phase grooming of house mice. He divided inbred mice in three groups, where one was a normal animal which functioned as control, the other whose one fore limb was amputated at birth and the third mice where both the fore limbs were amputated. He observed grooming movements on the animal's sitting posture, tongue movement and movement of the shoulder and upper arms. Striking similarities were observed in grooming patterns of amputed and in normal mice. A synchronisation has been seen between the shoulder movement and tongue movements in the amputated mice. Normally, the normal mice used to lick fore paws during grooming. Similarly, even in the absence of fore paws in amputated mice, the tongue is extended to lick the air while grooming, the near eyes remain closed in both the case.

It has been seen that territorial defense in the stickleback may be elicited by a dummy fish with a red belly even if the dummy is not shaped like stickle back. On the other hand, the faithful model of stickleback

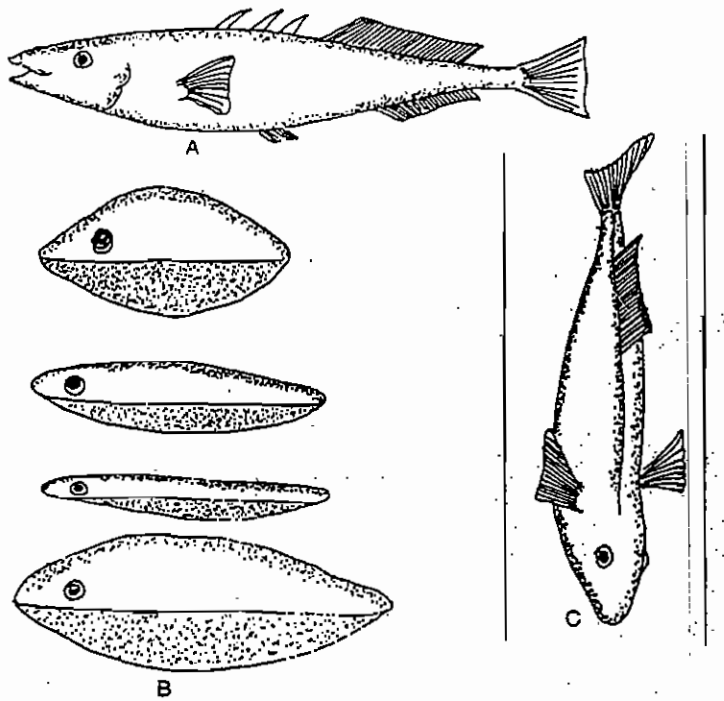

Fig. 9. Diagram showing territorial defense in stickleback.

A. A faithful model without red belly releasing no fighting response.
B. Dummy fish with red bellies releasing fighting response.
C. Fish in inverted position presenting threatening response.

failed to release fighting if it does not have the red belly. Further it is shown that more vigorous attacks will be made if the stickleback is presented in the vertical position with nose downward (Fig. 9).

From the classical ethological point of view instincts show following characteristics (Dewsbury 1978).

1. Instinctive behaviour of organisms were genetically based as the result of natural selection. Genes are responsible for all the behavioural patterns and these are modified and preserved with natural selection.
2. The instinctive behavioural patterns and acquired learning patterns were of separate categories and there was no gradation between these.
3. Organisms show "Instinct-Conditioning Intercalation". According to Lorenz (1937) units of behaviour were either learnt or innate and are interlaced in gross behavioural patterns.
4. Elements of instincts remain unchanged and instinctive behaviour is expressed with experience. However, the kind of response and its intensity is determined with experience.
5. Instinct adapted to the environment occur with out any conscious purpose on the part of behaving animal. Instincts were generally adapted responses and its performance was "blind" (Dewsbury 1978).

The word "Innate" either means behaviour has a genetic basis *i.e.* by natural selection new organisms develop showing distinct heritable components playing its role in the behaviour development or it means developmentally fixed behaviour, independent of certain environmental factors. Lorenz (1937) considered instinctive behaviour patterns in phylogenic and ontogenic sense. In 1941, Lorenz reported similarities between motor patterns of different species of ducks and geese, where behavioural homologies are seen. The salticid spider male shows specific display to the female to stop her prey catching behaviour. This behaviour originates in phylogenetic adaptation. Sometimes a behaviour is functional in some other geographical area and preserved through heredity *e.g.* on Galapagos islands, ground nesting doves exhibit "destruction display" whenever they are approached by human beings, even in the absence of natural predators on these islands to whom such display will be effective (Eibl-Eibesfeldt 1961). This shows that an instinctive behaviour may originate at some other place by natural selection. The genetic basis of behaviour gets ample support from the selective breeding and cross breeding of the organisms. It has been seen that organisms always inherit genes and cytoplasm on which their behaviour depends. Behaviour which comes under phenotypic areas cannot be inherited by organism. Moreover most genetic influences are indirect, mediated through the environment. The word "Innate" can be defined in the negative term as "unlearnt" while learning in the positive term is acquired with the span of time under the parental influence. In the ontogeny behaviour there are

important environmental factors. It has been seen that in the deprivation experiments e.g. [illegible] food to animal, the animal is deprived of certain factors [illegible] environment. Further, organisms differ phenotypically [illegible] edity and environment, so it is impossible to say which [illegible] important for any behavioural pattern. Behavioural [illegible] genetic origin is seen if two organisms showing different [illegible] in the same environment but if two having same genetic [illegible] are raised in different environment, their behaviours [illegible] due to environmental factors. Organisms exhibit [illegible] patterns where specific learning is not required (Dewsbury [illegible] vioural ontogeny is affected by environmental influences [illegible] rns are generally of instinctive nature.

[illegible] e seen in organisms, which provide lack of learn[illegible]y of instinctive behaviour patterns. Some behav[illegible]elop without learning *e.g.* young ducklings with [illegible]ings, when provoked, display the same motor co[illegible]g and shoulder as exhibited by the fighting adults. [illegible]ed such functional motor patterns? Sometimes [illegible]oural pattern in the absence of environmental [illegible]has raised pigeons in narrow tubular cases, where [illegible] to spread their wings but surprisingly after their [illegible]a normal development of wing was seen in the [illegible]ns can not be given or learnt. Such experimental [illegible]ation experiment" or "Deprivation experiment" or [illegible]riment".

[illegible]icised the classical ethological view of the ontogeny [illegible]iour (Leherman 1953, Jensen 1961, Tinbergen 1963 [illegible]. Their criticisms are mainly centered on two problems [illegible] influence on behaviour and learning-instinct dichotomy. [illegible]at genes and environment are necessary for behaviour. [illegible] that certain factors like brain lesions, drugs etc. interfere [illegible] development and can alter the pattern of behaviour in

[illegible] song is learnt or innate ?

[illegible]lisation of the birds are categorised into two types: Calls [illegible]lls are simple short signals uttered by either sex at any time [illegible] little individual variation, whereas songs are seasonal [illegible]sted patterns emitted primarily by males during its courtship [illegible] with more individual variation. Here genetic factors are [illegible] in vocal ontogeny (Nottebohm 1972) as seen in domestic [illegible]ng doves (Konishi 1963, Nottebohm and Nottebohm 1971). [illegible]al repertoire of the adults develops normally in birds, which [illegible] in isolation from other members of their own species. Every

bird has a specific "template" that rejects certain songs and is modified by experience with the species specific song. In many birds imitation is seen, whereby a bird learns songs e.g. in natural habitat, Australian lyrebird imitates calls of other species. Males of Indian Hill Myna bird imitate calls of other male bird of other species, whereas females imitate calls of females of different species. (Bertram 1970).

ACQUIRED ANIMAL BEHAVIOUR 1) Learning 2) Reasoning.

The acquired behaviour becomes more variable and modifiable through experience. The adaptation of the individual organism may develop uniquely in its life history through the process of learning. Such behaviour patterns are known as acquired behaviour. In lower organisms, what may be acquired is fairly simple and is still stimulus-bound but with the complexity of the nervous systems as in mammals, especially in primates and man, new patterns of behaviour originate. Here behaviour is not stimulus bound but most of it originates in the organism from its incestors and may be guided by complex symbolic processes, e.g. language in man. Such intrinsic processes constitute reasoning in man. Instinct and learning, both ensure adaptive behaviour, the former by sub-action operating during the history of species and the latter during the history of an individual. Acquired behaviours are of two types (1) Learning (2) Reasoning or Problem Solution.

LEARNING

It can be defined as a process, which brings about certain adaptive changes in the behaviour of an individual as a result of experience. The ability to learn is a striking feature seen in most of the living organisms. Thus a process through which life experiences leave their mark on the individual develops into new adaptation. Every organism can learn almost any response provided it is rewarded for that. E.L. Thorndike concluded that basic form of learning was to link an act with reward, which gradually improves with the time. Pavlov studied conditioned learning in dogs. His studies were concerned with the salivation of dogs when they were provided with food. He found that a dog showed drooling response at a light flash or tickling of a metronome if such stimuli are present with enough food. He has also observed conditioned responses in several animals like chickens, rats and even in human beings. From current studies, it is now known that it is not possible to link any response to any stimulus. Behavioural limitations are seen in an animal, which depends on the broadness or narrowness of the niche. In experimental studies, monkeys can see the colours as human beings with an exception of the night monkey. It was seen that monkeys can learn to press a red button in place of blue to fetch the food. It is a well known fact that monkeys of South America are able to see in the dim light also. For the survival of a species

must have unlearnt behavioural sequence which it acquired through evolution. The learning potential of a species depends upon the maturity of its nervous system and behavioural capacity according to its genetic record. During maturation, some aspects of nervous system follow others like that observed in *Robin* hatchling which cannot walk but can breed and chirp. In the higher animals, a new born when touched shows avoiding reaction of certain part of body to the stimuli. But in the lower invertebrates at first large part of the body moves away from the stimulus later it moves specific parts. A new born when touched on the side of its face, turning of the head occurs. In human beings, infants show innate behavioural patterns while the adults possess learned behavioural patterns. This shows that certain behavioural patterns occur inborn or innate, others can be learnt in different parts of life. More complex the nervous system, more it will rely on learning, rather than, on inborn actions. Monkeys improve with every problem they face and solve them without a mistake. It has been seen that the *Rhesus* monkey learns very quickly by watching *e.g.* it can learn to avoid a shock when *light* appears. It has been observed that if a stimuli is attractive for an animal, will learn faster.

Dogs, cats and lions think of their trainer as dominant (Super Boss). The learning ability of a species depends on the conditions under which it is evolved and on its living circumstances. In many animals like fishes and birds the parental care is seen. This influences the new borns in learning simpler acts by which it develops a strong emotional bond with the parent. Such a bond gives opportunities to learn many things from their parents. These factors come under imprinting studies.

Imprinting. This is a highly specialised and limited form of learning, which is seen in birds during the very early period of their lives after hatching. It consists of very simple thinking in the young bird, learning to follow the first large moving object it sees and hears in a manner reminiscent of the natural tendencies to follow its mother. This is a case of learning and the bird can be imprinted in this manner on almost any suitable object, animal or person. It must depend upon some special condition of the nervous system prevailing only early in the development, and if, the bird is not imprinted within the first few days of hatching, it may never be imprinted. If it is not permitted to get imprinted in this way during this period, then later on, it is unable to recognise and follow its mother. Therefore, imprinting is a restricted learning which is not possible at all the times of life.

Konard Lorenz suggested that bond between parents and young ones remains for a short period of time. Imprinting helps in recognition of his own team mate and in later part of life, it helps in choosing mating partners. In imprinting, object of attachment is learnt and it has been seen that

some of the objects influence better imprinting than others (Masson 1976). According to Masson, the object which moves or flashes or is attractive are more effective than others and there are inborn preferences for specific patterns of stimulation.

In many animals, parent and young relationship is in the form of a social unit where the behaviour of both should be studied simultaneously. The presence of parents, make the young feel more comfortable and contented, whereas, in the absence of parents, young individuals show distress condition which is exhibited by making sounds of mewing, crying, and chirping etc. (Masson 1976). This can be seen in the behaviour of infants of monkeys. If they are separated from their mothers, the new born will make a distress call and on hearing this, the mother will come to the infant and after identifying, clasp it to her breast. Mother gives motivational behaviour to the infants.

Learning in young individuals, depend on the nature of species and the circumstances e.g. an animal living in a city area will show different behaviour patterns than those living in the forest. Monkeys are a typical example of thistype.

Many animals imitate the act of others and thereby learn many behavioural patterns e.g. whenever a rat sees the copulating rats it is sexually aroused. Very often, work of an individual is enhanced in the presence of another individual. Such an act, is seen in ants. This is one way, by which, a parent can educate their young ones. In higher vertebrates, learning by making observations, is very common. An older one in the group of animals become dominant and educates the younger ones. In primates and many other gregarious animals, mother teaches infant whether to accept a thing or not. The infants learn to avoid unfamiliar foods under the influence of their mothers. A bond of love is seen between mother and infant which culminates into stable relationships later and leads into friendship and rank orders in the animal societies. Very often, male takes the role of mother and takes care of the infants. This has been observed in some Japanese monkeys.

Learning behaviour pattern. These are passed from one generation to another through heredity and modify under the influence of environment where that organism lives. Learnt information is stored in the form of "Memory". Learning is a process by which an organism connects information in its brain about feeding, hunting and killing etc. and using it in the right perspective. Primates learn faster than other animals. Heredity and environment influence many behavioural patterns. But in learning animals, environment influences the development of its behaviour. Man who learns many things quickly from his surroundings is not able to follow the song of a bird. There are many processes of learning, of which "Habituation" is one. This is a negative process of learning *i.e.* ignoring

any environmental event *e.g.*, a dog ignores the repeated tapping of the table and peacefully sleeps because by learning, it knows that tapping of the table does not signify anything worth noticing, like getting food or drinking water. Habituation provides the animal certain advantages as to which thing is of use and which is not. One way of learning behaviour pattern is by "trial and error" or "instrumental learning" where animal knows that by making such a response it will be provided with reward, like food or water etc. as has been experimentally demonstrated in the learning of cat by E.L. Thorndike. In this experiment, a puzzle box is used where cat learns by trials how to escape out of the box. In the experiments with rats in the "skinner box", rats learn to press a lever to get food. In the instrumental learning, modification of behavioural patterns of learning occur in order to fetch a reward like water, food etc. Animals know which of the reward is noxious or unpleasant of dangerous nature. Here avoidance learning is seen. Rats learn how to avoid poisonous food if they are saved once from its poisoning by inadequate feeding of the poison earlier. Avoidance learning may be active or passive. Active avoidance learning is seen in some species of toads (Boice1970). Behrend and Bitterman (1963) reported quick learning of a goldfish. A passive avoidance learning is seen in land snails by Stephens and Mc Gaugh (1972). Normally snails are geo-negative in behaviour. Under experimental conditions they were allowed to climb over a pole and at the top they were given electric shock. In further trials snails have avoided climbing over the pole. In many organisms, an escape learning from dangerous situations or response is seen *e.g.* rats quickly learn to move away from water (Festing 1974). Many animals learn how to discriminate between two objects. Warren (1959) carried out discrimination learning experiments on monkeys by using Wisconsin General Test Apparatus (WGTA) and reported that the *Rhesus* monkeys learn quick discrimination. Many animals know how to recognise its fellow individual in the group *e.g.* monkeys and baboons. They store information in their brains about personalities, relationships etc. Animals, while occupying new environment, learn about their home range and territory. They recognise specific landmarks of the territory which they make while living in groups. Dogs make their territory by urinating at specific points.

It is often argued whether animals have "intelligence" or not. Many animals like horse, dogs etc. obey the commands of their master (man) and act accordingly but it does not mean that they are "intelligent". It has been observed that man has a capacity to learn quickly and act accordingly towards any problem which environment poses on him. It seems that learning pattern goes on changing from organism to organism. Peter and Issacson (1963) reported that young chicks learn avoidance response at very early stage of development. Similarly in dogs, puppies of less than 2

weeks of age, learn a variety of tasks (Stanley 1970). Classical conditioning varies with age in monkeys (Zimmermann and Torrey 1965). Few animals have the capacity to learn imitation sounds as seen in Hill Mynahs and parrots. Wild Thursh produces a sound similar to that of a telephone. Professor W.H. Thorpe studied songs of male Chaffinches under laboratory conditions and prepared sonograms or sound spectrograph. He noted that a young *Chaffinch* kept in isolation in her adulthood sang songs apparently different from normal song of *Chaffinch*. Here in the song "Terminal Flourish" was absent. These observations show that young Chaffinchs can learn to sing normally if they hear sounds of other adults of their communities. They also imitate songs of Canary birds which produced songs almost of similar nature to that of Chaffinches. It has been seen that bird songs differ in different species and every bird has a "template" that rejects certain songs but modifies others through experience with the species characteristics songs (Dewsbury 1978). Bertram (1970) reported imitation of Hill Mynah under this category.

Learning ability of an animal depends upon the inheritance, whereas learning is important for developing a particular act in the organism. An organism possesses genes, wherein any change in a single unit of gene will bring about change in the behavioural pattern of that organism. Behaviour of an organism is achieved by the interaction of genes with environments and on the learning abilities of the organism.

Memory. Memory is an essential part of learning in animals. Animals collect information about their surroundings in the learning process, whereas, whatever information collected by learning is stored in the brain in the form of memory. Learning is of no use without memory because whatever learnt information is there in the organism, is lost or forgotten in due course of time. Many birds remember and recollect where they have hidden their foods which will be utilized in the scarcity conditions as seen in Marsh tits and European Jays. These birds remember where the food is stored. In many mammals, similar behaviour is seen in the "radial maze" experiment. David Olton demonstrated the measuring of memory for special locations in the rats. He used eight-armed "radial maze" where food was placed at the end of each arm and the rat had to collect food from it. The rat identified each arm by noting a certain landmark of the surrounding environment. Such landmarks may be a window or lampshade. The rats were confused if the landmarks were moved. They learn normally by marking a note of landmarks and move on each arm of the maze in the clockwise direction. A confusion developed in the rat when the landmarks were moved and it was not able to reach the arms which it had visited earlier, to collect the food.

Many behavioural patterns are controlled by the nervous system and are modified from learning. It can be said that nervous system must have some physical manifestation of learning which is termed "Memory Trace" or "Engram" without which learning is not possible (Lashley 1950). It has been found that the locus of habituation is located in a depression of activity across the synapse between two adjacent neurons (Dewsbury 1978). Thomson (1976) reported a decrease in the neurotransmitters during repeated stimulations.

Habituation. A simplest kind of learning seen throughout life is habituation. This is one example whereupon repeated exposure to a stimulus, the animal gradually decreases its natural response until it disappears entirely. Here the natural response is frequently repeated to a stimulus. Habituation occurs under those circumstances where stimulus is such, that response to it is insignificant from the point of view of animal survival or habituation. This is progressive rejection of an indifferent response to a frequently repeated stimulus e.g. if a snail like *Helix* is put on a substratum subjected to a mild electric shock it responds by withdrawal of its tentacles but if the shock is repeated frequently, then it is observed that snail's response disappears altogether. In positive learning, reverse phenomenon occurs and the sense is gradually perfected and made stronger with repetitive stimulus. This happens when the response is such that it can affect the survival of the animal. Most of the learning processes are of positive type where useful responses to significant stimuli are made more perfect during the learning process.

Classical conditioning or associated learning or reflex conditioning. When two stimuli are repeated simultaneously for a number of times, the animal develops the ability to respond to one of the stimulus to which it was unresponsive before a reflex. Pavlov has conducted experiments on these lines on dogs. Under normal circumstances, when the meat powder is blown into the mouth of the dog, it responses reflexively by salivation. When the bell is rung, in the beginning, no such response is seen. Then he associated the sound of bell with the meat powder and repeated this procedure many times at successive intervals. At first, the bell sound did not produce salivation but after repeated pairings with meat, the ringing of the bell alone could cause salivation because the dog was conditioned to this simulus. He called the salivation to the bell as conditioned reflex (C.R.), the bell as conditioned stimulus (C.S.), the salivation to the meat as an unconditioned stimulus (U.C.S.). The same experiment has been conducted many times on different organisms with different stimuli and responses.

Pavlov observed a number of interesting features during his

experiments with associated learning of the dog which are as follows:

1. The C.R. becomes progressive better established and frequency increases if U.C.S. and C.S. are applied more and more in association with each other. This has been named acquisition by Pavlov (Fig. 10).

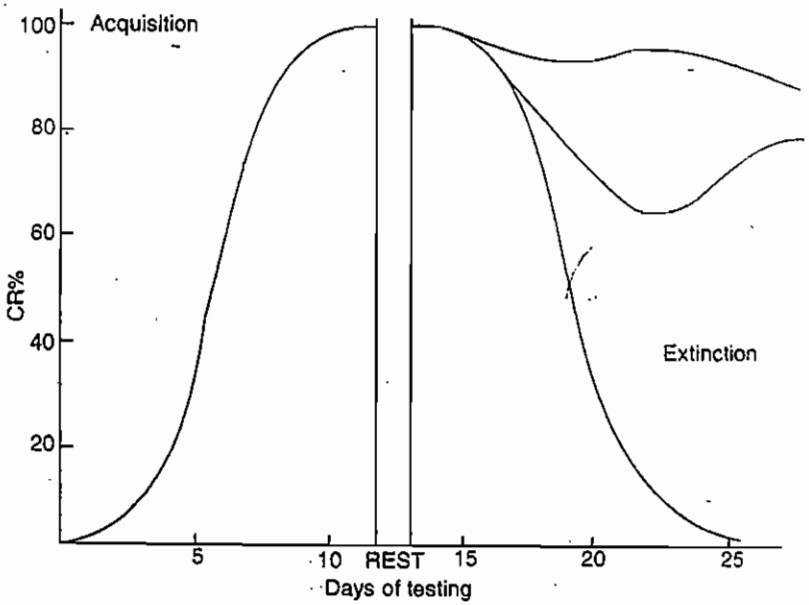

Fig. 10. Figure showing acquisition and extinction of a conditioned leg flexion response in dog.

2. If the so conditioned animals were now given a rest and conditioning was stopped then after the rest period, the frequency of the C.R. decreases gradually if only C.S. is applied at a start. This has been named as Extinction (Fig. 10).
3. If the distracting stimulus (D.S.);—like a loud and sudden noise is applied together with C.S. and U.C.S. during the early period of acquisition then the frequency of C.R. remains low and it becomes difficult to get established.
4. If the D.S. is applied during the early period of extinction, the extinction is nullified to a great extent and the frequency of C.R. does not fall as appreciably as in the case when no D.S. is applied.
5. If after the rest period the dog is subjected not to C.S. alone but both C.S. and U.C.S. together the extinction is prevented.
6. The timings of the application of C.S. and U.C.S. are important for establishment of C.R. It is found that maximum establishment occurs when C.S. is applied before U.C.S. and the time gap between the two does not go beyond 0.5 seconds (Fig. 11).

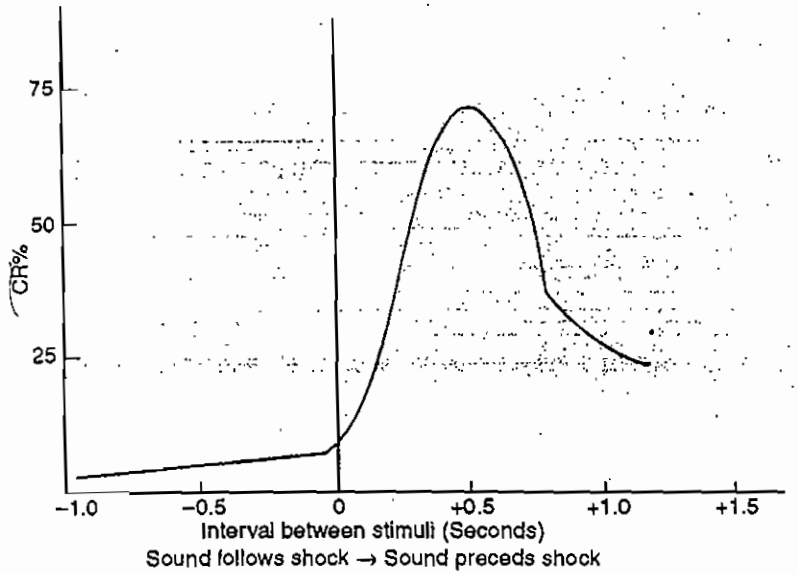

Fig. 11. Figure showing importance of temporal relations between C. S. and U. C. S. in conditioning.

From these observations following conclusions are seen regarding the process of associative learning which are as follows:

1. The presence of U.C.S. is essential not only for the acquisition of C.R. but also for the maintenance of C.R. The influence of U.C.S. on the establishment of C.R. is called reinforcement and Pavlov named it as Law of Reinforcement.
2. The external inhibition was easily understood because in the early acquisition period the associative learning of C.R. is comparatively weak and unestablished so that the animal can be easily distracted if a strong distracting stimulus is provided at this stage to interfere with the learning process. Interference through strong D.S. explains the phenomenon of Extinction and Disinhibition. If early in training D.S. (sudden noise) occurs as the C.S. is presented, the C.R. will be greatly reduced, called external inhibition. If the same D.S. occurs early in the extinction, the C.R. strength will increase which is called disinhibition. This is presumably the result of removing the inhibiting or interfering effects of new learning by external inhibition of that new learning. During the rest period the conditioned animal comes across many stimuli and situations other than C.S. and U.C.S. and the animal is bound to respond to these stimuli and situations. Thus tending to acquire some sort of learning different from the one which it acquires during the acquisition phase. This newly acquired learning interferes with the

associative learning with the result that after the rest period, a tendency of extinction begins and increases particularly when the reinforcement by U.C.S. is missing. However, in the extinction early stages the new learning acquired during the rest period is very young as compared to the learning achieved during the acquisition period and it is easily suppressed by interference from a distinctive stimulus which is the cause of disinhibition.

3. The concept of generalisation which is derived from the fact that an animal conditioned to one stimulus will also be conditioned to some degree towards other similar stimuli. In such cases, there is gradient of generalisation that the further stimulus is away from the original C.S. its capacity to elicit a C.R. will be weaker.
4. Discrimination which is the result of reinforcing the C.S. and extinguishing a similar stimulus to a point where the animal always responses to only one stimulus.

From these facts Pavlov described different laws which are as follows:

1. The first is the law of contiguity which says ti. .'ems to be associated must occur together in the time and place. It is seen that conditioning grows less and less effective as the interval between C.S. and U.C.S.-U.C.R. is lengthened.
2. The second is the law of repetition in which the strength of a C.R. grows progressively as more and more pairings of C.S. and U.C.S. are made.
3. The third is the law of reinforcement which describes a process which is essential to the strengthening of a C.R.
4. The fourth is the law of interference which includes the case of extinction or forgetting and states that a conditioned response may be weakened and inhibited by new learning which interferes with it.

In conclusion, reflex conditioning is definitely not the whole learning process because it is very rare that animals come across such related pairs of stimuli but the significance of reflex conditioning lies in the fact that it provides the basis for building of more complicated learning processes. Moreover, the simple passive nature of the associate learning makes it possible for the experimenter to control and analyse his experiment to such an extent that much can be learnt regarding the mechanism of learning of organisms.

Instrumental conditioning. Many kinds of learning are seen to be more complicated than that of classical conditioning. The animal has some control over the stimuli which he receives and often the response he uses and his behaviour has some effect on his situation *e.g.* the animal may learn to press a lever or a switch in order to fetch food delivered to him or to escape from an electric shock or its confinement. In such cases, the

animal behaviour is instrumental conditioning. Although, the animal is in a quite different training situation, the same phenomenon of acquisition and extinction and the same laws of contiguity, repetition, reinforcement and interference apply. In instrumental conditioning, the animal naturally emits a variety of responses that are stored in him. The trainer may select one response to reinforce *i.e.* depressing a lever, standing on his hindlegs, turning right rather to left etc. Due to the reinforcement this response is emitted in greater frequency and other responses go down or habituate where the reinforcement involves the satiation of a drive as seen in the case of hungry animals depressing a lever or turning right to get food. This training is called reward training. Where the reinforcement involves the escape from the same unpleasant situation such as electric shock, hot or cold water the training is called escape training and where the reinforcement involves avoiding of noxious stimulation altogether then it is known as avoidance training.

Trial and error learning. Instrumental Conditioning can be made complicated by simply increasing the complexity of stimuli or response possibilities. This can be done by giving the animal a choice of stimuli to respond. Here the animal is forced with a large number of alternative responses to a given stimulus where it has to choose that response which results into better survival of it. Animal tries all the responses one by one and ultimately it learns to exhibit the right response.

In the beginning of trial and error learning, animal makes large number of errors choosing wrong responses but with the time it learns to avoid these errors till it makes the right response without making any error (Fig. 12). This type of learning, forms a very major portion of the whole learning process of animals because they are always surrounded by many alternative situations and responses from which they have to learn, to select the right situation and responses for their survival *e.g.* the animal may be confronted with two doors one light and one dark, where food is behind the light door, the dark door is locked and the animal must learn to approach or jump to the light door whether it appears to the right or the left. The animal here is required to make a discrimination of brightness but the same test could be applied by using a triangle and a circle, loud and soft tone etc. In this type of situation, the animal is more obviously involved in a process of trial and error learning in which correct responses are encouraged by rewards and incorrect responses discouraged by withholding the rewards or in some cases by giving punishment. Likewise in *Euglena* if an algal filament becomes an obstacle, it soon stops and the anterior end begins to rotate in a wider circle, the posterior end works as pivot on which the body rotates and then suddenly it swims off towards a path that is free from the obstacle. Such a behaviour is

repeated if the obstacle remains there. This is called Trial and Error Learning.

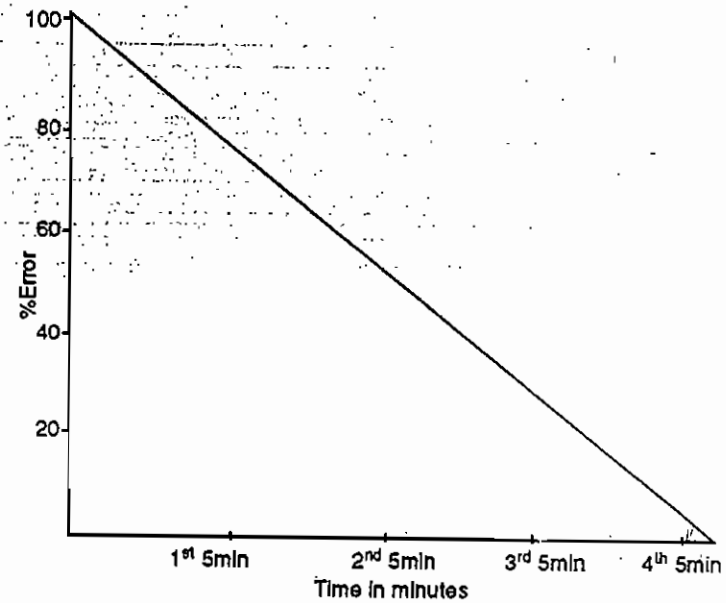

Fig. 12. Figure showing relationship between trials and errors. Number of errors decrease with the increase in time.

Still, more complicated is the "multiple choice maze" in which the animal may be required to make a number of discriminations in order to get the food at the end. Maze learning has been studied by using a number of devices. Many experiments have been carried out with maze on different animals like rat, mice etc (Fig. 13).

Phylogeny of learning. Learning of Protozoa group of organisms is still a debated question. *Amoebae* and *Paramecia* are capable of habituation to unpleasant stimuli, such as strong light, mechanical shocks etc. Learning is found at the level of worms, where a bilaterally symmetrical nervous system is already developed. Experiments with earthworms show that they can be trained to go to one arm of a 'T' maze learning to desk, moist chamber and to avoid the other arm which receives electric shock. Among Molluscs, some evidence of learning of a simple 'T' maze by snails have been demonstrated but such experiments were not highly successful. Learning has been demonstrated in *Octopuses* who were trained to come forward from their rocky place to seize a crab which was lowered into the far end of the aquarium by a thread.

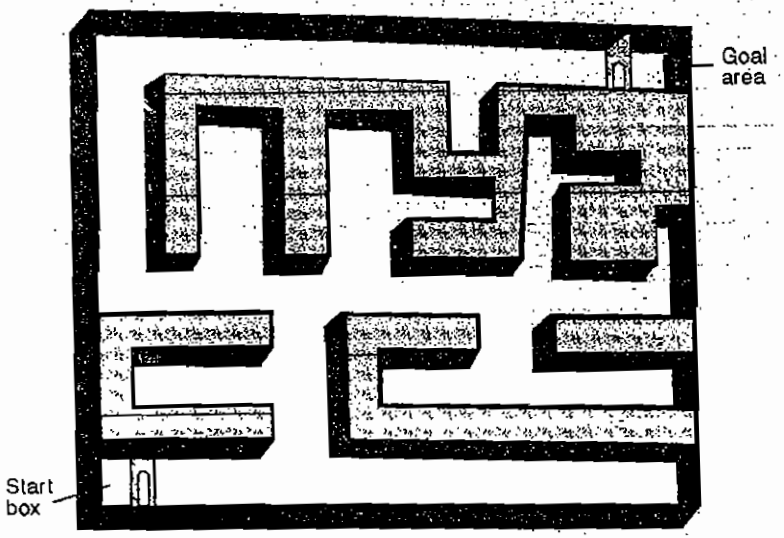

Fig. 13. Figure showing maze experiment.

Bees can readily learn to fly to dishes placed on blue paper and to avoid other dishes placed on grey paper if only the blue paper was associated with sugar water. However, the higher invertebrates have relatively poorly developed learning capacity. Mainly our knowledge of learning is based on mammals as compared to birds, reptiles, amphibians and fishes. This goes on degrading from mammal to fishes. Fishes have been successfully trained in a variety of discriminations involving simultaneous choice between two different objects. Birds have more faculty on learning than do the lower vertebrates. In mammalian series, still further experiments are obvious as we compare simple mammal like rats and subhuman primates.

Neural mechanism in learning. Learning represents some changes in the central nervous system. Pavlov believed that the cortex is essential for conditioning but studies have shown that simple conditioning is possible in the dog even after removal of its cortex. Several experiments on these lines have been done on different animals and it was found that cortex is not essential for learning Many mechanisms have been suggested as being responsible for establishment of new functional connections in the nervous system.

1. The growth of the nerve pathways.
2. Anatomical swelling or sprouting of synaptic terminals, resulting in the facilitation of crossing certain synapses.
3. A physiological increase in the case of crossing synaptic connections.
4. Bio-chemical changes such as alteration in the structural arrangement of the protein molecule in a nerve fiber. Memory takes time to set in the brain and consolidation requires atleast one hour. It is a two part process consisting of the following.
   (*a*) An early phase which is initially vulnerable physiological process lasting 15 minutes to an hour.
   (*b*) Invulnerable anatomical process providing the permanent basis of memory.

Learning in invertebrates. Many reviews have been written on the learning in invertebrates *e.g.* Corning, Dyal & Willows (1973 *a,b,* 1975); Thorpe (1963); Mc Connell (1966); and Dewsbury (1978).

In Protozoa group, habituation of responses to stimuli have been studied. Stimulus-specific habituation have been demonstrated in *Stentor coeruleus* (Wood 1973). *Stentor* contracts in response to mechanical or light stimuli. Patterson (1973) reported stimulus-specific habituation of the contraction response in *Vorticella convellaria*. Till now associate learning in protozoa remains a controversial subject. Gelber (1952) trained *Paramecium aurelia* to come near wire net 'baited' by dipping it into a suspension of bacteria which functions as food for *Paramecia*. Several trials were made and at last it was seen that *Paramecia* cling to the base of wire net in the culture medium even without bacteria. This experiment was contradicted by Jenson (1957 a,b, 1965) and said that it was not the training but *Paramecia* were attracted to food because they have unlearned positive Thigmotaxis response to cling to the materials. He said that it is due to the environmental modification but not that of the organism. French (1940) has observed that *Paramecia* show escape learning from the tube which was later contradicted by saying that some characteristics of the tubes have changed rather than of the animals as a result of training (Applewhite and Gardner, 1973). Bennett and Francis (1972) in their experiments with *Stentor* have demonstrated that escape response of *Stentor* is due to Geotaxis response and not due to learning. In Platyhelminths group, a bilaterally symmetrical nervous system with primitive brain occurs. Westerman (1963) found habituation in *Paramecia*. Generally, *Paramecia* secrete large amount of slime which influence conditioning. In the presence of slime, conditioning is rapid (Mc Connell and Mpitsos 1965). It has been further seen that *Paramecia* behaviour changes when the glass vessel is cleaned. Instrumental learning in flat worms has been reviewed by Corning and Kelly (1973). The Phenomenon of habituation, classical conditioning and instrumental learning can be experimentally demonstrated in this group (Dewsbury 1978) but the process of learning is different from the learning of vertebrates.

In Annelid group, Ratner and Gilpin (1974) demonstrated in earth worm a backward movement response to air puffs. The instrumental "T-maze" learning in earthworms has shown that pheromones control the movement of earthworm to select a correct path. Habituation has been

observed in many Arthropods. Nelson in 1971 found extension of proboscis in Blowflies when exposed to sugar solution. Horridge (1962, 1965) reported avoidance responses in insects with or without heads. Odours affect the learning of avoidance behaviour in *Drosophila* (Quinn *et al* 1974). Much attention has been paid on the behavioural studies of gastropod molluscs because of the presence of well developed nervous system and other systems for physiological studies. Gelperin (1975) observed food aversion learning in terrestrial slugs. The Cephalopod group has been found to be highly developed in learning. *Octopuses* learn discrimination by visual pattern (Sutherland 1957, 1961).

Psychology of vertebrate learning is dominated by a 'Continuity Theory' according to which, processes underlying learning are similar in all the vertebrates (Voronin 1962). Bitterman (1960, 1965a,b, 1975) contradicted this theory and said that a comparison of unconditional relationship between variables should be made rather that comparing the absolute scores. He studied reversal learning problems in monkeys, rats and pigeons and found an improvement in the learning of various reversal problems. In contrast to this, Bitterman *et al* (1958) have reported no such improvement in the case of Goldfish and Mouth breeders. He said (1965 a, b) 'we conclude simply that experiments on habit reversal tap an intellectual capacity of higher animals that is not at all developed in the fish and is manifested by the turtle in a restricted class of problem'. He was of the opinion that a qualitative difference exists among species. In his experiments with rats he could find that rats are able to show systematic strategic displays but they cannot show random matching. Bitterman (1975) concluded that random matching has not been demonstrated in mammals. Rats and fish qualitatively differ in performance of number of tasks (Bitterman 1975). In the development of learning theory, a depression effect is seen. Performance of two groups of animals depend on the amounts of reward that is the larger the reward, animals learns faster. In the case of rats, it has been found that rats run slowly in speed when they were given smaller reward which had received larger rewards earlier. Such a speed is even slower when the animal were trained throughout life on the smaller reward. Such an effect is called depression effect. It is interesting that fishes do not perform in this way. Fishes run faster in both the cases (Lowes and Bitterman 1967).

REASONING

It is the highest type of learning where animals are capable of evaluating in a comparative manner all the alternative situations and responses so that they may come to realise which would be the right response before actually taking up the response. Reasoning is the ability to solve the complex problem with something more than simple trial and

error, habit or stimulus response modification. The simplest type of reasoning can be experimentally demonstrated by the oldest and in some ways the simplest is Detour experiment where evolved animals like Cephalopods, monkeys and other Primates are able to reach the food even by acting against the natural instinct of moving away from the food. Reasoning reached the climax in human beings where the right response can be taken up through analysis so that the chances of errors might be minimised. In Detour experiment, an animal is blocked from direct approach to the food he can see and smell, by a barrier or some other arrangement. In order to get the food the animal must first move away from it and thus make "Detour" from the direct path. Of all the animals tested in Detour problems, only monkeys and chimpanzees show any degree of success upon first exposure to the situation. Many other animals have learnt to perform detours after failing on their first few trials. The *Octopus* can slowly learn to detour under some conditions but not others. Fishes and birds eventually learn the long way around the barrier. Laboratory reared rats, dogs and raccoons are rapid learners, although they initially fail.

The performance of Detour upon first exposure is similar to what we call insight into a problem in man. Even more direct evidence for insight-type solutions can be seen in other kinds of experiments with chimpanzees and to some degrees with monkeys. These studies were first performed by Köhler during the first world war and showed that chimpanzee is capable of attaining a banana out of reach by stocking boxes below it and climbing up or a chimpanzee will fit two sticks together to pull in a piece of food that is out of reach of either stick lane Unfortunately, it is difficult to be certain in these cases that the animal did not have some exposure with a similar type of problem before.

Other approaches to the ability to learn, to perform a task according to some general principle. These animals are given a great deal of training. The major question is whether they can learn to master the problem at all and if they learn, there is question of how rapidly they can master it and at what level of complexity they can perform. One of the easiest of these problems, is the conditional problem. Monkeys learn conditional reaching more rapidly and are more versatile and stable in their solutions.

A more difficult type of principle-learning is called the Learning set. In this case, an animal is first required to discriminate between two common objects that differ from each other in a number of physical dimensions. Displacement of the correct object, regardless of its position, yields food to the hungry subjects. For example, a monkey requires 50-100 trials to master such a problem. Very similar but more difficult is Oddity principle Learning on which three objects are presented, two of the same and one of different nature and the task is to pick the odd one

Another type of problem is the Delayed reaction, in which a hungry animal is presented with two identical cups. It is allowed to see food placed under one cup and then after some delay the animal is released to make its choice by displacing one cup. With odour controlled, the animal has no discrimination cue at the time of choice between two identical cups other than its memory. It has been suggested that to do this the animal must be capable of some "Symbolic process". Similar to the language which it can use to represent the missing discriminative cue at the time of choice, animals like rats, cats and dogs solve this problem by orienting towards the baited cup during the delay and then following their noses to the correct cup and if they break orientation during the delay or if the experimenter disorients them, they fail. Primates are capable of much longer delays than rodents and do not maintain an orientation towards the correct stimulus during the delay period. They may even be removed from the test situation and return after the delay and still perform successfully.

Another kind of symbolic process similar to counting is thought to be involved in double alternation test. In this case two alternating stimuli like food wells may be used. The correct order is RRLL which means food appeared twice on the right and twice on the left and it is this sequence that animal must master. Rats fail in this test. Cats master simple RRLL sequence only after prolonged training but they do not extend the series. *Raccoons* have been able to extend it as far as RRLLRR. Sub-human primates have extended the series to RRLLRRLL but in man indefinite extension of the series is possible.

Even more complex and more arbitrary sequences may be required of animals in the triple-plate problems.

Physiology of reasoning. With these tests, if problem solution involving insight, reasoning, concept formation, principle learning and symbolic processes, one is faced with the questions about what parts of the brain is really involved because performance on these tests improves so dramatically with higher animals which is sometimes possible only in primates which have highly evolved brain, it is believed that cerebral cortex and particularly its associated areas must be involved. This appears to be the case in the delayed reaction test where brain function has been extensively studied. It is believed that the cortex of the frontal lobe is more involved in reasoning behaviour. However, it is still not safe to conclude that the first lobes are essential for either secant memory or the symbolic processes believed to be required in delayed action. This is because the situation is extremely complex. Some evidences in animal experiments suggest that the associated area in the temporal lobe is important in the development of learning sets and that the visual association area in the occipital lobe is required for problems involving

visual recognition of objects. However, the evidence is neither extensive nor final.

One of the important and interesting consequences of development of those higher processes in the animal kingdom is the possibility of a social organisation that provides a cultural heritage upon which man's adaptation to his environment can be progressively and hopefully improved. When we trace the phylogeny and examine the precursors of social behaviour we find two solutions to the problem of social organisation in evolution.

1. In the invertebrates and simple vertebrates based on instinct.
2. In man and sub-human primates based on reasoning and symbolic capacities.

REVISION QUESTIONS

1. Describe different stereotyped behaviours.
2. Write an essay on the following:
   (*a*) Klinotaxis
   (*b*) Telotaxis
   (*c*) Menotaxis
   (*d*) Tonic reflexes
   (*e*) Innate Behaviour
   (*f*) Learning in animals
   (*g*) Imprinting
   (*h*) Habituation
   (*i*) Memory
   (*j*) Trial and Error learning.

2 MOTIVATED BEHAVIOUR

Motivational aspects of instincts have been analysed in different organisms. According to this, many instinctive behaviours can be analysed into "Drive" directed towards a goal, the attainment of which, results in reduction of the drive or satiation. Motivational behaviour is a drive that leads to a goal directed behaviour or satiation, which is measured by the intensity or the rate of consummatory behaviour e.g. in eating, drinking, mating or by the rate of intensity of work, the animals do to reach the goal. From the neurophysiological point of view, the motivated behaviour or instinctive behaviour is said to be controlled by the hypothalamus. Certain excitatory mechanisms are seen in the hypothalamus whose actions contribute to the arousal of motivated behaviour, whereas inhibitory mechanisms reduce the motivated behaviour in the organism.

Instincts, are the most complex of stereotype behaviours, seen in the organisms. In the lower organisms, the innate responses which are elicited by the combined influences of the internal environment and sensory stimulation. The internal environment "Primes" the response mechanism and the sensory stimulation triggers with the result that a complex neural mechanism set into action and thus brings about a complex behavioural pattern in animals. In the higher organisms, this innate mechanism is greatly modified by learning and overshadowed to a point, where it is difficult to recognise instincts as such. By the time the motivated aspects of instinct behaviour had emerged, it was very meaningful to talk about "Drives" or "Goal directed behaviour" and "Satiation". In mammals, it is believed that the arousal of drive is the result of activation of neural excitatory mechanisms in the hypothalamus and reduction of drive is due to activation of inhibitory hypothalamic mechanisms. The motivated behaviour is regulated by the combined effects of the internal environment, sensory stimuli, cortical influences and learning behaviour of the organism.

GOAL DIRECTED BEHAVIOUR

In practice, animals give many problems with that concept of "Goal". Goal can be defined as a situation where behaviour of an organism ends *e.g. Philanthus* after building its nest tunnel, stops begging. Occasionally, mental images of desired situations are created in organisms

e.g. dogs learn to procure food at one place and water at another place. There are three stages of motivation seen in the organism's behaviour.

1. A phase of "Appetitive behaviour" i.e. searching for its goal which is modified with experience e.g. predators search for the prey.
2. A phase of "Consummatory acts" once the goal is located, the behaviour of the animal changes with stereotyped fixed actions e.g. eating is a consummatory act of feeding and drinking for thirst etc.
3. A phase of "Quiescence" which occurs after achieving the goal.

It has been seen that the aforesaid stages are not truly applicable in all the cases but are true for only limited cases e.g. birds are in the habit of bringing large twigs to build their nests and then again they bring finer material to complete the building process. Dr. K.S. Lashley said that motivation is under the control of nervous system, external stimuli and changes in the composition of blood stream. He further stated that chains of stimulus-response sequences and alterations of responses within the organism, usually takes place under motivational behaviour. In different organisms, motivational changes occur at different occasions where motivation and learning go side by side. It is not possible to demonstrate learning in the absence of motivation and it has been found that in motivation some past learning may be required.

Human behavior may be influenced in the following two ways by motivation :

1. Generally motives make organisms, search oriented in the absence of external influences e.g. during sleeping, man stops doing work. This shows that motives bring about changes in the organisms relationship with its environment where it lives.
2. Under motivational behaviour, an organism is activated by having extra energy for performing an act from motives. Motives bring about an action of a general arousal system. Hebb found that the same stimulus may be responsible for the arousal of the action of an organism and it may also indicate the direction of appropriate activity, which can be seen in the case of predator- prey relationship. The smell of prey arouses predators to search for the prey and also provides clues as to where it may be seen in the area.

MOTIVATIONAL PATTERNS

More and more motives occur even after the quiescence of one motive. Once a goal is achieved, formation of new goals may be there. Sometimes many motives at a time may occur in the organism but the stronger motive remains effective under the influence of others e.g. a hungry man will not eat if the food available to him was asked by his religious leaders not to eat for some religious reasons.

Two categories of motives are seen where one is "Innate" or "Biological Drive" and the other "Psychological Motives".

Biological drive results from the basic need of the tissue of the body like food, water, sleep etc. They are satisfied by the influence of learning and many other cultural patterns. Psychological motives are of acquired nature as a result of experience of organisms, which are also influenced by cultural factors.

Biological drives motivate the behaviour of animals in such directions which bring about desired changes in the internal environment e.g. thirst drive motivates animals to locate and drink water which is urgently required by the body or hunger drive motivates animals to collect and eat food which is important for metabolism.

Generally biological drives are "Innate" in origin and are inherited through generations. The responses for this may be modified by learning in different animals.

DIFFERENT TYPES OF BIOLOGICAL DRIVES

1. The thirst drive. Animals have a tendency to quench their thirst which is necessary for the body e.g. a thirsty individual learns to find water (Goal) quickly. This is stereotype behaviour. The thirst drive is a regulatory device which operates in the body to control the intake of water to maintain a constant level of water inside the body of an organism. In the low supply of water during thirst drive, mouth and throat become dry. The nerve endings in the tissues of mouth and throat bring sensation in the organism to make it conscious about thirst. The thirst drive is activated by the hypothalamus. On the other hand, urination is also important in maintaining a water balance by which excess of water is removed from the body which is also under the control of the hypothalamus. The nerve cells present in certain hypothalamic nuclei activates the pituitary gland to release, Anti-diuretic hormone (A.D.H.) in the blood stream, which in turn, activates the kidney to retain water.

2. The hunger drive. The hunger drive is most complex of all the biological drives which has been extensively studied. It has been seen that blood sugar level is responsible for producing hunger drive, which is eliminated after food intake, which in turn, is regulated by taste stimuli and post-ingestion factors. The production of hunger and its control both are operated through the hypothalamus where excitatory and inhibitory centers are seen. Experimentally, it has been seen that the removal of excitatory centre causes cessation of eating whereas electrical stimulation causes overeating. Likewise removal of inhibitory centre causes overeating and deposition of fat in the body.

It is well known that certain brain centers control appetite (Consummatory) behaviour. The stimulation and inhibition of feeding behaviour are under direct control of these neural centers where humoral

and neural cues interact. Hyperphagia (Increase food intake) occurs when ventral medial hypothalamus (VMH) is destructed bilaterally, whereas Aphagia (Inhibition of feeding) takes place after destructing lateral hypothalamic nuclei (LH) leading to long lasting Anorexia. An inhibition of feeding behaviour occurs when VMH is electrically stimulated but electrical stimulation stimulates eating. The ingestive behaviour is initiated or inhibited by infusion of norepinephrine in the medial or the lateral hypothalamus. The control of food intake is done by monitoring blood glucose level by gluco-receptors neural cells of VMH and LH which are demonstrated by electrophysiological methods. Humoral or Neural cues may also control the activity of hypothalamic satiety and feeding centers. Chyme (Partially digested food) released in the duodenum or the small intestine from the stomach stimulates release of several gastrointestinal hormone that regulate the release of pancreatic digestive enzymes. Cholecystokinin (CCK) is released from the duodenum under the effect of certain factors present in the chyme in the stomach, stimulates the gall bladder contraction, secreting pancreatic juice having enzymes. The satiety function is taken by CCK (Peikin 1989). It causes inhibition of the food intake in the rat and Rhesus monkey. It has been found that intravenous injections of CCK in human reduces the food intake. As long as CCK level is more in blood, food intake is inhibited. Thus the C-terminal Octapeptide is responsible for inhibition of food intake but not water uptake. Dellafera and Baile (1979) reported that CCK acts on Central nervous system structures, involved in food intake which is supported by the results that anti CCK sera injections into the cerebral ventricles stimulates feeding in sheep (Hadley 1996). CCK released by the gastrointestinal tract or afferent Vagal neurons is stimulatory to noradrenergic neurons of the VMH which through the norepinephrine release are inhibitory to the lateral hypothalamic feeding centers (Hadley-1996).

The normal blood glucose level is maintained by pancreatic hormones as well as cellular glucostats within the brain. The cellular glucostats are found in the satiety centers (Basal Hypothalamus Region) of the brain. The neurons of satiety centers inhibit the neurons of feeding center which is present in lateral hypothalamus region. The satiety center neurons do not inhibit feeding center neurons under low blood glucose level. The neurons of feeding centers then stimulate other neural centers which are responsible for producing hunger sensation which ultimately leads to food intake and the blood sugar level is brought back to the normal again.

Many other centres control the feeding behaviour of the organism *e.g.* if food is not given to an organism for many days, the elimination of hunger drive occurs but in semi-starvation period when the food is given

in small quantity to the animal, increases the hunger drive and affects the behaviour of the organism. In cattle and rats specific hunger drives are motivated rather than general hunger drive in order to meet the requirement of the body.

3. The sleep drive. Animals have a habit of sleeping or taking rest. Sleeping is caused by certain chemical factors, which stimulate certain centres of the brain and nerves whereby muscles are relaxed. Whenever an organism is tired and body is fatigued, body requires rest and during rest cessation of the persisting stimuli leads to fatigue and compels the organism to rest but in the state of emotional disturbances rest does not bring relief and sleeplessness occurs. Experimentally it has been seen that sleeplessness can be caused by injuring some lower centres of the brain which control the sleep drive.

In the behaviour of an organism, many other cultural practices like regular alteration of light and dark also affect the sleep drive. This is seen in human beings which follow a regular pattern of sleeping during night and avoiding during the day. Some Bolivian Indian tribes who are adapted to sleep for a shorter length of period even during the day, are exceptional cases.

4. Heat and cold drives. Weather affects organisms. In the skin of organisms, a few receptors may be sensitive to heat and others to cold. Body temperatures are maintained at constant level by complex mechanisms in the higher vertebrates. The excess of heat, during summer days, is removed from the body, whereas, in cooler days it conserves heat. Many hormones in the body play an active role in bringing about the balance of the body temperatures like Thyroxine and Adrenalin. During cold, body temperature falls below normal, increasing the activity of the body by increasing secretion of Thyroxin and Adrenalin, due to which blood pressure rises in the body and blood flows more to the deeper layers of the body. During heat sensations, an opposite action is seen where the blood vessels at the surface dilate exposing more blood of the body for cooling purposes. Many other external devices like ice water, coolers, electric fans etc. are used by man to maintain his body temperature at normal level. Such controls are called by Hardy as "Servo control" which are different from the internal controls of the body. "Servo controlled" behaviour of an organism is also under the control of the hypothalamus and it is seen only in human beings.

5. The sexual drive. This is an important biological drive for maintaining social organization in organisms, which is dependent on the environmental influences as well as the hormones circulating in the blood. In both the sexes, presence or absence of certain hormones play an important role for developing the sexual drive. This is also influenced by the emotional state of the organism. Different hormones released by

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It is well known that certain brain centers control appetite (Consummatory) behaviour. The stimulation and inhibition of feeding behaviour are under direct control of these neural centers where humoral

and neural cues interact. Hyperphagia (Increase food intake) occurs when ventral medial hypothalamus (VMH) is destructed bilaterally, whereas Aphagia (Inhibition of feeding) takes place after destructing lateral hypothalamic nuclei (LH) leading to long lasting Anorexia. An inhibition of feeding behaviour occurs when VMH is electrically stimulated but electrical stimulation stimulates eating. The ingestive behaviour is initiated or inhibited by infusion of norepinephrine in the medial or the lateral hypothalamus. The control of food intake is done by monitoring blood glucose level by gluco-receptors neural cells of VMH and LH which are demonstrated by electrophysiological methods. Humoral or Neural cues may also control the activity of hypothalamic satiety and feeding centers. Chyme (Partially digested food) released in the duodenum or the small intestine from the stomach stimulates release of several gastrointestinal hormone that regulate the release of pancreatic digestive enzymes. Cholecystokinin (CCK) is released from the duodenum under the effect of certain factors present in the chyme in the stomach, stimulates the gall bladder contraction, secreting pancreatic juice having enzymes. The satiety function is taken by CCK (Peikin 1989). It causes inhibition of the food intake in the rat and Rhesus monkey. It has been found that intravenous injections of CCK in human reduces the food intake. As long as CCK level is more in blood, food intake is inhibited. Thus the C-terminal Octapeptide is responsible for inhibition of food intake but not water uptake. Dellafera and Baile (1979) reported that CCK acts on Central nervous system structures, involved in food intake which is supported by the results that anti CCK sera injections into the cerebral ventricles stimulates feeding in sheep (Hadley 1996). CCK released by the gastrointestinal tract or afferent Vagal neurons is stimulatory to noradrenergic neurons of the VMH which through the norepinephrine release are inhibitory to the lateral hypothalamic feeding centers (Hadley-1996).

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responsible for the production of sound as seen in the Zebra finch (Poephila gutata) where male brain possesses larger nuclei of the sound system than the female. It has been found that neonatal females of Zebra finch when administered with testosterone or di-hydro testosterone, started singing after becoming adults (Hadley 1996) which indicates that Zebra finch remains neutral sex with regard to sexual differentiation of song system (Degvoogd 1991). When testosterone is administered into ovariectomized adult canaries, they started singing (Hadley 1996). In the male canarie the nucleus robustus archistriatalis (RA) of the fore brain is larger in size than in females. In ovariectomized females, testosterone injections increase, the volume of RA as well as nuclear dendrites resembling that of the male canaries (Hadley 1996). Nottebohm 1981 found that in male canary during singing season i.e. spring season two telencephalic nuclei controlling sound become larger in size than in songless months. This shows that a variation in the number of synapses in the brain occurs with new motor co-ordination (Hadley 1996).

6. Air hunger. Oxygen is required by the body of every organism. Whenever there is less oxygen it is replaced by methane, the organism looses consciousness and a discomfort occurs in the body due to accumulation of carbon dioxide. The presence of excess carbon dioxide provides a stimulus to the mechanism of air hunger.

7. Pain drive. Pain in the body can become a drive if it persists for a longer time in the organism. For example, if any part of the body comes in contact with a hot iron rod accidentally and even after withdrawal of the part from the iron rod, it continuously burns, then the pain becomes a drive. Organisms have a tendency to avoid pain due to injury. Pain is not a true biological drive, but it is more closely related to the general emotional settings, where it occurs. It has been seen that mental cases are less responsive to pain stimuli than the normal individual.

PSYCHOLOGICAL MOTIVES

Many psychological motives are seen in man. For example, man has curiosity about his political and religious beliefs and his capacity to hate and love and his ambitions to acquire a high position in the society. This has become more important than his other biological drives. Some times man becomes frustrated, which may cause physical illness in him but the frustration may not lead to death. Many psychologists think that certain psychological needs for happiness and health are inborn or innate in origin and they are not acquired but their expressions in the animal may be due to learning. Many animals have a curiosity to know about certain things where curiosity functions as an important psychological drive, e.g. infants of monkeys show visual curiosity for exploring certain objects which are inborn or innate in origin. Psychological drives undergo many manipulations with the advancement of age, e.g. many motives are

important in monkeys during development before the motive to eat soli things. Monkeys have a capacity to learn many things even without rewards but in the case of dog, a quick learning may be seen when they were offered different rewards.

Another important psychological motive is seen particularly in man and not in many other animals i.e., "The need to achieve" which means to perform better than others or to get something more than others. This is thought to be a learned behaviour. The motivational behaviour is under the control of hypothalamus of the vertebrate brain. Hypothalamus has both excitatory mechanism activating motivational behaviour and inhibitory mechanism known for reducing motivational behaviour, e.g. experimentally it has been seen that destruction of the ventromedian regions of the hypothalamus increases the eating response in rats and monkeys.

REVISION QUESTIONS

1. What do you understand by "Goal directed behaviour".
2. What are Motivational patterns ?
3. Describe in detail the different types of Biological Drives?
4. Write short notes on the following :
   (*a*) The Sleep drive
   (*b*) The Pain drive

3 ROLE OF HORMONES IN BEHAVIOUR

A hormone is a chemical messenger secreted by a specific endocrine gland of the body, transported by the blood stream, producing a specific effect on some other organ in the body. Many intricate neuroendocrine feed back systems control the production and release of hormones in the organism. A number of hormones like MSH, ACTH, Vasopressin and Oxytocin etc. affect the behaviour of the organism. Generally, hormones affecting behaviour are of peptide nature and they show some similarity in their structure. Hormones and behaviour interact in many functional systems like sexual behaviour, maternal behaviour, aggressive behaviour, territorial activity and many other behavioural attitudes. *Cockerels*, after castration, showed a reduction in the comb and spur size, a cessation of crowing and loss of sexual behaviour as seen by Berthold. Such losses are prevented when a single gonad was transplanted in the bird. He concluded that the testis may be secreting something with the bloodstream, which maintains the secondary sexual characteristics and behaviour in the bird. Since then a new branch called "Behavioural Endocrinology" or "Psychoneuroendocrinology" has developed. Hormones show specific effects on a variety of behavioural patterns which are as follows :

1. SEXUAL BEHAVIOUR

The role of hormones in the control of sexual behaviour is well documented. Beach (1976) divided female behaviour into the following three phases:

a. Attractivity: evoking the sexual responses from the male by a female stimulus.

b. Perceptivity: initiation of female in establishing and maintaining the sexual interaction e.g. soliciting.

c. Receptivity: the postural responses of female which are necessary in the achievement of ejaculation by the male.

In the female *Rhesus* monkeys, estrogen enhances the female attractiveness whereas female perceptivity was heightened by both estrogen and androgen and female receptivity was stimulated by estrogen but not by androgen (Johnson and Phoenix 1976). The male copulatory behaviour *i.e.* erection and ejaculation is affected by ACTH and other

related peptides (Bertolini, Gessa and Ferran 1975).

LH-RF released from the hypothalamus have direct effects on copulatory behaviour (Moss and Mc Cann 1973).

2. MATERNAL BEHAVIOUR

Maternal Behaviour is elicited in the absence of certain hormones. Lisk (1971) has observed that estrogen and progesterone work in synergy in stimulating maternal nest building. Hormonal *milieu* of the new mother assumes that she is ready with maternal behaviour at the time her pups are ready to receive it (Dewsbury 1978). During parturition, oxytocin level is high which affects behaviour of the mother. Experimentally, intracerebroventrocular injections of oxytocin influence maternal behaviour. The maternal behaviour of the parturating rat is activated by estrogens and oxytocin within the brain.

3. AGGRESSIVE BEHAVIOUR

The aggressive nature of the animal has been studied by many ethologists to look into their circumstances under which animals become violent and fight among themselves. In human beings aggressiveness ends into wars (Grobel and Hinde 1989) Aggressiveness increases with the time and ultimately results into fighting (Lorenz 1966). This indicates that in both humans and animals, aggression is a genetically based phenomenon demanding expression (Manning and Dockins 1995). Sevenster (1961) and Wilz (1970) have studied aggression levels in male 3-spine sticklebacks by using the number of bites delivered to a test-tube containing another male. They found that aggressive motivation of male lasts for 10 minutes test period than at the beginning of showing aggressive behaviour which results into fighting tendency. Such a phenomenon is also reported in many other animals like spiders (Riechert 1984) and lizards (Ranek and Rand 1978) etc. Wilz (1970) reported in Stickleback that even if rival male is removed after the attack, the remaining male even attack females and are unable to respond sexually for some time which indicates the act of aggression does not show any quiescent phase. Kruijt (1964) found that in fish and mice after keeping them in isolation for months, they fight amongst themselves with their own tails making circling fights. Lorenz proposed an idea that animals become more aggressive if they are unable to find an outlet for their aggressive behaviour. Heiligenberg and Kramer (1972) tested this idea in cichlid fish, Pelmatochromis where males are found to be of aggressive nature. They kept males without stimulation to fight and found against the theory of Lorenz's idea, that fight tendency decreases over few days indicating that aggressive tendencies require an opponent. Many other ethologists like Scott (1958) Brain (1975) criticised the idea of Lorenz and showed that in rodents, the level of aggressiveness can be changed by regulating

arly experiences of the animal. The male mice reared in litters having male siblings become less aggressive as adult than those reared with their isters (Namihas and Wehmer 1978). In young Rhesus monkeys aggressiveness increases leading to high level conflicts with their mothers Chamove 1980). This shows that both in animals and human beings aggressiveness remains as their inherent quality which depends upon xperience and internal state of the animals (Manning and Dawkins 1995). The aggressive behaviour in animals and human beings were surveyed by any ethologist like Archer (1988), Grobel and Hindey (1989). In aggression other individual is displaced showing overt fighting to subtle osture where physical contact is not observed. In human beings verbal discussion insulting each other and physical violence occurs during gression. Sometimes this ends in a war between two human populations. In aggressive behaviour motivation of the individual is not clear in ifferent situations of the aggressiveness. Animals fight for getting shelter, food and mating partner all for protecting their territories. In few species ominance hierarchy is maintained to achieve this. The aggressive mode in animals generally occur when they are in frustration or pain. When ats in cage are given electric shocks they attack their other cage mates. Such a thing did not occur earlier when they were not given electric hocks. A psychologist Miller in 1941 said that aggression occurs due to frustration, which is proved to be wrong in all cases of aggressive ehaviours because in the aggressive mode a single behaviour phenomenon is not involved (Brain and Jonesa 1982).

Aggressive behaviour is produced under certain situations or in certain stimuli. Aggressive mode is common amongst males because male hormone estosterone increases aggressiveness where stimuli is provided by the rival males. Upbringing of different number of species does not have any influence n aggressive nature of the species as shown by Cullen (1960) in male sticklebacks reared in complete isolation. Here they set up their territories nd started attacking rival males in a similar way as normally the fishes do nder reared condition. The individuals in natural population of some species o differ quantitatively in the level and expression of aggression, which is enetically based as reported in desert spider Aegelopsis which differ genetically in protecting their webs (Riechert and Maynard Smith 1989). According to Lorenz (1966) aggressive nature of animals is often very beneficial to animals but in doing so they get injuries and even die in combat. Animals do not fight with each other if their opponent is stronger. He who fights and runs away lives to fight another day (Manning and Dockins 1995). aggressive behaviour natural selection plays an important role where nature selects better adapted species by weeding out the unfit individual.

Aggressive behaviour is under the control of variety of hormones released both from the pituitary-gonadial system and the pituitary - adrenal

system. Rose, Holaday, Bernstein (1971), Leshner and Candland (1972) reported in monkeys a variation in the levels of both testosterone and adrenal hormones in dominance rank of individual males. In red-billed weaver birds, Luteinizing hormone (LH) from the pituitary gland plays an important role in controlling the aggressive behaviour (Lazarus and Crook 1973). Kostowski, Rewerski and Piechocki (1970) found that Hydro-cortisone increased aggressiveness and hydroxydione decreased it. Desoxycorticosterone decreased muricide in rats but failed to alter isolation induced aggression (Dewsbury 1978) whereas Gstophanthin decreased isolation, induced aggression and no effect on muricide.

Aggressive behaviour is related to increased Plasma Testosterone level (Hadley 1996). A reduction in the aggressive nature and sexual drive is seen in the individuals where low levels of testosterone are found due to genetic abnormality in steroid bio-synthesis occurring before puberty. Such individuals when injected with testosterone showed sexual interest and aggressiveness. Reinisch (1981) reported an increase in aggressiveness in human females who were exposed to synthetic progesterone which is generally taken to prevent abortions. The changing hormonal levels at the time of menstrual cycle may cause alteration in the behaviour of the female. In human females a pre-menstrual tension syndrome occurs. When young ones are exposed to testosterone hormones a pubertal shift from female to male gender occurs altering their sexual behaviour as reported in an interrelated group of male pseudo hermaphrodites in Domainican Republic rural communities (Emparto-Mcginley et al. 1979). It has been observed here that feminization in males occurs because of absence of 5 - reductase enzyme activity. They remain first as females and then becomes males (Hadley 1996).

Aggressiveness may develop in certain environmental factors e.g. XYY men are sub normal in intelligence and they are taller than their counterparts. They are also found to be more aggressive physically because of unfavourable social conditions like taunting done by their associates under which they have developed their adulthood (Gardner and Snudtad 1984). Many observations were made on genetic and environ-mental factors developing behavioural patterns by J.P. Scott and J.L. Fuller. Behaviour develops as a result of interaction of genetic make up and environmental influence. In case of dogs, the environment helps in learning and developing innate faculties at each developmental stage. At the early stage of development when behaviour is found to be minimal, genetic differences do not express themselves quickly but once the behaviour pattern is established, genetically determined differences appear slowly which are modified later with experience under the influence of different environmental factors. This shows that variation of response threshold is one way whereby the dog is influenced by heredity. Here genetic influence

occurs by heredity and its actual appearance of specific function depends upon the individual experience. In the selection trials performed on dogs it has been found that fighting behaviour is observed in the terrier but it is absent in hounds. This is of rare occurrence in nature (Gardner and Snustad 1984).

Animals always maintain individual distance among themselves which varies in response to overcrowding. This can be seen in case of blackheaded gulls, flamingoes etc. but in some tortoises and hedgehogs an animal pile is made by overcrowding. Many birds flock together but during breeding season they disperse to defend their territories. Animals always keep social distance which is the visiting area of the animal when it goes away from the group e.g. in Baboon group while feeding, during the day time they show dispersal activity but at night they come together to sleep on adjacent trees. The overcrowding creates over aggressiveness. The inherent aggressiveness (Innate aggressiveness) which is important for survival of species becomes destructive in overcrowding (Gardner and Snustad 1984). Aggression may vary under different conditions and may lead to nervous disorders and other psychosomatic diseases in individuals. In a group, few individuals become dominant by showing aggressiveness over others as seen in chickens. The aggressiveness increases due to winning attitude of individuals and is a product of inheritance maturations and various other endogenous factors which are supported by experience of the individuals in its life time. It is further dependant on the external stimuli like sign stimuli from other individuals of the same species (Gardner and Snustad 1984).

4. TERRITORIAL MARKING

The territorial marking of Mongolian *gerbils* have been extensively studied by Thiessen (1973). Both males and females secrete pheromones for marking, from their mid-ventral sebaceous gland. At this time, a gerbil shows stereotyped behaviour pattern. At first it approaches a prominent object, scenting it by lowering its abdomen and moving forward. Castration leads to a low level of scent marking which is recovered by androgen administration. A dose—dependent marking is seen. More the dose, the more scent marks result.

Ovariectomy causes a decrease of marking in females but normalcy returns after injections of either testosterone or estrogen plus progesterone. Implantation of estrogen and testosterone in the pre-optic area of the hypothalamic region restores the marking in females.

5. WHEEL RUNNING

Wang (1923) reported association between hormones and wheel running activity in the non-pregnant female rat. They show a 4 day cycle of wheel running activity which is correlated with her oestrous cycle. [illegible] fluctuations in

controlling cyclical wheel running pattern.

6. HOARDING

Food hoarding by male *gerbils* is increased by castration and decreased by injecting testosterone. This shows that testosterone inhibits hoarding (Nyby, Wallace, Owen and Thiessen 1973). Herberg, Pye and Blundell (1972) reported a variation in hoarding activity by female rats associated with their oestrous cycle.

7. PERSISTENCE

The persistence of animals is increased by testosterone particularly in young chicks in performing different tasks like searching, discrimination and open field-testing.

8. PLAY

In *rhesus* monkeys, normal males display much more active play than females. An intermediate behaviour is seen in "Pseudo hermaphrodite" females (Phoenix, Goy and Resko 1968)

9. AVOIDANCE BEHAVIOUR AND ROLE OF HORMONES IN LEARNING AND MEMORY

De Wied (1976) has shown that rats give avoidance responses when injected with ectopic MSH or ACTH. These hormones also increase the resistance to the avoidance behaviour extinction. Alpha-MSH and ACTH 1-10 and ACTH 4-10 fragments increase resistance to the extinction of avoidance behaviour whereas ACTH 11-24 fragment devoid of action of adrenal glands is without such effect. It has been seen that Alpha-MSH, Beta - MSH and ACTH show a central common sequence -His-Phe-Arg-Trp- which is responsible for such a behaviour in rats. From electrophysiological studies it has been seen that the central nervous system is excited by ACTH. In the brain, thalamic reticular area is important in integrative behaviour because all the incoming informations converge at this centre. Experimentally, if MSH and ACTH peptides are implanted in this area of the brain, the extinction of conditioned behaviour is changed. MSH and ACTH peptides are responsible for facilitated learning by improving the motivation (Mac E. Hadley 1988). In humans, these peptides have been found to influence memory processes. The behaviour of learning and memory retention is affected by Neurotransmitters or neuro modulators like MSH and ACTH peptides released from Neurons projecting from other parts of the brain where pituitary does not play a role. A number of neuro peptides are released within the brain by opiomelanotropinergic neurons. These peptides come from precursor protein called pro-opiomelano-anocortin within some neurons. From this precursor protein desacetylated Alpha-MSH is formed. In the rat, desacetylated native form of Alpha—MSH is more effective in eliciting

behavioural activity than desacetyl—Alpha MSH. Besides these, Beta-endorphin also plays a major role in behaviour. The regulation of behaviour either through Alpha-MSH or Beta-endorphin mainly depends on the modulation of neural inputs which controls the chemical nature of the secreted neuro-peptides.

Vasopressin maintains adaptive behaviour in an organism (De Wied, 1976). An avoidance behaviour is seen in posterior lobotomized rats where they are injected with vasopressin hormone. They function similarly as that of MSH and ACTH in learning and memory process of different organisms. The arginine vasopressin, is more active than lysine. In the human being, learning and memory are influenced by the analog DDAVP (1-Desamino-B-D-arginine vasopressin).

A behavioural change in one animal that is created by hormone administration can, in turn, affect the behaviour of other animals in the group.

REVISION QUESTIONS

1. Describe in detail the role of Hormones in behaviour of animals.
2. Write short notes on the following:
   (*a*) Territorial Marking
   (*b*) Wheel running
   (*c*) Avoidance Behaviour.

4 COMMUNICATION IN ANIMALS

Communication phenomenon between members of a species or between two species is of universal occurrence. It can be defined as any transfer of information through signals that have evolved for the mutual benefit of the two animals e.g. foraging ants produce certain scent as signal for communication purposes which help other members of the group to find the source of the food but such signalling system in ants is also disadvantageous to them because predatory snake, Leptotyphlops detects the same scent trail and eat the brude of ants. In a communication system the following seven essential components are seen (Ewsbury 1978).

1. **Sender:** An individual which emits a signal
2. **Receiver:** An individual which receives the signal and whose behaviour is changed due to this.
3. **Message:** The behaviour emitted by the sender i.e. signals like intention to fight aggressiveness, finding mate partners, location of the food etc.
4. **Channels:** A pathway through which normally a signal travels. These are vocal – auditory channel where different sensory receptors are involved.
5. **Noise:** This is a background activity in the channel which is not related to the signal.
6. **Contacts:** The setup under which a signal is emitted and received.
7. **Code:** A possible complete set of signals and contacts.

Broadly speaking in a communication system one is the sender and other is the receiver where both are mutually benefited like that seen in case of bees which are attracted towards nectar of flowers and in turn flowers are benefited by being pollinated so both partners are benefited but this definition is not true for all the cases. Altmann (1962) defined social communication as a "process by which the behaviour of an animal affects the behaviour of others". In the Rhesus monkey group dominant individual provides certain stimuli in the form of body posture in which it walks, visual signals for others to follow, which influences the movement of subordinate males. There are many ways by which animals communicate among themselves like producing sound, singing songs, visual displays, scent trails or changes in the body postures etc. which will be helpful

under the environment in which a particular animal lives e.g. while moving through a dense forest when two animals loose sight of one another they produce large sound signals by which they come to know their whereabouts. Besides this many "messages" are communicated via signals which are dependant on various sensory modalities which animals have developed in the animal kingdom.

The following methods are adapted by the animals for their communication purposes.

1. Chemical signals: In animals the production of odours occur for attracting opposite sexes and for territorial markings. This is the most primitive type of communication technique. These odours may be pheromones, which are released in air or water or deposited on to or near the ground under certain behavioural states. The other member of the species detect these pheromones and act accordingly. The pheromones are chemical signals produced by exocrine glands which help in certain behavioural activities of the animal whereas hormones function as chemical messengers between different groups of cells within the body produced from endocrine glands. Pheromones can be classified into two basic categories: 1. Signaling pheromones which produce immediate effects on the behaviour of the recipient animals. 2. Priming pheromones which trigger hormonal activities manifested in overt behaviour only at a later time (Verma and Agarwal 1993). The pheromones are released through urine or from different glands located in different regions of the body in different species or into the faeces. Pheromones are released into the air and they help in identifying different species or races or for the purpose of sexual identification and reproductive state age and mood of the animal. They help in reproductive behaviour and another forms of social behaviour like aggression, dominance, scent marking, withdrawal and submission. Various mammals produce pheromones from their anal or facial glands which are rubbed into trees or rocks to mark the territories of individual animals as seen in the case of a male dik-dik deer which marks its territory by depositing secretions from an eye gland on to the twigs. Cats and dogs urinate to mark the edges of their territory. Species-specific sex pheromones are released by many female mammals like cats and dogs when they are in heat for attracting males. Such sex attractants help to excite the males. This is common in different insects like silkworm moth (Bombyx mori) and gypsy moth. The pheromones are secreted by the special glands located at the female abdomen and detected by receptors on the female antennae. Males detect the minute amount of sex attractants released from the females. In *Bombyx mori* bombykol sex pheromone is found to help in attracting the opposite sex several kilometers away from its origin. The total amount of bombykol produced from the body is about [illegible] The male moth reacts when forty out of forty receptors on

the antennae receive one strike of a pheromone molecule per second (Schneider 1974). Chemical communication is better developed in social insects like termites, ants, bees and wasps. In honey bees and ants chemicals are secreted from a dozen of different exocrine glands which produce different behavioural activities in their nest mates. For example the workers in a honey bee colony feed larvae to develop into future queens. For this they build larger cells than the usual queen cells. The worker bee helps to develop this egg deposited by the queen in such cells. This behaviour of worker bee is regulated by a pheromone called 9-oxodec-2-enoic acid, which is secreted by the mandibular glands of the healthy queen, which spreads this pheromone over the surface of her body as she cleans herself. The workers lick it of her and this then enters the food-exchange stream and is passed from bee to bee round the hive. This makes the worker sterile, but once the queen dies in the hive, the effect of this pheromone disappears. This pheromone also helps in attracting drones towards the virgin queens. In stinging, an alarm pheromone (Isoamyl acetate) is left at the site of wound along with the sting of the bee which diffuses in the air and excites other bees to aggregate and sting. In ants also alarm pheromones are produced which help in aggregation, running and for attacking enemies. An ant produces chemical trail marks with the help of her stinger on the ground every few feet to give information to other nest mates about the rich food source. From the body of dead ants Oleic acid is secreted by which the other live ants pick them up from the source of death and carry it out of the nest. A trophallaxis phenomena is observed among nest mates which serves as a social bond between different members of the society by distributing a common "nest flavour".

2. Tactile communication: A number of informations are transmitted by tactile communication which is more developed in social interactions of many invertebrates like that seen in the blind workers of some termite colonies. In many mammals and certain insects tactile signals such as nose rubbing or rubbing of antennae like in bees and a "kiss" are used to identify the different members of a group and during this phenomenon they communicate among themselves by giving certain information. Very often touch is closely associated with chemical senses like the antennae of palps of insects which possesses Chemoreceptors. The tactile communications are involved in passing out information between the colony members of the social insects. In mammals also tactile communication is seen e.g. the two adults dusky titi monkeys show tail twining with each other (Moynohan 1965). The tactile communication is highly developed in monkeys where one monkey grooms another by touching and passing some information. Cockroaches and Lobsters have long "feelers" which help them to know each other in their sex. Few animals have mechano receptors by which they know some mechanical disturbances in air or

water around them. (Wilcox 1979) found that pond skaters ascertain the sex of other adults by producing ripples on the water surface. The female produces three to ten Hz suface ripples but males produce eight to ninty Hz frequency waves to which other males respond. The blind fishes know the presence of other fishes in the group by creating mechanical disturbances in the water through their lateral line organs.

3. **Visual communication:** This is common in few arthropods, certain fishes, lizards, birds and mammals. The visual information is communicated by various means like colour identification, posture or shape of the body, movements or timing for sending the information e.g. the male peacock displays its plumate colouration by dancing during breeding season. In octopus sexual displays are made by rapid colour changes of the body. In butterflies few males are attracted to the female by her specific flight movement. Fire flies show attraction among themselves by producing intermitant flashes where each species has its own frequency. The African elephant displays different messages by moving his head, ear and trunk. A submissive posture in elephant is indicated by curling trunk inward but if the trunk is forwardly directed it indicates threat to enemy. Aggressiveness is indicated by raising his ear or head. In dogs and wolves aggressiveness is displayed by raising the hair of the trunk reason and showing teeth by exposing mouth and creating a grunting sound. The male baboon displays threat signals by exposing his long canine. Visual alarms are also seen in birds which flock together. They flash their wing and tail feathers when there is danger.

4. **Auditory communication:** Auditory signals for sending information from one member to another member is a common phenomenon in animals where acoustic and vocal signals are produced e.g. in crickets, cicadas and grasshoppers body parts are rubbed together for producing sound signals while many fishes vibrate their swim bladders by muscle contractions to emit information. In the rattle snake, the rattle which is a modification of the skin in the tail region vibrates to produce sound. Animals produce sound in both air and water which has an advantage of reaching to a considerable distance. Generally, low frequency sounds are helpful for long distance communication rather than high frequency sounds because they are scattered by incoming obstacles (Manning and Dawkins 1995). Animals occupy an elevated place over the ground and convey their signals by producing large sounds over a longer distance. Paul and Walker (1979) reported that the cricket sings to spread the mating call from the top of a tree which covers fourteen times the area than those that sing from the ground. Birds also, produce their territorial sound to increase the effectiveness from an elevated area (Morton 1975, Wiley and Richards 1978). Fishes and whales produce sound in the water for communication purposes. In the case of hump back whales, Payne and

McVays (1971) reported that these whales produce a sound which can be heard several hundred miles away from its source of origin. Sound signals help animals in reproduction, food collection and for different purposes. In many animals like insects, birds etc. the sound signals are produced to attract the males. Sound signals are species specific e.g. similar species living together in a small area (Sympatric) make distinct calls but those animals which live apart (Allopatric) make different calls (Manning and Dawkins 1995). Animals use their sound signals for finding food as seen in herring gulls and gibbons or produce buzzard signals for location of dead animals. Birds make alarm calls for alerting flock mates about the presence of enemies. The alarm calls may be of two types as seen in some European finches, where one high frequency call is produced on sighting hawks overhead and the other call is produced on seeing danger on the ground. In United States, Eastern crows make mobbing calls or assembly calls to draw the different members of the group together to defend themselves. Like mobbing calls, animals produce departing calls on getting the danger from the enemy e.g. Eastern crows produce a departing call before flying off on getting the danger.

Karl Von Firch and his colleagues have reported the language of honey bees. The honey bees show a round dance for nearby foods and tail wagging dance for distant food. The tail wagging dance also gives information about the direction of food source. The kinds of food present in the hive is determined by chemoreceptors present on the antennae of bees and by following the pattern of the dance bees locate the pollen and nectar (Verma and Agarwal 1993). Sometimes a low humming sound is created along with the dance indicating the distance. After repeated dancing the bee goes to the food source for collecting more nectar. The dance slows down when the food source is exhausted. If the food is in limited quantity, the bee makes short trips to the location of the food source.

REVISION QUESTIONS

1. Describe in detail communication in animals.
2. What is communication? How are chemical signals passed in animals?
3. Write short notes on the following:
   (*a*) Tactile communication
   (*b*) Visual communication

communicatn by sound freq.
-signals in the form of sound -auditory signals

5 PHEROMONES

Chemical communications have been recognised in animals, particularly in insects, fishes and mammals. This forms a part of animal communication system which has emerged as one of the youngest disciplines in biology. Regnier called "Semiochemicals to such substances which are employed in conveying messages between animals." The chemicals which are released in environments for intraspecific communication have been identified as "Pheromones" (Karlson and Butenandt, 1959). The word Pheromone originates from a Greek word "Pherein" meaning "to carry" and "harman", "to excite". This term was proposed by Karlson and Luscher to include such substances which are "secreted by the individual and received by a second individual of the same species in which they release a specific reaction affecting development process". They are released in minute quantities bringing about major effect functioning as chemical messengers (Novak 1975). They are known as chemical regulators produced by exocrine glands causing change in the behavioural and developmental physiology of animals. Pheromones are secreted generally by specialised glands distributed in different parts of the body and are conveyed to the recipient by smell, taste or by absorption. This term was originally applied "to the sex attractants", but now it included "all those chemical substances which are released in the environment to control the behaviour of members of the same animal species". This term is used for those chemicals or substances which act via the nervous system or the sensory pathway. The other term "Exohormones" is used for those substances which have direct bio-chemical activity transmitted within the colonies of social insects (Novak 1975). Sometimes hormonal metabolites released from the body also act as Pheromones. Karlson defined "Pheromones as chemical signals exchanged between individuals of same species which produces a specific reaction in the form of behavioural response or in a particular development process". The biochemically active substances produced by the exocrine glands working outside the body are called "Pheromones", whereas those which are produced by endocrine glands acting inside the body are known as "Hormones". Pheromones can be differentiated from Hormones on the following basis:—

1. They are released by the exocrine glands and transmitted externally through the environment.

2. They are species specific and produce specific behavioural, reproductive and developmental reponses in the bodies of other members of the same species. On the other hand hormones which are released by endocrine glands, bring about effect in physiology of the same organism.

The term allelochemics are used for semiochemicals which are utilised in interspecific communication. These are further classified into two categories, allomones and kairomones. Allomones are those, which induce effects adaptively favourable to the emitter, for example, repellents of certain insects, spray of shunk (Dominic 1978). The Kairomones induce effects that adaptively favour the receiver, for example, the signals that enable the predators to locate the prey (Dominic 1978). Norlund and Lewis have added two more categories to these, called as Synomones and Apnomones. When both, emitter and receiver, get beneficial responses from the chemicals or substances, they are called as Synomones. Flower scents come under this category. Apnomones are such substances which are emitted by a non-living material and is favourable to the recipient but detrimental to an organism of another species that is located in or on the non-living material like decaying meat, food grains, the attractant being emitted by the meat or food grains rather than by the prey (Dominic 1978). The substances which act by senses are called "Tellomones" and those which act biochemically by releasing from the exocrine glands in the environment are called "Pheromones" (Karlson and Butenandt 1959).

The pheromones are produced by the exocrine glands whose activity is under the control of hormones. Bruce is of the opinion that their action on the recipient may be either by ingestion, absorption or by olfaction. Mainly they come under the olfactory category for *e.g.* sex attractants of insects. The queen bee substance produced by the Mandibular gland of the queen causing inhibition of ovarian development in the worker bee is one of the examples of orally acting pheromone (Dominic 1978). Mostly mammalian pheromones are of olfactory nature.

Mainly pheromones are categorised into the following:-

1. The Signalling or Releaser Pheromones.
2. The Primer Pheromones
3. The Imprinting Pheromones

THE SIGNALLING OR RELEASER PHEROMONES

Such Pheromones cause "Releaser" effect in the organism which is a central nervous system mediated response, bringing about quick behavioural changes in the recipient *e.g.* sex attractants or love pheromones, evocation of aggregation, recognition etc. or through rapidly acting neurohumoral pathways *e.g.* milk ejection reflex (Dominic

1978). Besides sex attractants, trail and alarm substances also come under this category. Such substances are also seen in the mammalian urine and foot pads where odours play an important role in attracting opposite sexes. These substances have high volatility. They are called Releaser Pheromones helping in sexual attraction, recognition of oestrous females by the male and of her own young ones by the mothers (Dominic 1978). In mice, male urine contains releaser pheromones for attracting females or organising aggressive activities and communicating fear between individuals (Dominic 1978). Brouson found in many other animals like deer, dog, horse and sheep etc. urine containing releaser pheromone which helps to elicit sexual attraction and arousal. Vaginal secretions of sheep, hamster and rhesus monkeys act as releaser pheromones. In Primates including human vaginal secretions contain short chain aliphatic acids called "Copullins" whose function is still unknown as said by Michael. In marine as well as fresh water fishes, alarm pheromones are produced in special flask-like cells of the skin, whenever an intruder approaches a fish. The fish is frightened by the odour of the intruder tadpoles of the toad. Alarm pheromones are produced in the skin cells of a toad tadpole and whenever the tadpole is injured, all other tadpoles in the medium move either to the bottom or run away from the injured tadpole. When the nerve leading to the olfactory organ is cut in the tadpole, no alarm response is seen. Alarm pheromones are also produced in ants in the form of formic acid from the abdomen to protect themselves from enemies. Honey bees and wasps also release alarm pheromones. In honey bee, while stinging she releases alarm pheromones with poison and immediately after stinging she moves to other fellow members of the colony to show her sting and flutter her wings to aggravate the fellow members. Alarm scents are also produced in many mammals like pole cat, *antelope* etc. Whenever an *antelope* is frightened, it produces alarm pheromones from large glands concealed in the fur on the sacral region of the body by the contracting sacral muscles. In many animals like tree shrews of South and South Eastern Asia special scent glands are seen. In this animal the male releases its urine on the branches of the trees and presses his throat gland against various objects to mark the boundaries of his territory. Urine moistened palms are used to mark the tree branches in animals like the *slender loris monkey capuchin*. The Madagascar ring-tail *lemur* presses its tail tip against its odour glands present on the inner right and left forearms and the scented tail is moved in the air to disperse the scent in the environment. It may also rub the gland of the limbs against tree branches to propagate the scent. The Indian *Blackbuck antelopes* mark the territory with secnt produced by the orbital glands of the body. The *Boar* saliva contains odourous steroids that induce a standing response which is essential for the prolonged act of coitus. In rats, a maternal pheromone is produced by

the females for synchronizing the mother and young relationships (Leon 1974). The pheromone is produced by the intestinal bacteria of mothers which attracts mobile young ones.

The male *Musk deer* possesses a sack on the belly whose secretion attracts the females during the breeding season and it helps in marking scent at the territorial boundaries.

(2) PRIMER PHEROMONES

The pheromone induces a delayed response prolonged stimulation mediated through the nervous and endocrine system *e.g.* queen bee substance of honey bee.

Primer pheromones and oestrous suppression in mammals. The unisexual grouping of regularly cycling female mice results in the mutual disruption of oestrous cycles in small unisexual groups of the females which show an increased incidence of spontaneous pseudo-pregnancies (Dominic 1978). According to Whitten in larger unisexual groups, the females exhibit decrease in ovarian and uterine weights.

Primer pheromones and oestrous induction in mammals. Whitten found that a male mouse produces an olfactory acting urinary pheromone which is androgen dependent and acts in low concentration to initiate an oestrous cycle via olfactory stimulation. The oestrous inducing pheromone present in the bladder urine of male laboratory mice free of any accessory gland secretion, rules out the pre-putial gland from being involved in its production. The influence of the male is to stimulate the gonadotrophic secretion in female (Dominic 1978).

Primer pheromones and pregnancy block. Bruce (1960) found that the pregnancy block occurs if male mouse is merely caged inside the female's cage to prevent physical contact. The pheromones responsible for the pregnancy block is present in the urine of intact males.

Primer pheromones and sexual maturity. Sexual Maturity in female mice is accelerated by the presence of an adult male mouse while the presence of an adult female mouse retards it. Drickamer suggests that the acceleration of sexual maturation observed in the presence of an adult male may be mediated by atleast two classes of sensory stimuli *i.e.* odours and tactile stimulation.

(3) IMPRINTING PHEROMONE

In certain laboratory rodents, particularly mice, olfactory influences of the preweaning environment have been shown to affect their adult reproductive behaviour. For example, females of *Mus musculus domesticus* reared with their parents, generally mate males of strains different from their own (Dominic 1978). They however, display sexual preferences for males of their subspecies (*Mus musculus bactrianus*). Such

a sexual preference and aversion of the males of the two subspecies are not exhibited by females which are raised by their mothers alone in the absence of the fathers, thus not exposing to the odour of male parents (Dominic 1978).

INSECT PHEROMONE

In insects, pheromones are produced by the epidermal cell as seen in *Schistocerca* species or it may originate from definite glands present in the body. In different groups of insects different pheromones are produced, which may function as either sex attractant or help in caste differentiation or metamorphic processes which are as follows:

Pheromones in Locust. Mature male *Schistocerca* which are bright yellow in colour accelerate the maturation of other less mature locusts of either sex. The pheromone responsible is produced in the epidermal cells. Its effect is to stimulate the activity of corpora allata probably via nervous system.

Pheromones of Lepidoptera group. The males of Lepidoptera group are often able to produce aphrodisiac scents from glands which are commonly associated with scales. These scales are known as androconia which often occur on the wings as seen in Pieridae and they may be either scattered or grouped together. Comparable scales may occur on the legs or abdomen. In *Ephestia kuhniella*, for instance, the male has dorsolateral tuft of androconia on each side of the eight abdominal segment. Normally these are hidden from view by being telescoped in side segment seven, but are exposed by extension of the abdomen releasing their scent.

In the male of some species, the scent secreting zones is separated from dispensing zone. The male of a Niavious have a small scent patch on each of the hind wings. These contain highly modified scales called scent cups by Elteringham which arise from the upper surface of the wing as dome shaped eruptions with a small median pore.

A sex attractant called "Bombykol" is released by the female silk worm moths, *Bombyx mori* to attract males. The chemical formula of the Bombykol is as under:

$$CH_3 - (CH_2)_3 - CH = CH - CH = CH - (CH_2)_8 - CH_2OH$$

The female gypsy moth *Porthetria dispar* attracts males from over 4500 meters by releasing a sex attractant called "Glypleure" whose chemical structure is :

$$CH_2 - (CH_2)_5 - \underset{\displaystyle O}{\underset{|}{CH}} - \underset{\displaystyle (CH_2)_3}{\underset{|}{CH_2}} - \underset{\displaystyle CH_2OH}{\underset{|}{CH = CH}}$$

$$\underset{\displaystyle CO - CH_3}{\underset{|}{O}}$$

PHEROMONES OF HYMENOPTERA GROUP

1. Communication in honey bee. Honey bees have two important glands producing pheromones: the Mandibular gland in the head and Nassanoff's gland in the abdomen. The mandibular gland is well developed in the queen and the worker but greatly reduced in the drones. They are present nearly in all Hymenopteran insects. Nassanoff's glands are beneath the inter segmental membrane but is absent in drones. In honey bee, a pheromone called 9-Ketodecanoic acid is produced as a pheromone from the mandibular glands which inhibits ovarian development of worker bees.

2. Communication in ants. Many ant species lay scent trails by which they are able to find out their ways. The scent is produced in Dufour's gland or the poison gland in Myrmicinae from Pavane's gland in Dolichoderinae and from the hind gut in Ponrine, Dorylinae and Formicinae. Hence it may be dispersed via the sting, the edge of abdominal sternite six or the anus. The scent marks in ants are made at the territoral boundaries to indicate home route. Wilhelm Gotsch performed experiments with ants and found that ants release a trail of scent marks by pressing their abdomen leaving an odour which is followed by other team mates. This is caused by a pheromone produced by Dufour's gland located at the posterior end of the abdomen above poison containing "Vial" or by Pavane's gland placed below the vial or by some other gland. This pheromone may be called as Marker pheromone.

In Africa the larvae of Driver ants secrete a larval pheromone which nurtures the larvae. Ants discriminate their own nests with other ones. This is done by odours produced from the ants, which are nest-specific. If, by chance, one of the ant member comes in contact with the pheromone of other family member, the other ants of his own family either kill the ant or drive it away from the nest. According to E. Wilson in the ant nest, different pheromones are released to keep normal life of the ants in the nest. Such pheromones are called Organisation pheromones.

Pheromones as sex attractants. Pheromones are employed by large number of insects in bringing sexes together for mating. The details of which are given below:

Pheromones attracting males. Usually the glands producing the male sex attractants in insects are between the more posterior segments of the body and they regulate the release of scent by exposing or covering the glands by the movements of the abdomen or by averting and retracting glands. Normally scent is released at a particular time of the day and are characteristic for the species. Voden *et al* (1972) and Rogoff *et al* (1973) have reported that the female housefly (*Musca domestica*) produces z-(9)-tricosene pheromone to attract males.

Commonly in insects pheromones are not released for a day or two but after emergence they produce it until the females are mated

Sometimes, however, the pheromones attract insects and they are produced before the emergence as seen in the females and males of Megarhyssa of Hymenoptera group. The males may congregate on the tree trunks occupied by the females, waiting for them to emerge. After mating, the attractiveness of females wane in most of the species. The scent is perceived by olfactory receptors on the antennae of the male and it is significant that antennae of many male Lepidoptera which are attracted by the scent, are of pectinate type.

Pheromones attracting females. In many insects, males produce sexual attractants *e.g.* male *Bumble bee* possesses a scent gland at the base of their mandibles which produce male scent. The male secnt is left over the leaves and grasses. The female detects the scent and waits there for the male to come to mate her. Different species show different markings *i.e.* sometimes a mark is made on the lower branches of the trees and their roots whereas, others prefer leaves on the top of the trees. The males of beetle Anthonomes produce sex attractants after the male has caught his prey and has started feeding. The vesicles are positioned between posterior abdominal tergites, by expansion and contraction and the scent is released from the vesicles to attract the female.

Sometimes pheromones attract both sexes. In the timber boring beetles the effect of pheromone is to attract the other member of the species for suitable food. *Lycas loritas* (Coleoptera) pheromones promote grouping. It is a distasteful insect with yellow colour. As a result of grouping, which makes them more conspicuous, predators learn to avoid them more quickly and hence wastage of population is reduced.

The male of *Bombus terrestris*, flies in a circular motion and at intervals the route is marked by scent produced from the mandibular gland.

PHEROMONES OF MAMMALS

Mammals produce many volatile substances which are utilised in communication. They use pheromones for territory marking, individuals and group identity, induction of aggressive behaviour and for reproductive purposes. In mammals releaser, primer and imprinting pheromones are found. In releaser pheromones odour plays an important role in sexual attraction, recognition of oestrous females by the males and of her own young ones by the mother. The urine of the male mice contains releaser pheromones which attract the female and helps in organising aggressive activities. An olfactory CNS from female evokes ultra sounds from male mice that presumably elicit sexual attraction in other mammalian species *e.g.* the deer, mouse, guinea pig, black-tailed deer, dog, horse, sheep and many ruminants.

According to Michael vaginal secretions are also the source of releaser pheromones which help in sexual attraction and arousal in the

males of species like sheep, hamster and rhesus monkey. The active substance consist of short chain aliphatic acids.

Secretions of cutaneous glands in many species are implicated in sexual attraction and evocation of sexual behaviour. The odourous steroids present in the saliva of the boar induce the appropriate standing response (Immobilised reflex), essential for prolonged act of coitus. Leon (1974) reported the presence of a maternal pheromone liberated by the female rats which are involved in the synchronization of mother-young relationship. The pheromone is produced by caecal bacteria of lactating females. These pheromones attract the mobile young and keeps litter together. This maternal pheromone is prolactin dependent (Dominic 1978). The *musk deer* possesses a sac on the belly whose secretion attracts the female during the breeding season. The scent marks are made as territory boundaries.

Releaser Pheromone in the form of alarm scents are produced in many mammals like pole cat, *Amercian pronghorn antelope* etc. When the pronghorn is frightened, it produces alarm pheromone from a large gland concealed in white fur on the sacral region by involuntary contraction of the sacral muscles. In mammals, primer pheromones affect oestrus cycle, pregnancy and sexual motivation (Dominic 1978).

Human reproductive pheromone. In human beings, olfactory sensitivity is comparable to that of the dog but this is suppressed in the adult life for psycho-sexual reasons (Dominic 1978). Olfactory cues are claimed to play an important role in an infantile psycho-sexual development. There is sex difference in the ability to smell certain substances. Women have great power of olfactory sensitivity to certain odours (*Bore* odours in Pork). The changes in the quality of the odours of human female are progesterone dependent and each stage of menstrual cycle has distinctive odour (Dominic 1978). Healthy women's vaginal secretions show volatile aliphatic acids which are released with regular menstrual cycles whose concentration increases during mid-cycle. Michael reported that the functional significance of such volatile acids is not well understood. However, infra human Primates vaginal secretions shows same type of substances by which they possess sex attracting property. McClintock, suggested the existence of a human pheromone.

Sources of mammalian pheromone. The chief sources of mammalian pheromone are urine, faeces, saliva and secretion of cutaneous glands. The odouriferous glands of mammals differ in origin, position and in the nature of secretory products (Dominic 1978). In about 15 to 19 mammalian odours scent glands have been identified and depending upon the location in the body they have been categorised into 40 types (Dominic 1978).

Chemistry of mammalian pheromone. Cis-4 hydroxydodec-6-enoic acid lactone has been identified in the sacral gland of the male black tailed deer, *Odocoilaus hemionus columbianus* (Dominic 1978)

Eight major compounds of which Isovaleric acid is highly active in nature, have been reported in the secretion of the sub-auricular gland of male pronghorn (*Antilocapra americana*). Saturated alcohols and aldehydes are seen in the tarsal scent gland secretions of Reindeer, *Rangifer tarandus*. Methyl ketones have been reported in the secretion of inter digital gland of antelope *Damaliscus dorcas dorcas* (Dominic 1978). Besides these, in different animals trimethyl amine and many other short chain aliphatic acids are found.

Bruce effect. The house mouse is a territorial animal and the female of which under normal situations encounters only her male. Such a female when becomes pregnant from her own male, aborts if she is mounted by a strange male. Not only this, if such an impregnated female would have seen a strange male within 4 days, the chances of abortion would be 50-50. It was further demonstrated that the same failure of pregnancy would result if she were merely placed in a cage where a strange male was kept. These facts suggest that the presence of a strange male in the cage has left something in its urine which leads to abortion or pregnancy block (Bruce 1960). This is known as *Bruce effect*. It was later on found that the pheromone responsible for the Bruce effect is present in the urine of the male and it is some form of Androgen or Testosterone metabolite.

PHEROMONES AS TASTE SUBSTANCES

Lome chusa beetles are found in the nest of sanguinary ants which imitates the behaviour of ants. Whenever beetle and ants come close, it would tap the ants with its antennae. The ants feed on the beetle and in turn ants surround *Lome chusa* to get a liquid drop coming out of their yellow bristles called trychomas growing on the sides of anterior abdominal segments. Just to fetch this liquid from *Lome chusa* ant nurtures *Lome chusa larvae* together with their own young ones although *Lome chusa larvae* and adult eat ant eggs and larvae. Ants take more care of these larvae than its own. In different nest of ants different types of beetles are seen *e.g.* in the nest of meadow ant, *Claviger testaceus* beetles are found. It has been seen that a volatile odorous fluid in the form of pheromone is released from the skin glands and fat bodies located under the trychomes. The worker ants of some species release pheromones which attract ants of another species and they live happily in foreign nests. Similarly few beetles are seen in the nests of termites where visitor releases a pheromone or imitates female termite by having swollen abdomen. Termites generally feed their visitor with same food which they feed the queen and in turn, termites get exudate from the beetle.

DEFENCE AND COMBAT PHEROMONES

Many animals release defense and combat substances in the form of [illegible] in the beetles, crickets,

are offensive, irritating to the skin and eyes, and are of paralytic nature. The glands which release these pheromones are placed either on the head, thorax or abdomen. The bombardier beetle releases a pungent pheromone from its posterior end of abdomen whenever approached by another beetle. A number of poisonous substances like formic acid, metacrylic acid, benzoic acid, methyl quinone, hydrocyanic acid etc. are released in different insects. Blisters are formed over the skin of human beings by the poison of blister beetle. The Centipedes release hydrocyanic acid. Ethyl mercaptan is released by American *Skunk* to victimise its enemy.

Many poisons in the form of combat substances are released in different animals which are used either to kill their preys or repel their enemies. A few poisonous snakes, spiders, scorpions, Centipedes, some wasps etc. discharge poisonous substances, whenever any enemy approaches them. Sometimes a combat substance is released to attract the prey and then to kill it, like that seen in Ptylocerus. Few bugs release some attractive substances from their abdomen to attract ants which lick the secretion to become senseless, after which the bug sucks the ants with its proboscis and the ants are finally killed.

PHEROMONES REGULATING THE BEHAVIOUR AND PHYSIOLOGY OF ANIMALS

Pheromones regulate behaviour of animals e.g. queen bee pheromone blocks the ovarian development in worker bees. This also obstructs the formation of new queen cells. *Chemicromis* fish fry releases a substance in water under whose influence their parents are compelled to take care of their offspring. After three weeks of developments fish fry stops releasing pheromones after which their parents leave them on their fate. In such fishes this pheromone helps parents showing aggressive behaviour to defend its territory.

In many animals, parasites release *Tylacogens* which help in the formation of *Tylacoids chords* in animals functioning as pheromones. Such parasite pheromones may help in disintegrating host tissues or functioning as enzyme inhibitors to stop the action of digestive fluids on the host body. Many helminths, living in the digestive tract of the host body, are protected by this mechanism.

REVISION QUESTIONS

1. What are Pheromones ? Give the role of any two Pheromones seen in Insects.
2. Describe the signalling or releaser Pheromones.
3. Write short notes on the following.
   (*a*) Imprinting Pheromones
   (*b*) Communication in Honey Bees
   (*c*) Sex attractants
   (*d*) Bruce effect

6 COURTSHIP AND MATING BEHAVIOUR OF ANIMALS

Introduction

Reproduction is a multifaceted behaviour. In many animals such as sea—anemones, worms, oysters and—sea urchins, it consists of merely shedding sexual products into the sea, where fertilization takes place. Almost all animals, including sedentary, have in their life histories atleast one brief free living stage during which dispersal takes place.

In higher animals, like birds and mammals, the timing of reproduction is more complicated and fertilization involves both synchronization and mating *i.e.* bodily contact between the sexes. However, normally animals show a behavioural adaptation in which they tend to avoid contact with each other and no doubt form a part of their defence against predators. One of the functions of courtship, therefore, is to break down these natural inhibitions. In addition, courtship results in animals coming together and orienting themselves so that their genital organs may come in close contact.

What is courtship

The term "Courtship" refers to the behavioural interaction that occurs between males and females before, during and just after the act of mating. In some animals, courtship is brief and short but in others, it lasts for a long time and involves vigorous and elaborate displays. The male plays an active role during courtship. It is usually, he that initiates a sexual interaction and display to the female whose behaviour is receptive or non receptive. According to De Morris "Courtship" is the hetero-sexual communication system leading to consummatory sexual act. It is often called "Instinctive activity" but this term is difficult to be defined. A nervous organisation must develop within the animal before sexual maturity, which determines both the form of courtship movements and their link with significant stimuli.

Courtship is not evoked in any animal with mechanical consistency. A male encountering a female may on one occasion court her intensively and on another occasion ignore her. Variations in responsiveness are often called changes in motivation. Many factors affect sexual responsiveness. It may decline temporarily just after coitus or after prolonged unsuccessful courtship. It may drop sharply if an enemy appears. It may fall gradually if the animal becomes ill. It may disappear entirely during the winter months.

WHY DO ANIMALS COURT ?

Sexual reproduction is a usual feature of animal's life and commonly involves the close association of a single pair of animals. There may be external fertilization, simultaneous spawning or internal insemination. For all those methods, there seems no reason why the males and females do this act? However, there are two answers to this question. One can be explained in terms of evolution and the other in terms of mechanism.

In an evolution explanation, the function of courtship is considered as possible reason for its evolution. It provides chances for better survival. It is generally believed that courtship is concerned with reproductive fitness rather than with survival. As such it is not less important, since a sterile animal, how long it lives, cannot influence subsequent generations but reproductive fitness depends upon many factors; among them obtaining a mate, as well as, producing and rearing healthy offsprings are important. Charles Darwin pointed out the winning of a mate as an exceptionally complicated process in which display gives one mate an advantage over another. However Huxley and others have argued that courtship is not a simple process. As Darwin believed, it some times helps male and female to find one another, to indicate suitable breeding sites to one another and to synchronize physiological processes for fertilization. It may help to break down barriers which prevent the mates from coming together. According to Hamilton, sex helps in better survival because it offers unique advantages to the hosts in their struggle against parasites. This argument favours the recombination of large blocks of genetic information resulting from sex, covers up for the information that will make animals susceptible to parasites. Robert Urijenhock and Craig Craddock of Rutgers University have studied wild Minnow fish in Mexico and found out that clones of asexual fish were parasitised by worms more often than the sexual fish excepting in breeding cases. The number of parasites in the inbred fish was almost same number as the asexual ones since these did not have the genetic vitality of the sexually reproducing ones. In an explanation in terms of mechanism it relates to factors, which are present within the animal and promote courtship. It has been shown that a male courts because sex hormones circulating in the blood prime certain nervous mechanisms to respond to stimuli provided by the female.

ROLES OF COURTSHIP

Each of the many varied activities forms a part of the courtship behaviour and has a specific function. One of the most important obvious functions of many displays is that of locating and bringing potential mates at the right time. Once a male and female have come together, the male commonly displays and his behaviour serves to make her sexually receptive. This is obvious in territorial animals but non-territorial white fish also displays it but in specific locality only. In many species, the

mating act is a complex affair and requires both partners to behave in very specific ways at a particular moment if it is to be successful. The function of many courtship activities is to achieve precise synchronization of male and female activities. Finally mating will be only successful in the long term if it occurs between males and females of the same species. Hybrid offsprings are typically infertile and so represent a loss of reproductive potential. Many courtship activities ensure that individuals mate only with members of their own species. Thus courtship fulfills four major functions:

1. Mate finding 2. Persuasion 3. Synchronization
4. Reproductive isolation

(1) MATE FINDING (Receiptive partner — site, smell)

In unisexual animals, the discovery of a suitable mate is necessary for their survival. Recognition of a receptive partner is the first link in the chain of events leading to fertilization. In higher animals, mate finding is a highly organised process, which involves one or more of the senses such as sense of sight, smell, sound, touch and even taste.

For large number of diurnal and some nocturnal animals vision is the primary factor which plays an important role in recognising a mate. Owls and certain insects have special lenses which enable them to find a mate by straight site. Fire flies and many of the inhabitants of the deep ocean have light producing organs which help in mate finding. Sea cows and whales rely upon chemical trails for mate finding on land and scent is very important for bringing the sexes together. In many animals sound produced by the males works as auditory cue by which females locate males.

(2) PERSUASION

Among some animals, meeting of male female leads almost immediately to mating. In many species, usually the male is more ready to mate than the others. After recognising a potential mate, the next hurdle for the male is to bring the female into close proximity. Male performs behaviour patterns whose function is to stimulate the female until she is sexually receptive. The female is generally more valuable than the male because in most cases, she carries the eggs after mating and also plays a larger role in protecting the young. In addition, the male is usually capable of fertilizing more than one female. Therefore, the female requires some persuasion and male plays more active role in courtship. Often, such displays involve a variety of activities that stimulate the female in different ways.

Indeed, the male by no means, is always at first and may have to repeat his releaser signals over and over again before he can induce the female to mate with him. Feminine coyness probably stimulates the male. In animals, as well as, in human courtship, a show of resistance or a

In some cases, the female attacks the male and eats him. In these circumstances, male courtship behaviour may serve not simply to stimulate the female sexually but also to suppress her non-sexual behaviour. Therefore, male establishes his identity as a mate and makes necessary arrangements to remove temporarily the carnivorous instinct of female before he approaches her.

(3) SYNCHRONIZATION

The occurrence of the same behaviour in different individuals at the same time is called synchronization. Precise synchronization of male and female courtship activities is especially important in species in which there is external fertilization. It occurs because both respond to external cues such as day length, lunar cycle, the presence of predators etc. In marine forms, it is related with the tides and phases of the moon.

(4) REPRODUCTIVE ISOLATION

The role of courtship in ensuring that animals mate only a member of their species, is typically achieved because courtship displays are highly species specific. Thus, the signals used for attraction, persuasion, appeasement and synchronization vary in different species. Allied to this, the partner that received such signals is usually responsive only to the displays of its own species. In most frogs, males produce calls which are species specific in terms of their pitch and timing. Female approaches only to the calls of their own species. The antennae of many male moths are selectively responsive to the odours emitted by females of their own species. Consequently, hybridisation between species is exceedingly rare in nature. This is partly due to difference in nature of the organism.

Even then, there may be temporary lack of recognition as male *Grayling* butterfly begins to court another kind of butterfly or a falling leaf mistaking it for a female of his own species. In a similar way, a *stickleback* may begin to court a young tench with deep body and understands wrongly for the swollen abdomen of a female of his own species. Such mistakes do not persist long because recipient of these attentions invariably react and the brief romance is brought to a sudden halt.

Differences in courtship and mating behaviour in different species may be due to either the evolution of different languages which prevent hybridisation or geographical separation. In both cases, distinctiveness has functional advantages.

ORIGIN OF COURTSHIP BEHAVIOUR

The origin of courtship behaviour has been understood from observations of animals in their natural environments. The great ethologist Tinbergen saw that territorial and mating behaviour often coincide and came to the conclusion that there might be some significance of holding territories at breeding times by the courting animals. Breeding territories

are common among Mammals, Aves and Reptiles, sporadic in Amphibians and Pisces, and rare among invertebrates. Usually the males of a species establish themselves early in the breeding season in a separate locality which they defend from other mates of the different species. They proclaim their occupancy by displaying themselves conspicuously by patrolling on the boundaries and attacking the intruders. Later pairing, courtship and mating occur within territory since males and females often remain there together until their young ones are reared.

Territorial behaviour probably has many advantages for a breeding animal. It provides a base by which the male can advertise himself to the female. It provides a protected place where courtship, mating and nest building can occur free from interference. It also provides both protection from predators and sometimes a private food supply close at hand. However, it can complicate the process of pairing and mating by introducing an element of hostility. Hence, territorial males often seem ambivalent (coexistence of opposite emotional attitude) in their approaches to females. Attacks or encounters occur easily in a situation which invokes two opposite kinds of behaviours. Situation of this type are often called conflict situations in which animals behave in characteristic ways. They are restless and disturbed; they change from one activity to another; their movement may be incomplete or distorted and they do apparently irrelevant things. Such behaviour is collectively called conflict behaviour, and Lorentz and Tinbergen see it as a clue to the origin of courtship. Behaviour patterns of courtship vary greatly in different groups of animals.

COURTSHIP IN INVERTEBRATES

In marine forms synchronization of the two sexes takes place and it is related with the tides and the phases of the moon. The Pacific palolo worm, *Eunice viridis* lives among rock crevices below the low tide marks. During breeding season, the hind part becomes packed with reproductive cells. In the month of October or November at the beginning of the last quarter of the cycle of moon, it breaks away and floats upwards to the surface of the sea where genital products are discharged and fertilization takes place. *Eunice schemacephala*, the Atlantic palolo worm, swarms in July during the first and third quarters of a lunar cycle. In the early morning, the worms emerge from their burrows and make spiral swimming movement breaking their epitokal regions.

The lunar breeding of *Odontosyllis enopla* in West Indies is very interesting. This worm swarms during the night at the third quarter of the moon and the shining light from the females attracts the males. The luminescent glow at the surface of the sea lasts only for 5 to 10 minutes. The females appear first at the water surface and emit a stream of brilliantly luminous secretions with the eggs. Males rush in with short intermittent flashes.

Some species of *Nereis* perform nuptial dance, in which males and females swim rapidly in a circle. The females produce a substance called fertillium which attracts the males and stimulates shedding of sperms which in turn excites the females and stimulates shedding of eggs. In case of *N. succinea*, the males first swim to the surface and wait for the females. When the latter appear, the males swim around and shed sperms. In response to this, the females get excited and shed ova.

Certain animals modify their environment to make themselves conspicuous to potential mates. Male ghost crabs dig a deep burrow and build the excavated sand into a pyramid that enables females to find them. Male crickets rub their legs together to produce a typical call from the safety of a burrow which is specially shaped so that sound is greatly amplified.

Mating calls and bird songs still pose many unsolved problems. Peter Mayer of the university of Notre Dame made studies in this direction on grasshoppers. According to him, grasshoppers are difficult to study because they are incurably romantic. He recorded the song of a female grasshopper on a cassette player and kept it in a cage full of male grasshoppers, where he found that the males fell in love with the cassette player.

In many moths, females secrete odours (Pheromones) at night; these are carried by the wind to the males which have an acute sense of smell in their antennae. The males then fly upwind to find the females. During the courtship, male balloon flies of the genus *Empis* present silk balloons to the females as a wedding present. Females are voracious eaters and are likely to attack the males during courtship. So in a few cases, the male presents the female with insect prey wrapped in the silk balloon for her to eat while he mates.

MATING BEHAVIOUR OF *DROSOPHILA*

Drosophila commonly known as fruit fly, is a Dipteran insect. Presently more than thousand species of the genus *Drosophila* are known and nearly two hundred species are known to occur in India. This insect was used for the first time in genetic studies by T. H. Morgan in 1909 and has been recognised as a very good system for genetic studies. In 1915, A. H. Sturtevant described and analysed the courtship of *Drosophila melanogaster* for the first time. Since then mating behaviour of *Drosophila* has been studied by Spieth, Spiess, Manning, Ewing, Bennet-Clark, Ringo, Grossfield, Ehrman, Parsons, Singh and others with special reference to basic nature of mating behaviour, courtship elements, involvement of various stimuli in mating behaviour, intra-inter specific sexual isolation, genetic basis of mating propensity and rare male mating advantage (Chatterjee and Singh 1989).

Mating behaviour of *Drosophila* consists of species specific fixed action patterns which are accompanied by orientation movements. Such patterns are known as courtship displays and involve a number of elements

or signals which are performed sequentially. The male initiates courtship by performing a fixed action pattern directed towards an individual that may be a potential mate. The response of a potential mate to the males pattern results in information being transmitted which enables the two individuals conspecific from non-conspecific males from females and also the physiological readiness of the females to engage in copulation.

After initiating the courtship display, the male terminates its actions at any point in the sequential performance of the signals or he may repeat the full pattern numerous times. If the potential mate is non-conspecific, a conspecific male or a previously inseminated conspecific female then he usually terminates the action quickly. If the individual approached, is a conspecific virgin female, he usually persists until either copulation occurs or one or both flies terminate the encounter. The visually observable courtship signal and orientation movement of both sexes are performed by specific movement of insect bodies (Spieth 1952). Male actions are of two types: those involved in male-to-male encounter and those of male-to-female encounter. In most of the cases the forelegs, wings and mouth parts of the male serve as signalling structures. The female signals are more limited as compared to those of the male and are produced by the wings, legs, genitalia and movements of abdomen.

Females perform these signals in response to the males courting over turns and are divided into two types: rejection response and acceptance

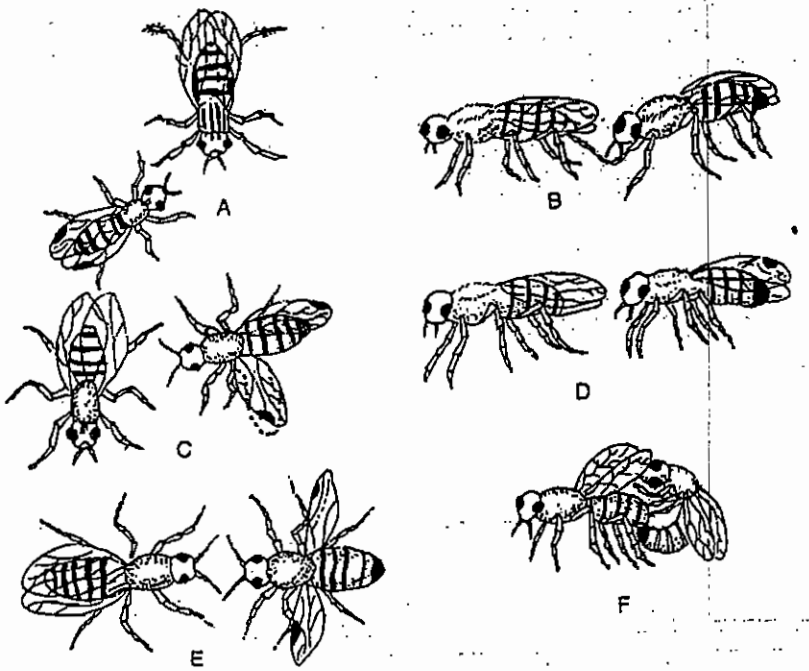

Fig. 1. Diagram showing courtship and mating behaviour of *Drosophila*

response. During courtship a number of orientation movements occur. The most commonly observed one is designated as orientation and occurs when a male visually lives upon a potential mate. He slightly elevates his body, turns to face the potential mate and approaches it after making the physical contacts with a potential mate usually by tapping the male quickly and then moves to the rear of the approached individual and positions himself close to and facing the tip of the other individual's abdomen. Copulation occurs only if the female responds by performing acceptance signals. The male is positioned at the rear of the female when she indicates readiness to copulate. The male mounts and copulates by curling the tip of the abdomen under and forward, simultaneously lunging upwards, and forward thrusting his head under or between her wings (Fig. 1). If she has spread wings grasping her body with his fore and middle leg and then achieving intromission.

Males of many species attempt to mount and copulate with non-receptive females but they are unsuccessful. During copulation the female may walk about and even feed while male is inert except that they periodically stroke the area of genitalic contact with their hind tarsi. Near the end of copulatory period, the female typically kicks vigorously rearward with her hind legs against the face and thorax of the male. These actions may influence the male's behaviour but the physical force is never effective in breaking the genitalic union and it appears that the male determines the termination of copulation. When the male withdraws and breaks away from the female, he falls inertly to the substrate and remains quiescent for a short period before jumping to a standing position. The duration of the copulation is species specific. The shortest time recorded is 5 seconds in *Drosophila enigma* and longest is that of *Drosophila acanthoptera* with 62 minutes.

Male courtship elements. Tapping, wing flicking, wing fluttering, wing semaphoring, wing scissoring, wing vibration, leg vibration and licking.

Female rejection signals. Abdomen elevation, abdomen depression, decamping, flickering, fluttering, kicking, extrusion.

Female acceptance signals. Genitalic spreading, wing spreading and ovipositor extension.

Stimuli involved in mating behaviour. The role of the various stimuli such as visual, chemical (both contact and air borne), auditory and perhaps mechanical has been identified during courtship. The male provides the female with a battery of these stimuli. The function of these stimuli is to inform the female of species identity of the male and to stimulate the female beyond her acceptance threshold for accepting the male in copulation. The female may respond with an acceptance signal or rejection.

During courtship, *Drosophila* males produce wing vibration which results in the production of the courtship songs which have been recorded and analysed. These songs consist of two elements: the sine song and pulse song. The sine song in *Drosophila melanogaster* consists of a humming sound that is reminiscent of flight sounds. The pulse song is comprised of repeated sound pulses separated by time or interpulse intervals. Pulse song exhibits variation between the species in the number of cycles per pulse, pulse repetition rate and duration of interpulse intervals. Both males and females are capable of receiving auditory courtship signals via their antennae whose aristae serve as velocity sensitive receptors. Flies of both sexes that lack wings and aristae are mute and deaf.

The role of olfactory stimuli in the form of pheromones in mating behaviour of *Drosophila* has also been suggested. The main olfactory receptors of both sexes are located on the third antennal segment. The males of Hawaiin *Drosophila* species exhibit lek behaviour and pulsate abdominal droplets of clear fluid for prolonged period of time. Volatile pheromones are produced by both sexes which are essential in initiation of courtship. During courtship species specific fixed action movements result in physical contact between males and females. The structures most widely used for such movements are the male forelegs and mouth parts. As a result of these physical contacts mechanostimuli or chemostimuli or both may be transmitted between the individuals. Visual stimuli play a role in *Drosophila* mating behaviour. All species court during the period of daylight and some also court in darkness. However, no species restricts its courtship only during darkness. It has been shown that presence or absence of light has a profound effect on mating behaviour of *Drosophila*. Various species exhibit varying degree of light dependency in their mating behaviour. They have been classified into three different categories (*a*) Light independent - the species mate effectively in darkness also, (*b*) Light dependent - the species are unable to mate in darkness, and (*c*) Facultative species are those which are depressed by darkness but can achieve some copulation (Chatterjee and Singh 1988). In light dependent species the important component of courtship appears to be visual. In some species males possess a dark black patch on their wings which serve as a visual stimulus to the females during courtship (Singh and Chatterjee: 1987). Thus there is ample evidence to show that during courtship exchange of various stimuli between male and female takes place and mating occurs only when both sexual partners reach a state of physiological readiness.

Sexual (Ethological) isolation. It has been defined as lack of mutual attraction between males and females of different species due to behavioural incompatibility which constitutes the largest and most important class of reproductive isolating mechanism in animals. The individuals respond in such a manner to the stimuli they receive from the individuals of opposite sex belonging to the other species, that mating does not occur. Thus the word Ethological isolation refers to the different behavioural patterns of a species by which it remains separate from another species. Ethological isolation becomes a barrier to mating due to incompatibility in behaviour. Males of one species have specific courtship patterns to which only females of the same species are receptive. The specific reaction of males and females towards each other is known as species recognition. In most cases, it is the males which actively search for the mate. The phenomenon of sexual isolation has been extensively studied in *Drosophila* and has been found to be widespread. A large number of investigations have been carried out in different species of *Drosophila* by several workers (Chatterjee and Singh: 1989; Singh and Chatterjee: 1991) who have demonstrated that complete sexual isolation exists between same species but is demonstrated in other species. It is known that it is the females which exercise discrimination. Mating isolation is based on production and reception of various stimuli by sex partner. Sometimes geographic population or strains of the same species may show incipient sexual isolation as a result of genetic divergence caused due to natural selection and genetic drift. The degree and pattern of mating performance have often been used to know the phylogenetic relationship among closely related species (Singh and Chatterjee: 1985; Chatterjee and Singh: 1989).

Sexual selection. According to Darwin, sexual selection is the advantage which certain individuals have over others of the same sex which affects the efficiency of sexual behaviour exerts selective differences which are of considerable significance for gradual perfection of the sexual process. Reports on sexual behaviour in the genus *Drosophila* clearly shows that efficiency of mating varies for different genotypes which provides evidence for sexual selection in *Drosophila*. It has been demonstrated that various mutations and inversions of karyotypes affects sexual activity, further more, males contribute greater, to the variance of next generation and are inherently more subject to intrasexual selection (Singh and Chatterjee 1986, 1988). It is an interesting phenomenon demonstrating the existence of frequency dependent sexual selection. When two strains of the same species are present together the rare type is more successful in mating than the common. This phenomenon is of considerable evolutionary significance as from the view point of population genetics. It may represent a way of maintaining a high level of genetic variability in natural populations without genetic load at equilibrium.

MATING BEHAVIOUR OF SCORPIONS AND SPIDERS

In scorpions and spiders, the male not only stimulates the female sexually but he has to suppress the non-sexual behaviour of the female so that she does not eat him. In Ethological terminology, the function of courtship is to provide releaser stimuli which block hunger drives.

In scorpions, courtship takes the form of a dance called "Promenada a deux" by Fabre. On finding a suitable mate, the two scorpions stand face to face with their tails upraised and intertwined. The male seizes the pedipalp of the female with its own (Fig.2) and the two animals go on

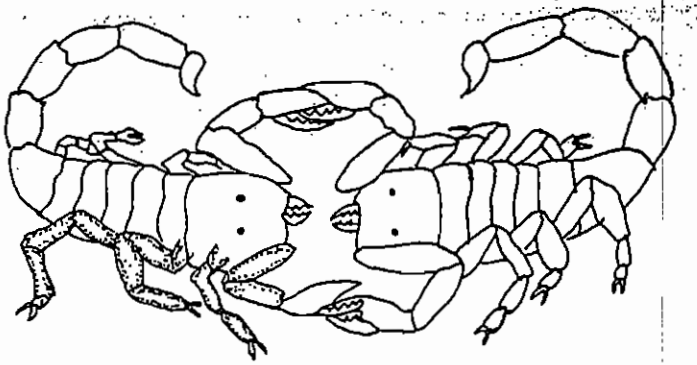

Fig. 2. Diagram showing courtship dance of the male and female scorpions by seizing the pedipalp.

moving round and round for an hour or more. When the dancing pair reaches a suitably firm surface which the male apparently detects with his pectens, he deposits a capsule of sperm (Spermatophore) on the ground and forcibly jerks his partner over it. There is no coitus, only spermatophores are sucked in by the female in her genital aperture when she lowers her body.

Spiders are nearly always offensive. They are ready to kill and eat the animals of small size that come within their range. They are invertebrate cannibals, so mating is difficult and dangerous to the male who is smaller and weaker. In such circumstances, male courtship behaviour not only stimulates female sexually but its non-sexual behaviours are also suppressed. Among web builders, the male vibrates the female's web with a characteristic rhythm, indicating that he is a potential mate and not a prey. In some species, male spiders present the female with a "Nuptial gift" consisting of an insect wrapped in silk. While the female unwraps the gift and eats the insect, the male is able to mate with her, without being attacked. The mating procedure is quite unique. Male weaves a small pad of silk on which a drop of sperm is deposited and this is sucked up by specially modified pedipalps. In due course of time, this is inserted

COURTSHIP IN VERTEBRATES

The most important display of courtship is presented by the spin*stickleback*. Male adopts sigmoid posture and swims with the female. After some time he leads her to his nest and nudges the base of her t with his snout. Then she leaves the nest and the male immediately follows her shedding his sperms on the eggs released by the female.

In salamanders, scent is the main factor in recognition of sex and species. Males and females are of different colours and small in size a each species has its own peculiar smell. In the males, the "Hedonic glands" are located mainly at the base of the tail and on the underside of the he Although the females lack any readily differentiated glands, their skin secretion evidently possesses the odour that enables the male to ident them as to which species and sex it is. After finding a mate, the male rubs its chin against her head, so that, she may smell his perfume. He captu her with his tail and invites her to dance. The dance may consist of him transporting her on his back or joining together making a figure of ei around each other. In certain species, the female straddles placing her head on the base of the male's tail and then the two waddle togethe this position. The male of two lines Salamander, *Eurycea bislineeta* applies a secretion from glands on his head on to the female's skin. He th lacerates her skin with two protruding teeth so that the secretion enters her blood stream (Fig. 3). In most Salamanders fertilization is internal b it is accomplished in a manner different from that employed by mammals where the male feels that the female is sufficiently excited. Ma Salamander deposits a small jelly of covered package of spermatozoa known as spermatophores, either on land or in water according to t habit of his species; female comes and picks up one of the spermatophores with the lips of her cloaca. It is then placed inside her body in a spec receptacle known as spermatheca where the sperms remain to fertiliz

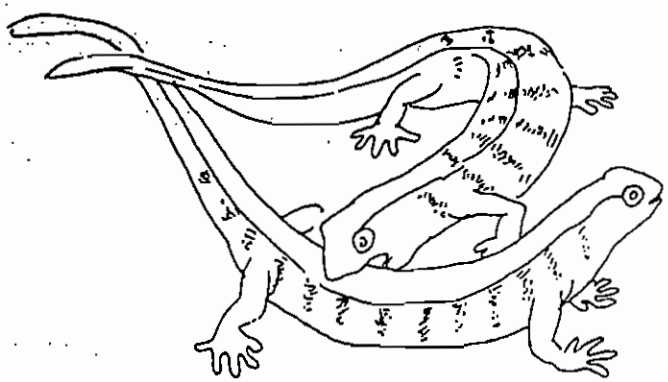

Fig. 3. Diagram showing courtship of two-lined salamanders (*Eurycea bislineata*).

the eggs. The male newt, *Triturus* develops a large crest, black, blue and red spots; and an orange belly in the breeding season. He performs a dance to attract the female. If she follows and touches his tail with her snout, he deposits spermatophores which are picked up by her cloaca. Just after, he again renews his dance and deposits two or three more spermatophores before his arrival to the surface for breathing. She picks up these spermatophores once again. The female thus tests the vigour of the male. According to Halliday the chance of fertilizing the female by the male depends on how long he can stay submerged and the number of spermatophores he can produce. Sperms may be stored for many months in a spermatheca. Fertilization takes place in the oviduct and then eggs are laid separately wrapped in a leaf. Male bullfrogs produce advertisement calls by their vocal cords and amplify them by inflatable sacs present in their mouths because, probably louder and longer calls are more attractive to females, and more inhibitory to other males. Females are attracted by such calls and clasped by males in a state termed "Amplexus". Ova and sperms are released simultaneously and fertilization takes place. Many reptiles exhibit well marked courtship and display phenomenon during the breeding season. The males of certain lizards fight and display ritually either to terrify each other or to evoke a suitable response from the female. The male American *Chameleon, Anolis carolinesis* displays a rhythmical up and down bobbing of his body to show his dewlap, a bright red spot beneath the skin. As the female approaches the male, the latter twists his tail around that of the female and inserts his hemipenis.

In case of the spotted turtle, when a male approaches a female, the usual response of the latter is to move away but often she looks coyly over her shoulders to make sure that he is following her.

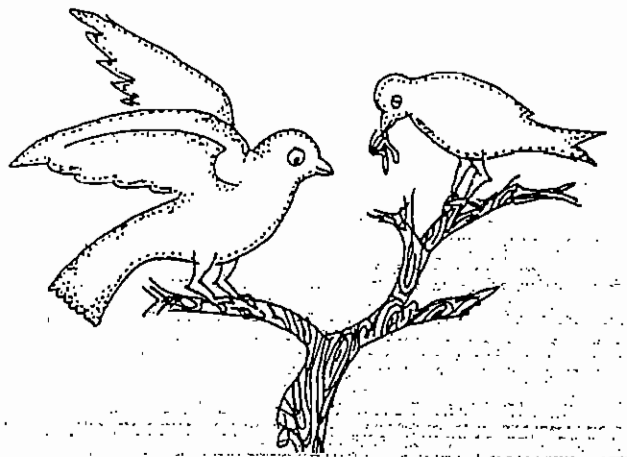

Fig. 4. Diagram showing male Kestrel passing prey to female.

In birds, phenomenon of display and courtship attain a complexity incompatible to man. A song is often an initial feature of the ritual and first attracts and excites the female. The male sex is frequently aggressive in defense of territory. Consequently, courtship in females often takes the form of reactions which tend to avoid provoking of the attack. For example, female gulls show infantile behaviour reminiscent of the appeasement employed by the young. Ceremony begins by offering food to each other which is a behaviour pattern carried over from infancy (Fig. 4).

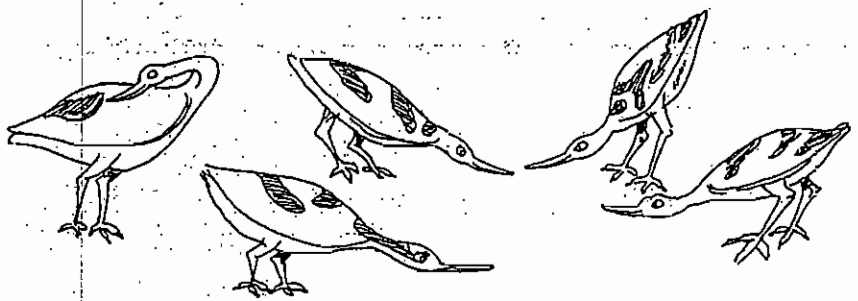

Fig. 5. Diagram showing displacement – preening courtship and group display among *Avocetes.*

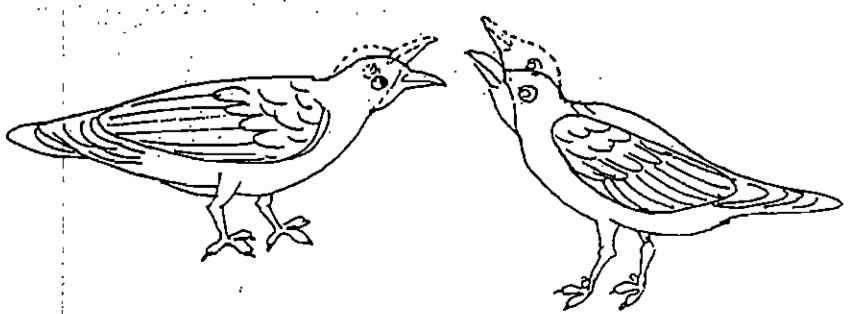

Fig. 6. Diagram to show pre-coition display of gull.

In Avocetes, male and female both preen their feathers in hasty fashion during courtship (Fig. 5). After preening the female adopts a characteristic flattened attitude which is the sign that she is ready to mate and only then the male mounts and copulates. The precoition displays of herring gulls, *Harus argentatus* is also very interesting. Both male and female bob their heads upwards uttering a soft melodious call with each bob (Fig. 6). After a series of such mutual head tossing, the male takes the initiative in copulation and suddenly mounts and mates.

The great crested grebs, *Podiceps crestatus* show some of the most elaborate courtship and pair-bonding which is not found anywhere in the animal kingdom. The courtship ceremony consists of a series of behaviours such as head shaking ceremony; dive and cat display; mutual gretting and cat displays; and penguin dance (Fig. 7). Sometimes, the birds go through a head shaking ceremony in which they raise their conspicuous crest, face each other and shake their heads emphatically from side to side. Sometimes when a pair comes together, one bird dives while the other waits in extraordinary cat attitude. The diver then emerges with its back to the other bird and settles close to it. Alternatively, the cat attitude may be part of a mutual greeting in which one bird shows the display while the other rises out of the water in front of it. There often follows penguin dance in which both birds dive and reappear with bunches of weeds in their bills. They swim towards one another, and then spring upright and move together shaking their heads. The brilliantly coloured bower birds of Australia, New Guinea and neighbouring islands build display grounds and decorate them with various subjects such as flowers, stones, shells etc. The satin bower bird *Ptylonoihychus violaceus* of East Australia constructs a bower with two parallel walls of arched twigs (Fig. 8). On one side of it is a display ground in which is found assemblage of things and varieties of decorations. It may contain upto seventy blue parrot feathers, flowers, fragments of glass, papers, shells, wasp nests etc. Display begins with sunrise and may occur throughout the day except during feeding, bathing, preening or calling. The male stands squarely on his territory making a whirring noise, arches his tail in fan-like manner and stiffens his wings, at the same time holding his neck low and erect. His plumage glistens magnificently while eyes bulge and become rose red. The somber female

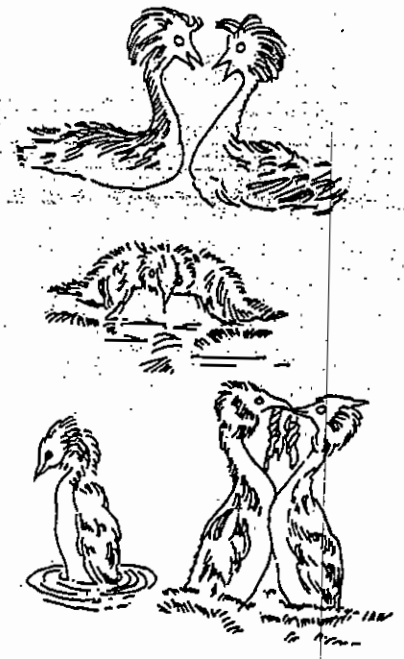

Fig.7. Diagram to show ritualized courtship dances in the great-crested grebe (*Podiceps cristatus*).

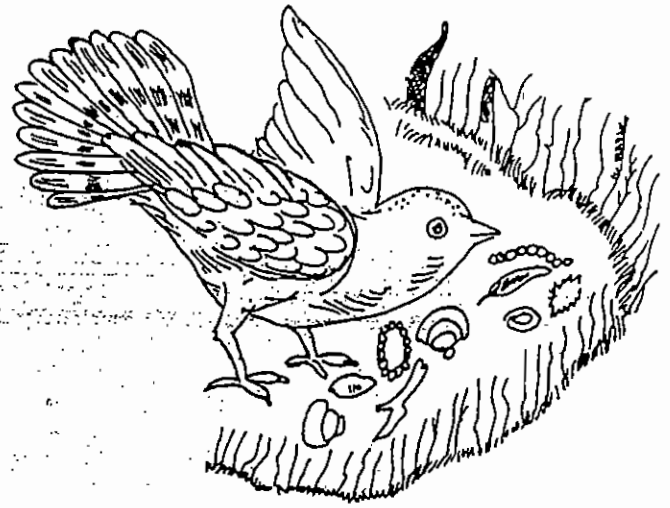

Fig. 8. Diagram to show satin bower-bird on its display ground.

utters convulsively a few guttural sounds. Occasionally, she arranges the disordered twigs of the bower. In the mean time the male shies violently sideways, hops or runs quickly forward and backward. The male then suddenly snatches up one of the display objects and hops excessively around the decoration. The courtship behaviour of the Indian peacock is very fascinating. While courting, the peacock spreads its beautiful tail whenever a peahen approaches but as she comes near him, he takes an about turn, showing her his rear portion. Now if peahen is ready for mating, she will run swiftly around the tail to be able to see it from the front again. The cock responds by rustling his tail feathers. Then he turns around again and this courtship game will be repeated several times. At last the peahen lies down in front of him giving signal for mating. In mammals, olfaction plays a major role in the regulation of courtship behaviour. After smelling a female, the males of many species display a response in which neck is extended and the upper lip is curled. Female often solicits mountings. Sometimes by approaching a male she muzzles or licks him. Often she runs away from the male when approached but appears again as solicitation behaviour starts and then she escapes. In the case of red deer, the female deer (hind) frequently runs away when approached by the male deer (stag) but she soon stops and waits for him, licks him and then runs again only to wait once more for his approach. In bottle- nosed dolphins vocalization, nuzzling of the partner's genitalia, rubbing of bodies, stroking with flucks or flippers, displaying of the underside, chasing an head butting occurs during courtship. The puzzle of the lek is

still unsolved. In guppies, birds and mammals a lek is seen which is a vast conglomeration of male animals which attract females by virtue of their large numbers. The females then choose a mate and rest of the males are left behind. Why do all the males conglomerate and what is the advantage for the males which are not chosen in this race? The reply may be on the line of ancient Indian Swayambara where a female used to select her male partner from the crowd of males (The Hindu News 1992).

REVISION QUESTIONS

1. Describe courtship and mating behaviour of animals.
2. Why do animals court?
3. Describe in detail courtship in invertebrates.
4. Write an essay on mating behaviour of Drosophila.
5. Write a short note on sexual isolation.

7 COLOURATION AND MIMICRY

Most animals are in potential danger of being eaten by another animal at some time in their life. Their survival depends on how they are adapted in an environment in which they inhabit. They have evolved some ways to diminish the danger. A wide spread method is to acquire a garment of invisibility (Camouflage). This is very common among animals and it occurs in many forms and degrees. The reason why it is so common is because of the struggle for existence. The simple form of Camouflage is colour matching and the complex form is Mimicry.

COLOURATION

Colouration is one of the protective adaptations which has protective value for harmonizing with the surrondings. The effect of colouration is concealment because the animal becomes indistinguishable from the background. Concealment of an animal is possible by counter shading disruptive colouration and colour harmony.

In polar regions, the animals like polar bear, polar fox etc. are white and thus are invisible in the white background of the snow. Similarly, the snakes, tree frogs, grasshoppers, caterpillars etc. living in foliage have green colour and show concealing effect. Many desert animals have light brown or sandy colour which harmonises with the sand. Sometimes, counter shading and disruptive colouration also helps in concealment. Some animals like flat fishes, tree frogs and *Chameleons* change their colours to harmonise with their surroundings. Many insects inhabiting barks of trees, the harmonise with the colour of the bark. A spider places itself in the middle of a little patch of lichen where its self-effacement is complete.

WHAT IS COLOUR ?

The Trichromatic theory of colour vision describes that the colour is perceived by comparing the levels of excitation of three different types of cones which are reactive to red, green or violet light. The comparison is carried out both in the nerve circuits, in the retina of the eye and in the visual centre of the brain. In animals, fishes and birds posses good colour vision. Most of the mammals excepting primates and few species of squirrels, are colour blind. In animals the general body surface causes physical colouration where a falling beam is refracted and broken down

into its component rays. The chemical colouration is produced due to the presence of fragments in the body on its outer surface. Different fragments have different absorptive powers and on oxidation produce different colours. Animals may be provided with pigment containing changeable pigment spots of chromatophores which change skin colour from time to time.

Animal colouration is of three types which are as follows:

1. Structural colours
2. Iridescent colours
3. Integumentary colours

Structural colours. In many insects and birds, few colours are generated by the physical constitution of the surface layer by reflecting certain wavelengths of light and eliminating others. They are known as structural colours.

Iridescent colours. Such colourations are produced due to reflection of light from many layers of thin, transparent film. Mostly brilliant colours are produced due to phase interference when light wave weakens or eliminated to produce colours.

Integumentary colours. These are produced by pigments or biochromes which reflect light rays. Such pigments are seen in branched chromatophores of crustaceans and some vertebrates. They may be concentrated in the centre of the cell or dispersed throughout the cell and its processes but in Cephalopods, chromatophores have a sac-like cell filled with pigment granules surrounded by muscle cell.

Following types of pigments are seen in different animals:

1. **The melanins.** Black or brown coloured group of polymers producing earth coloured shades in the body of animals.
2. **The carotenoids.** These are yellow and red colour producing pigments contained in special pigment cells called Xanthophores. Vertebrates receive this from plants because they are unable to synthesize this pigment.
3. **Iridophores.** They contain crystals of guanine or some other purine rather than pigment which gives silvery or metallic effect to the body by reflecting light.

Besides these three important classes of pigments, there are other classes called ommochromes and pteridines which are seen in molluscs and arthropods producing yellow pigments of the body. The green colour of the body which is of rare occurrence is produced by the combination of yellow pigment overlying blue structural colours. According to Metchnikoff, the wandering amoeboid cells of the body called phagocytes may creep up into the hair and come back again with microscopic burdens of pigments. The place of pigment is taken by gas bubbles and cause the

whiteness. The white colour is like that of snow or foam due to the complete reflection of light from innumerable minute surfaces of crystals or bubbles. Generally mammals are a somber coloured group excepting that which is seen in coloured patches of some baboons and mandrills. The melanin deposited in growing hair by dermal melanophores is responsible for muted colour of mammals. Primates can appreciate different colour type seen in animals due to the presence of colour vision. In man, red colouration of skin is due to sun burn which is caused due to the damage in the epidermis and dermis regions of skin by Ultraviolet radiation where histamines and other vasodilator substances are accumulated producing redness of the skin. Sometimes photo-oxidation of pigment melanin in the skin produces a different colour of skin.

CAMOUFLAGING

Many animals living in sandy places have a light brown colour, as is seen in some lizards and snakes. The green lizard is like the grass and the green tree snake is inconspicuous among the branches. The spotted leopard is suited to the interrupted light of the forest.

GRADUAL COLOUR CHANGE

Some animals change their colour gradually with the change of the surroundings thus becoming less conspicuous. The young common shore-crab shows many different colours and mottlings. It may be green or grey red or brown and so forth depending on the colour of the rock pool where it is inhabiting. Experiments have shown that the colour of the new shell tends to harmonise with the general colour of the rocks and sea weed. The colour seems to change with the next moult. A full-grown shore-crab is well able to look after itself so does not change with the next moult It is very interesting to note that variety of colouration is mainly found among the small individuals who ofcourse, have a much less secure position.

In his experiment, Professor Poulton observed that in black surroundings the pupae of the small tortoise-shell butterfly tend to be darker, whereas they become lighter in white surroundings and appear golden in glided boxes. It appears that the surrounding colours affects the caterpillars through the skin during a sensitive period *i.e.* twenty hours immediately preceding the last twelve hours of the larval stage making the quiescent pupae less conspicuous during the critical period of metamorphosis.

SEASONAL COLOUR CHANGES

The *Ptarmigan* moults three times in a year. Its plumage is rather grouse-like above, with a good deal of rufous brown in summer; in autumn the back becomes much more grey; and in the winter almost all feathers are white. The white winter plumage makes the *Ptarmigan* very

from the hungry eyes of golden eagles. Similarly, the brown Stoat becomes the white Ermine mainly by the growth of a new suit of white fur. The same is true for the mountain hare. The mountain hare may escape the fox more readily because its whiteness makes it very inconspicuous against the background of snow.

RAPID COLOUR CHANGES

Bony flat-fishes such as *Plaice* and *Sole*, have a remarkable power of adjusting their colour and pattern to the surrounding gravel and sand so that it is very difficult to see them even when we know that they are there. They are also very quick to get a sprinkling of sand over their upturned side. It may be affected within a few minutes or in some cases even in a minute. Probably, their self-effacement often saves their life.

In these self-effacing flat-fishes, the adjustment of colour and pattern is due to changes in the size, shape and position of the mobile pigment cells, chromatophores in the skin. The colour and the pattern of the surrounding affects the eyes. The message travels by the optic nerves to the brain. From the brain, instead of passing down the spinal cord, message travels down the chain of sympathetic ganglia. From these, it passes along the nerves which come out of the spinal cord and control the skin. Thus the message reaches the pigment cells in the skin and the flat-fish soon becomes invisible.

In cuttle fishes also the same power of colour change is seen. It occurs with much suitability in the *Aesop* prawn, *Hippolyte*, which may be brown on a brown sea weed, green on sea lettuce or sea grass, red on red sea weeds and so on. Professor Gamble writes "According to the nature of background the pigment's compound form a close reproduction both of its colour and pattern."

Colour change in chameleons. The highest level of rapid colour change occurs among lizards. *Chameleons* are adapted for life on trees where they hunt insects with great deliberation and success. When they wish they can make themselves very slim contracting the body from side to side so that they are not readily seen. The power of colour change is remarkable and depends partly on the contraction and expansion of the chromatophores in the dermis and partly on close packed refractive granules and crystals of a waste product called guanine. The repertory of possible colours in the common *Chameleon* is greater than in any other animal except the Aesop prawn. The so called "*Chameleon*"(Anolis) of North America is so sensitive that a passing cloud makes it change to emrald hue.

There is no doubt that a *Chameleon* may make itself more inconspicuous by changing its colour, being affected by the day or light on its eyes. A bright green hue is often seen on those that sit among strongly illuminated green leaves. The colour also changes with the time

of day and with the animal's mood. A sudden irritation may bring about a rapid change in the *Chameleon* which is peculiarly interesting because

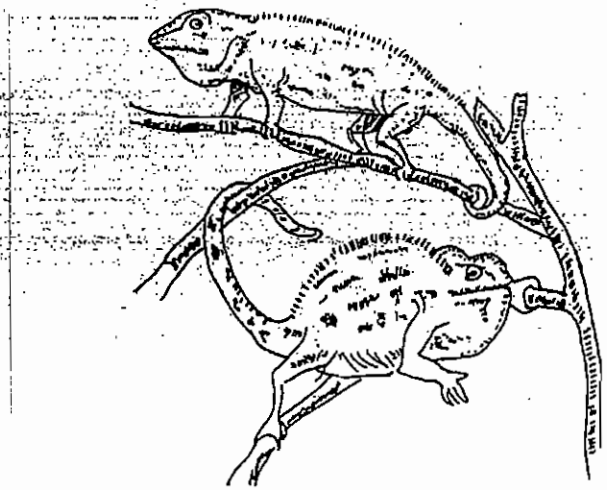

Fig. 1. Diagram showing rapid colour change in *Chameleons.*

the animal has two tactics: self-effacement on one hand and bluffing on the other. Dr. Cyril Crossland observed that a *Chameleon* attacked by a dog-terrier, turned round and opened its great pink mouth in the face of the advancing dog, at the same time rapidly changed colour and became almost black in natural leafy surroundings. This alarming effect would be much greater by sudden throwing off, the mantle of invisibility and exposure of a conspicuous black body with a large red mark (Fig. 1).

WARNING AND SIGNALLING COLOURATION

There are also protective colours of warning and of recognition. In some insects, there are warning colours such as red, yellow or black. These colours advertise to unpleasant taste, toxic nature and foul smell.

Butterfly *Danaus* has warning colour. It never tries to hide but flies boldy exposing its colour. The enemies avoid it as food, as they know that butterflies are of an unacceptable nature. Wasps also show warning colours. Torpedo possesses blue spots which advertise the danger of electric shock. Other examples showing conspicuous colouration for the purpose of advertising themselves are *Heloderma*, porcupines and rattle snakes etc.

MIMICRY

In simple camouflaging, the animals match the background but there are other animals which resemble a particular inedible part of a plant in the environment. Many looper caterpillars, stick insects and some praying mantids closely resemble individual twigs or sticks, while certain brush crickets and leaf insects are precise mimics of green leaves, complete with apparent veins.

The meaning of mimic is imitation. The imitating individual is called mimetic form or mimicker and the object which is imitated or copied is called "Model" or "Mimicked". The phenomenon is which animal resembles some other animal, plant or other natural objects of the same habitat, is called "Mimicry". The resemblance is in colour markings, shape, size, structure and other details. This is the highest form of camouflage and marvellous device for protection. The theory of mimicry is that the mimickers live on the reputation of the mimicked. It was propounded by the English naturalist H.W.Bates in 1862 on his studies of butterflies from the forests of Brazil. The word mimicry comes from the Latin word "Mimicus" or Greek word "Mimikos" meaning to imitate closely. According to Bates mimicry can be defined as the resemblance in external appearance, shape and colour between members of widely different families. At the International Zoological Congress in Washington in 1963, mimicry was defined as "The superficial but close resemblance of one organism to another or to natural objects among which it lives, that secures concealment, protection and some other advantage by which it escapes itself from observation or advertises itself being harmful". Mimicry can be classified into following three categories:

1. Protective Mimicry
2. Conscious Mimicry
3. Aggressive Mimicry

PROTECTIVE MIMICRY

In this type of mimicry, animal mimics some other organisms or the natural objects in form, colour or behaviour and protects itself from predation. Protective mimicry is obtained either for camouflaging or concealment or for warning so it can be studied under two heads: camouflaging mimicry and warning mimicry.

Camouflaging or concealment mimicry. This type of protective mimicry is very common in the animal kingdom. Here animal conceals itself by matching its colour with the background. A crab, *Cryptolithode* harmonises so perfectly with white pebbles on the beach that it is sometimes very difficult to recognise it. Its rounded shape, texture and white colour almost completely resembles the pebbles. The pupae of swallow tail butterfly, *Papilio machaon* appear green when attached to plant leaves and grey when attached to stems.

Sometimes animal is not able to change its colour and itself moves to some suitable background. The caterpillar of geometric fine moth, *Bufalus finianus* possesses green colour with white longitudinal stripes because it is seen on fine needles protecting itself from predatory birds. The caterpillar of noctuid moth, *Hyloicus finasten* is blue green with six longitudinal white stripes and rests on fine needles but after moulting, it occupies brown twigs and becomes brown in colour with irregular white

Sometimes, an animal mimics the living or dead objects. Several butterflies are leaf-like in appearance resembling either a dead or withered leaf or its petiole. Indian dead leaf butterfly, *Kallima paralecta* possesses

Fig. 2. Diagram showing protective colouration in leaf butterfly, *Kallimn paralecta.*

brown colour or under surface of the wings resembles a dry leaf (Fig. 2). Whenever it sits over a plant its wings are folded upwards and it resembles dry leaf (Fig. 2) other examples are the Catterpillar of moth and leaf insect (Fig. 3 and 4) stick insect resembles a dry stick. Similarly leaf insect *Phyllium* resembles a green leaf upon which the fungus or rust is grown

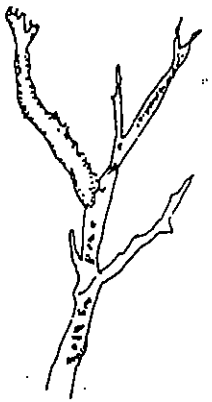

Fig. 3. Diagram to show protective colouration (resemblance) in

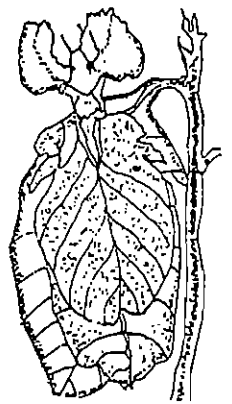

Fig. 4. Diagram to show protective resemblance of leaf insect, *Phyllium*

because its body is flattened, green, leaf-like and possesses yellowish spots. The preying mantid, *Phyllocrania paradoxa* resembles a dead, shriveled brown leaf. Several frogs and toads from South America are flattened and mimic dead brown leaves on the forest floor.

b) **Warning mimicry.** In this type of protective mimicry, non-poisonous and harmless organisms mimic the poisonous and harmful organisms and the palatable organisms resemble to be non-palatable. This is very common in reptiles. For example *Heterodon*, which is a non-poisonous snake, flattens its head and hisses like a poisonous snake. In insects, the palatable viceroy butterfly, *Ementis* mimics the non-palatable monarch butterfly of the genus *Danaus* (Fig. 5). In some butterflies, only females resemble

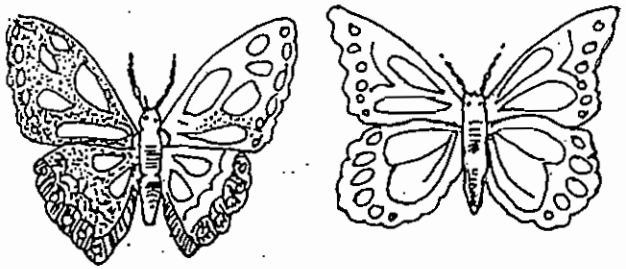

Fig. 5. Diagram showing warning mimicry.

with distasteful butterflies. Female *Papilio dardanus* of Africa mimics an impalatable *Danoid* butterfly. A moth, *Sesia crabroniformis* mimics wasp, *Vespa crabo*. A few spiders living in association with ants develop some warning colour and general appearance as that of ants and thus are mistaken as ants by their enemies (Fig. 6). This imitation by a harmless species of a protected one is called Batesian mimicry. Thus in Batesian mimicry, an edible species resembles an inedible one. Muller found out that several species of butterflies are not edible by birds because they resemble inedible or unpalatable species. This type of mimicry is called Mullerian mimicry.

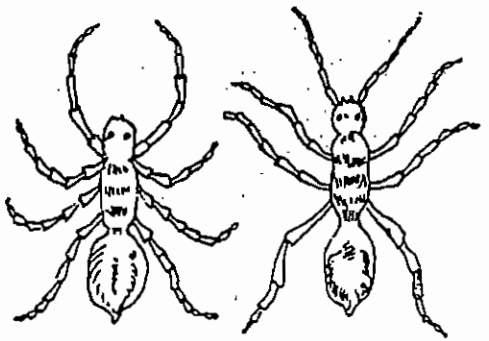

Fig. 6. Diagram showing warning mimicry.

Conditions for protective mimicry. Wallace summed up some conditions for protective mimicry. These are as follows:

1. Mimicker and mimicked (model) must occur in the same area and same situation.
2. Mimickers are always more defenseless and the model is avoided by enemies.

3. Mimickers should always be in lesser number than the models, otherwise bluff will be exposed.
4. Mimicker should differ from bulk of their allies.
5. Imitation should be external and visible.

2] CONSCIOUS MIMICRY

Many animals behave as dead bodies when they feel any danger. Such conscious imitation in called Conscious Mimicry e.g. in American *Opossum, Didelphis virginiana* and in some beetles drop like pebbles, when they are about to be captured and lie inert after falling.

3] AGGRESSIVE MIMICRY

This type of mimicry is mostly exhibited by the carnivorous animals like fishes, spiders etc. They either conceal themselves to the surroundings or allure the prey. Depending on these, the aggressive mimicry is categorised into the following:

a) 1. Concealing Mimicry
b) 2. Alluring Mimicry

a) **Concealing mimicry.** In this type of mimicry cryptic colours are developed in animals to blend with the surroundings so that they are not easily differentiated. It helps the animals in getting their prey easily. E.G. Peckhammian observed that the zone-tailed hawk, *Butec olboonotatus* flies with vultures in America closely resembling in colour and shape of the wings with vultures. Similary a species of beetles resemble wasps. The spider *Amycela lineaopis* resembles the red ant in shape of body and colouration. However, the resemblance is always superficial and never anatomical in character *Phyllopteryx* (Fig. 7) an Australian fish which lives in seaweeds and resembles *Hippocampus*.

Fig. 7. Diagram showing frightening colouration in *Phyllopteryx*.

Alluring mimicry. Here, animal camouflages with the surrounding and possesses some lure to attract its prey so that the misleaded animal falls a victim to the mimicker. *Laso* and *Bolo* spiders show this type of mimicry. They form a single horizontal thread from which they hang. Another trap thread in the form of a terminal sticky droplet is provided which is grasped by one of the legs of the spider. This trap-thread is aimed at the prey flying near to the spider. Another example is that of angler fish, *Lophius* which camouflages at the sea bottom. It possesses illicium, a modified first fin-ray of the dorsal fin placed on the dorsal edge of the upper-lip at some distance in front of the mouth. This structure possesses a fleshy cutaneous appendage in the form of a bait at its free end and is rotated freely in its ball and socket joint. If another fish approaches this, the *Lophius* kills the prey immediately.

CAUSES OF MIMICRY

Different workers have given different opinions. Weismann was of the opinion that Natural Selection is the only reason responsible for production of mimicry. He also suggested that occurring between the white butterflies and Heliconidae depends on selection. In contrast to this view, it is argued that mimicry is not of any selection value. Another explanation of mimicry is that minute forms may have arisen as a mutation and that two forms persisted. However, whatever the cause may be secondarily operating, resulting in colouration and mimicry, Natural Selection is the main cause.

REVISION QUESTIONS

1. Write an essay on colouration and mimicry in animals.
2. What are the different causes of mimicry?
3. Write short notes on the following:
   (*a*) Warning colouration
   (*b*) Mimicry

8 FISH MIGRATION

Environmental conditions on earth vary from place to place and also at the same place depending on the season. The seasonal changes in some parts of the world are very adverse and taxing. They threaten the survival of the animal population. Many animals try to escape from such taxing climate by migrating to more favourable climate or hibernating at the same place. Out of these, fish migration is a more dynamic process and many animals use this process for their survival. The process of migration in some animals was initiated as means of survival but later on by virtue of Natural Selection (since it provided better survival, more easy food, better habitat etc.), it became genetically, a fixed pattern of behaviour and differs from species to species.

Generally, fishes live in a constant habitat and restrict their movement within particular territorial limits, but there are many others which migrate from one type of habitat to another and travel long distances moving from fresh water to sea water or vice-versa. In most cases, this movement of a large number of fishes may occur for the purpose of feeding, spawning, shelter and is called Migration. Migration may be defined as the periodic movement of any animal species from one region to another. According to Heape "It is a class of movement, which forces migrants to the regions from which they have migrated". During this process,the population mortality of numerous individuals occur due to different ecological hazards, such as temperature fluctuations, scarcity of food, predation etc. However fish migration has certain benefits for population as it enables wider dispersion of population. It avoids intraspecific competition for food, shelter or any other means.

In mature adult fish, migrations are mainly for spawning and feeding. Migration provides chances of better survival. They breed in one area and feed in another area. The important migratory fishes are:

1. Pacific Salmon (*Oncorhynchus*).
2. Atlantic Salmon (*Salmo salar*).
3. European Eel (*Anguilla rostrata*).
4. American Eel (*Anguilla vulgaris*).
5. Herring (*Clupea harangus*).

6. Sword fish (*Xiphias gladus*).
7. Hilsa (*Hilsa ilisha*)
8. Cod fish (*Gadus morhua*).
9. Plaice (*Pleuronectis platessa*).
10. Barracudas (*Sphyraena zygaena*).
11. Mackerels (*Scomber microlepidotus*).
12. Tunnas (*Thunnus thynnus*).
13. Milk fish (*Chanos*).

MIGRATION IS OF THE FOLLOWING TYPES:

1. Diadromous migration.
2. Potamodromous migration.
3. Oceanodromous migration.
4. Latitudinal migration.

1. Diadromous migration. Many fishes spend a major part of their lives in fresh water or sea and migrate during breeding period for spawning. This type of migration between the sea and fresh water is called Diadromous Migration. This type of migration is further classified into the following categories:

a. **Anadromy or Anadromous migration.** Movement from salt water (sea) to fresh water for spawning is called Anadromous Migration. Atlantic Salmon (*Salmo salar*), species of Pacific Salmon (*Oncorhynchus*) and Hilsa (*Hilsa ilisha*) present the best example of this migration. The *Pacific Salmon* adult lives in salt water of Pacific ocean until they become fully matured for reproduction. They then migrate long distances into the fresh water rivers that empty into the Pacific. The females lay the eggs and return to their feeding ground. Males also discharge their sperms for fertilising the eggs. The fertilised eggs grow, hatch and ultimately mature into young ones which live in fresh water for some time and then start downstream movement towards the sea. This upstream and downstream migration takes about one year. These migrated young *Salmons* grow in size and attain full maturity for reproduction in about seven years and further starts upstream migration towards fresh water rivers for breeding purposes. As they proceed up the river, they come to many forks and turns, waterfalls etc. but they return to their place of origin where they took birth seven years ago. *Hilsa* also show this type of migration. These fishes have been observed in fresh water river during the breeding season. Experimental evidences show that strong olfactory sense of *Salmon* determines its homing into the original birth place, for different streams having different odours.

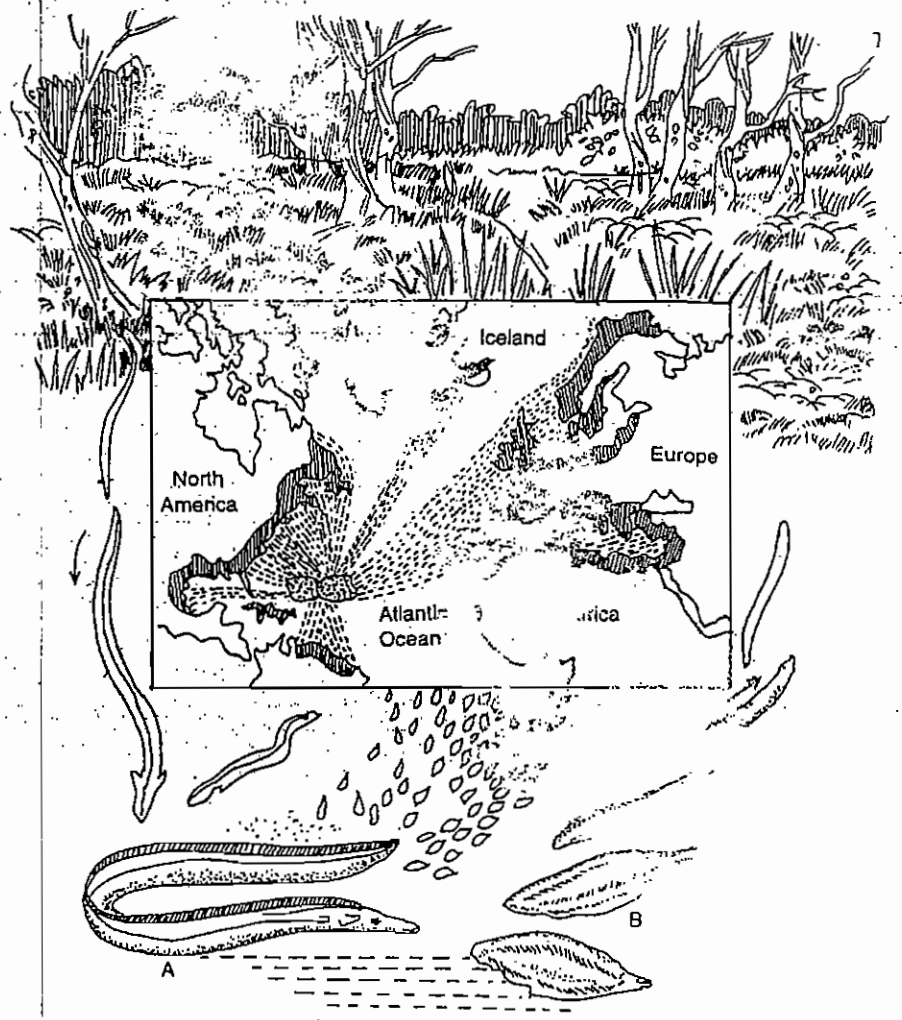

Fig. 1. Figure showing Catadromous migration of Eel (*Anguilla*).

b. **Catadromy or catadromous migration.** In this type of migration, movement is from fresh water to salt water (sea). The best example of this migration is furnished by two common species of eel *Anguila vulgaris* of America and *Anguila rostrata* of European fresh water rivers. With the starting of autumn, several changes occur in the body of these fishes. Their colour changes from yellow to metallic silver, digestive tract becomes compressed and functionless due to full growth of gonads and eyes become larger with thinner lips and sharper snout. The silvery eels now migrate to the sea for breeding purposes. *Anguila vulgaris* travels about 4,500 Kms eastwards from America and Anguila rostrata westwards

from Europe reach their breeding place in the Sargasso sea, south-east of Bermuda. The adults die immediately after spawning in deep waters and young larvae (*Leptocephalia*) drift and swim back towards the fresh water. During their long return journey towards home of their parents, they metamorphose into about 8 mm long elvers. They take about three years in reaching the rivers. Here they feed and grow to become yellow eels in some years and on reaching maturity, start their seaward migration again (Fig. 1).

c. **Amphidromy or amphidromous migration.** Some gobies are widely distributed in the sea and fresh water and present this type of migration *i.e.* from fresh water and vice-versa. This type of migration is not for the purpose of breeding but occurs regularly in the life cycle for other purposes. Irregular movements of the Asiatic milk fish (*Chanos*) in and out of fresh water also falls in this category.

2. Potamodromous migration. Migration confined to the fresh water is known as Potamodromous Migration. An example of this type of migration is represented by carps and trouts which travel long distances in large rivers in search of suitable spawning grounds. These fishes return to feeding area after spawning.

3. Oceanodromous migration. This type of migration is represented by many marine fishes such as the Herrings (*Clupea*), Mackerels (*Scomber*) and the Tunnas (*Thunnus*). These fishes travel long distances in the sea from deeper ocean waters to the shallow inshore spawning areas at the time of reproduction. After spawning they return to their feeding grounds. Like birds, many marine fishes perform seasonal migration. Sword fish (*Xiphias gladus*) and Barracudas (*Sphyraena*) living in warm tropical seas perform latitudinal migration, moving north in spring and south in autumn. This migration is only for suitable climatic conditions.

On the basis of the purposes, it may be of following types:-

a. **Alimental migration.** This type of migration is for search of food.

b. **Spawning migration.** In mature fish, migration is mainly for the purpose of reproduction and is called spawning migration or gametic migration.

c. **Climatic migration.** This type of migration takes place to secure more suitable climatic conditions.

d. **Osmoregulatory migration.** Migration, for the purpose of osmoregulation is called osmoregulatory migration.

DENATANT AND CONTRANATANT

During migration, fishes move either in the direction of the water current or it takes the opposite route. These two terms are used to describe the movement of the fish in relation to the water current. The movement [illegible] current is known as denatant.

Movement of pelagic eggs and young *Salmons* are examples of this type of movement. Similarly movement occuring against the water current is called contranatant. Example of this type of movement is migration of adult *Salmons* towards spawning grounds.

METHODS OF MIGRATORY MOVEMENTS

Fish show migratory movements by several methods:

1. **Drifting.** By this method fishes are carried passively along with the water current. If the movement of water is overall in one direction it may result in movement of fish in that direction (Directional Movement). The young one migrates to nursery grounds by drifting.
2. **Swimming.** Fishes may swim either at random or in a particular direction. Random swimming leads to uniform distribution or to an aggregation. Oriented swimming takes place either towards or away from the source of stimulation or at some angle to an imaginary line running between them and the source of stimulation. The juveniles go to the adult stock on their feeding grounds; and mature and ripe fish move from feeding grounds back to the spawning area by swimming method. The spawning migration is against the current and the spent fish returns to the feeding ground with the current.

ADVANTAGES OF MIGRATION

In most cases, migration of population may occur for food, shelter, or reproduction. The greatest advantages derived from the migrating movements are the better utilisation of untouched new habitats and their resources. According to Nilolskym, migration is an adaptation towards abundance. The nursery or spawning grounds alone do not have sufficient food to maintain both mature and immature members of a large population. Hence it would be advantageous to have separate feeding, breeding and nursery grounds. Migration provides favourable climatic conditions for spawning and survival of the larvae, thus leading to greater number of spawners on a particular ground.

FACTORS REGULATING FISH MIGRATION

Several factors are responsible for influencing fish migration. These may be physical, chemical or biological and vary from species to species which are as follows:

1. Physical factors. These include depth of water, pressure, temperature, light intensity, photoperiod, current and turbidity etc. These factors form a part of the environment and fish migrate to that area where the climate conditions are suitable for its survival. The water current influences considerably the direction of movement of the fishes. Eggs and juveniles are transported passively along with the water current to [illegible] spent *Salmons* are carried by

the river currents towards the sea.

Light intensity and the photoperiod also influence migration of many fishes. Lampreys and *Sturgeons* migrate during the night and Herrings migrate during full moon. Similarly, rise in temperature of fresh water rivers during summer provides a stimulus to influence upstream movement of fishes for spawning.

2. Chemical factors. Chemical factors influencing fish migration are the salinity, pH, smell and taste of water. Salinity of water influences the fish behaviour. Most of the fresh water fishes are Stenohaline (narrowly tolerant or comparatively intolerant to salinity changes). They restrict their movement to fresh water only and do not undertake large scale migration. Besides, a few species like *Oncrohynchus, Salmon, Anguilla, Hilsa, Gasterosteus* and *Fundulus* are Euryhaline (broadly tolerant to salinity changes) and travel long distances from the ocean to fresh water and vice-versa and are called diadromous fishes.

Smell also appears to guide fishes during migration. It has been shown experimentally that strong olfactory sense of *Salmon* determines its return to the original birth place, where its own hatching and early development takes place.

3. Biological factors. The food, memory, gonadial activity, biological clock and endocrine glands are the biological factors influencing fish migration. Availability of food is one of the important factors responsible for migration of many species of fishes going out in search of feeding areas. In some species, changes in hormone production is essential for the changes of habitat, while in others, it is the gonadial activity which regulates this process. The fresh water to salt water transportation and vice-versa in diadromous fishes is associated with well marked endocrine changes. *Leptocephalus* (oceanic larva of European eel, *Anguilla rostrata*) migrates more than 3218 Kms. across Atlantic from the breeding ground of eels near West Indies to reach European fresh waters, where it becomes an adult. Similarly annual migration of *Herrings* from deeper ocean water to the shallow inshore spawning area at the time of reproduction is associated with pituitary, thyroid and gonadial changes.

REVISION QUESTIONS

1. Write an essay on fish migration.
2. Write short notes on the following:
   (*a*) Anadromous Migration
   (*b*) Catadromous Migration

9 PARENTAL CARE IN FISHES

Parental care occurs in many lower animals as well as in social insects, fishes, amphibians, and reptiles, but it is usually limited to protection of eggs and young by their parents. Fishes show all grades of parental behaviour from random spawning to internal fertilization, from oviparity to viviparity; and from the deposition of large number of uncared eggs to the protection of young but a few. The lack of parental behaviour is correlated with the production of great number of eggs and sperms. Marine fishes rely simply on safety in groups. Many marine species lay planktonic eggs which float near the surface of the sea. The Cod fish whose eggs are scattered at random in the open sea produces over nine million of them; the carp lays two to four million again at random but in fresh water and in the neighbourhood of vegetation. The species spawns at a depth of 30 to 40 meters and produces about 3,00,000 eggs. There are, however, some notable examples in which the eggs and young ones are guarded with great care mostly by the male parents. Fishes have evolved many means of affording care to fertilized eggs and young ones by one or both sexes.

1. SCATTERING EGGS USUALLY OVER AQUATIC PLANTS

In some fishes like pikes, *Esox lucius*; carps, *Cyprinus carpio*, *Carrassius auratus* etc. eggs are scattered usually over aquatic plants to which they are attached.

2. DEPOSITING EGGS IN STICKY COVERING

In many cyprinids (Carps etc.) eggs are usually laid with some special sticky covering by means of which they are attached to each other and to the bottom of stones, weeds etc. In yellow perch, *Perca flavescens* eggs are deposited in a rope of single mass (Fig. 1).

Fig. 1. Diagram showing a rope of single mass of eggs of *Perca flavescens*.

3. LAYING OF EGGS AT SUITABLE PLACES

Suitable spawning grounds are selected by *Salmo solar, Acipenser, Oncorhynchus* etc. These fishes show anadromous migration for depositing eggs at suitable places. The sand gobi *Pomatoschistos minutus* lays its eggs in some protected spot where they are guarded by the male who aerates them by his movements.

4. NEST BUILDING

Nest building fishes are geographically wide spread and the habit appears in many orders, from the Bowfin of North America and lung fishes of Africa, to the well known *Sticklebacks* of Europe and North America. Some nests are merely hollowed out depressions in the bottom, as in the lung fishes. Males of many species like the Darters (*Etheostoma*), sunfishes and the cichlids prepare a shallow basin like nest. All stones and rock crystals are carefully removed from the bottom. The eggs are laid in the nest and the male remains on guard till the young ones are hatched.

The male African lung fish, *Protopterus* prepares a simple nest in the form of a deep hole in swampy places along the river banks. After spawning he guards it. The south African lung fish *Lepidosiren* also prepares a nest in the form of a burrow and the male develops highly vascularised filaments on pelvic fin for aeration. The male Bowfin, *Amia*

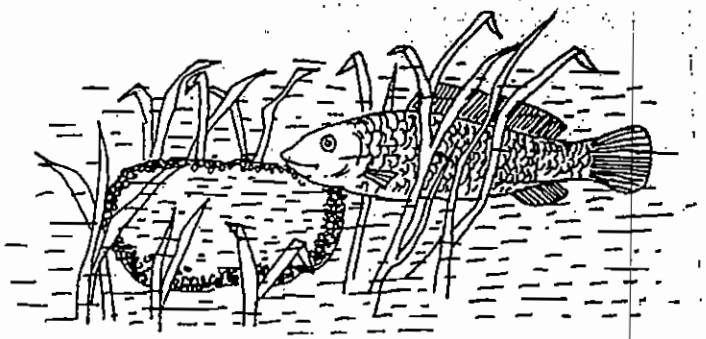

Fig. 2. Diagram showing male *Amia calva* providing protection to the young ones.

calva of the great lakes of North America builds a crude circular nest among aquatic vegetation. The male stands on guard till the young ones are hatched. The young ones leave the nest only under the protection of the father (Fig. 2).

The male *Stickleback, Gasterosteus aculeatus* builds a quite elaborate nest before courtship begins. A sticky secretion from the kidney of male helps in nest building. By an elaborate courtship, he induces females to [illegible] in a tunnel in the nest.

After the eggs have been fertilized, the female leaves the eggs while the male stays to care for them (Fig. 3). Floating nests are made by a

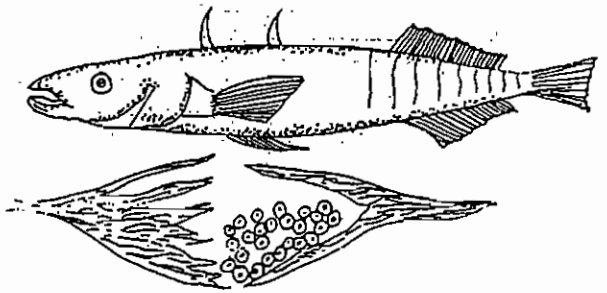

Fig. 3. Diagram showing two-spined male Stickleback caring fertilized eggs laid in the nest.

number of anabantids and south American catfishes, in which the eggs are suspended in a mass of bubbles and mucus produced by the fish. The male Siamese fighting fish, *Betta splendeus* builds the nest in the similar manner and sticks the fertilized eggs to the lower surface of the foamy nest. He stays on guard and fights till death to defend it (Fig. 4). The male paradise fish, *Macropodus* also prepares a similar foamy nest but without the active participation of the male.

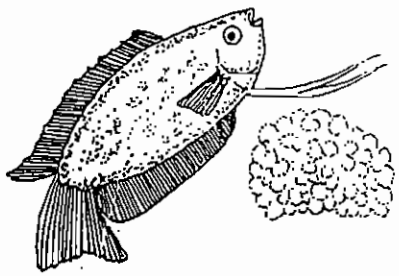

Fig. 4. Diagram to show male Siamese fighting fish defending his nest.

5. COILING ROUND THE EGGS

Shannies and gobies are well known for the assiduous way in which they guard the eggs. The butter fish or Gunnel of the British coast (*Pholis gunnellus*) rolls them into a ball and curls around it (Fig. 5). Both male

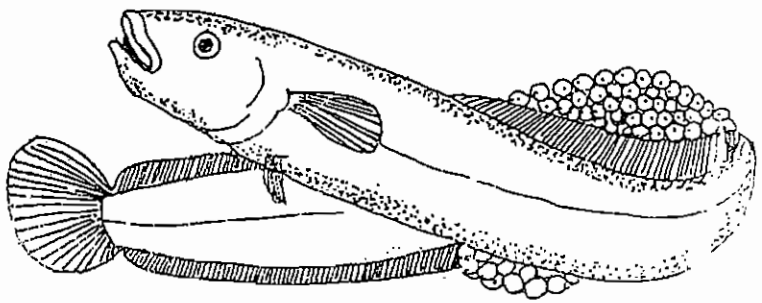

Fig. 5. Diagram showing the butter fish (*Pholis gunnellus*) coiling round the eggs

and female perform their duties. The male lump sucker guards the eggs at considerable risk to himself both from violent wave action and activities of predators such as birds and crabs.

6. BY OVIPOSITOR

The European Bitterling (Cyprinidae) *Rhodeus amarus* takes extra care for the protection of the eggs. Eggs are laid within the siphon of a swan mussel (Fig. 6). For this purpose the cloaca of the female develops into a tubular ovipositor, development of which is under the influence of

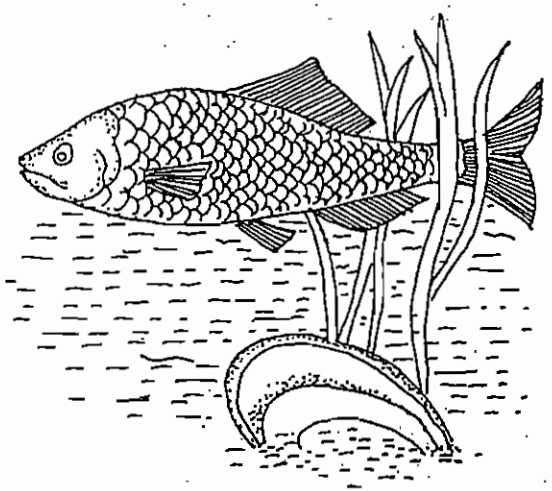

Fig. 6. Diagram showing female European Bitterling (*Rhodeus amarus*) with swan mussel (SM) in which eggs are deposited by ovipositor (OV).

a hormone produced by the ovary. Addition of progesterone and related substances to the fish causes growth of the ovipositor. Presence of the male and the swan mussel is necessary for the full growth of ovipositor and preparation of the female for spawning. When the female is ready to deposit the eggs, she adapts a vertical position in the water and the spawning male swims around her. The ovipositor helps to place the eggs in the siphon of the mussel and the male then immediately sheds his sperms over the opening. For the perfection of this remarkable method of caring for the young, pheromones, external stimuli and interplay of internal devices are necessary.

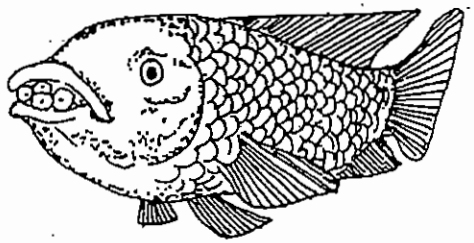

Fig. 7. Diagram showing mouth brooding habit of cichlids (*Tilapia*).

7. SHELTER IN MOUTH AND INTESTINE

Some catfishes (*Arius*) and cichlids (*Tilapia*) have developed the habit of mouth brooding (Fig. 7). One of the pair (in cat fishes, the male; in cichlids, the female) gathers the fertilized eggs into its mouth and carries them until they hatch. The young ones take shelter in the parental buccal cavity in times of danger. In the North American catfish (*Galeichthys felis*) the male carries eggs in the mouth for a period of nearly six weeks (Fig. 8). The eggs in this oral incubating fish are large (upto 7/8 of an inch in diameter) and relatively few in number; and it appears impossible for the fish to take food during the whole of this period, thus subjecting himself to a great degree of self sacrifice. *Tachysurus* keeps the fertilized eggs in its intestine till hatching occurs.

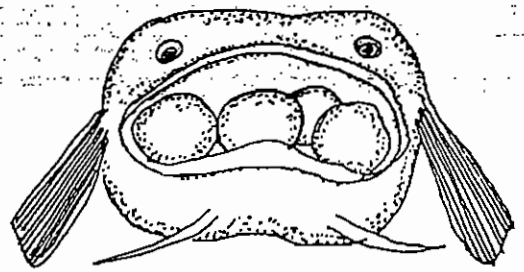

Fig. 8. Diagram showing the male North American catfish (*Galeichthys felis*) carrying eggs in his mouth.

8. BROOD POUCHES

In pipe fishes and sea horses, the males are provided with special pouches for the young, containing a nourishing secretion which is dependent on the presence of prolactin. In sea horse (*Hippocampus*) eggs are transferred by the female into the brood pouch on the belly of the male who carries them till hatching (Fig. 9). Fertilized eggs become embedded in the folds of the pouch and it is believed that a sort of placenta is formed. Certainly an exchange of oxygen and carbon dioxide must take place, since the pouch is closed completely during the period of development. However, when the babies are ready to leave, its mouth opens and the young sea horses are ejected by a series of jerks.

Fig. 9. Diagram showing male sea horse (*Hippocampus*) carrying eggs in his brood pouch (BR).

In male pipe fish (*Syngnathus*) a brood pouch is formed by two flaps of the skin on the underside of the body, in which eggs are placed by the female (Fig. 10). The pouch develops an inner spongy lining which is richly supplied with blood vessels. The eggs get nourishment until

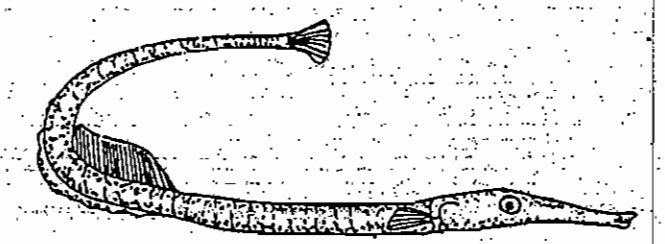

Fig. 10. Diagram showing male pipe fish having brood pouch (BR) on his under side.

hatching but even after this event, the fry may utilise it for sometime. The swimming fry may return to its shelter when in danger. Other pipe fishes, such as the worm pipe fishes (*Nerophis and Phyllopterys foliatus*) from Australia have a shallow dent along the tail in which the eggs adhere and develop.

9. ATTACHMENT TO THE BODY

In the male New guinea fish (*Kurtus*) the egg mass is entangled on a hook-like process developed by the dorsal fin on the head until they are hatched (Fig. 11).

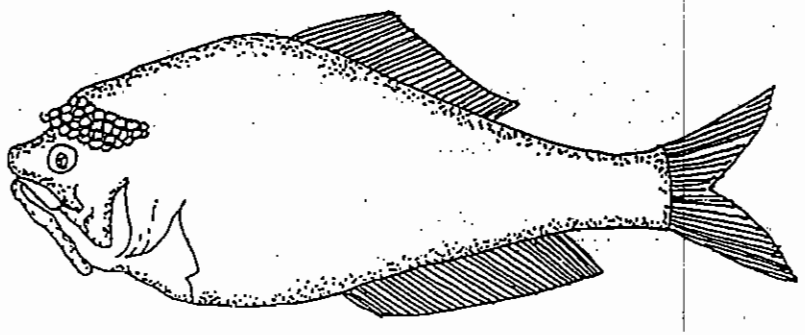

Fig. 11. Diagram showing male New Guinea fish (*Kurtus*) carrying egg mass entangled on a hook-like process.

10. INTEGUMENTARY CUPS

In some species the males play a relatively passive role in the protection of the eggs. In siluroides (Aspredo and Platystacus), female carries the fertilized eggs in the soft spongy skin of her belly (Fig. 12). During breeding season the skin of the lower surface of the body of female fish becomes soft and spongy. After the fertilization of eggs, female presses

the body against the eggs so that each egg becomes attached by a stalk into a cup like depression of integument. The eggs remain fixed in this position till hatching.

11. EGG CAPSULES

In oviparous Elasmobranches, rays and some sharks such as the cat sharks (*Scyllium and Raja*) fertilized eggs are laid inside protective horny egg capsules made of keratin, the "Mermaids purse" which remain attached to the aquatic weeds by their tendrils (Fig. 13). The development proceeds inside the capsule until the yolk has been used up. The young hatch out after rupturing the egg case.

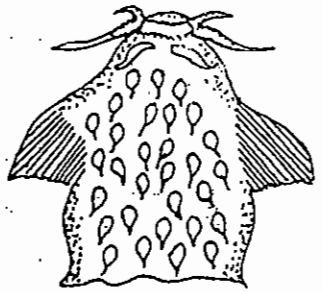

Fig.12. Diagram showing female *Platystacus* carrying integumentary cups (IC) on her belly.

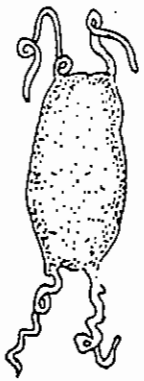

Fig. 13. Diagram showing "Mermaids purse" of cat shark (*Scyllium*).

12. VIVIPARITY (TRUE INTERNAL INCUBATION)

Viviparity represents the highest degree of parental care and provides maximum protection to the young ones. In viviparous Elasmobranchs the oviduct forms a "Uterus" but many species are aplacentals, in which young develop at the expense of yolk. In some species uterine wall secretes embryotrophe or uterine milk. In two orders of teleosts, Cyprinodonts and Perciformes some species (*Zoarces, Gambusia and Poicilia*) show internal fertilization and the young then develop within the ovary. The embryos are not attached to the

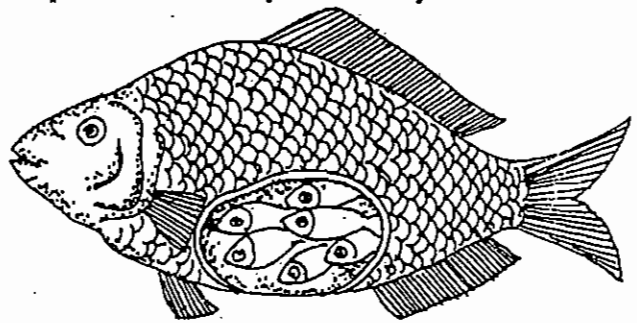

Fig. 14. Diagram showing body cavity of *Cymatogaster aggregatus* cut open to

wall of the ovary, but develops freely in the sac feeding upon an "Embryotrophic" material, apparently produced by the discharged ovarian follicles, which become highly vascular and remain throughout the several months of pregnancy.

In shiner surf-perch (*Cymatogaster aggregata*) also the eggs are fertilized in the ovarian follicles but are soon released into the cavity and are nourished by a secretion from the ovary (Fig. 14). The males are

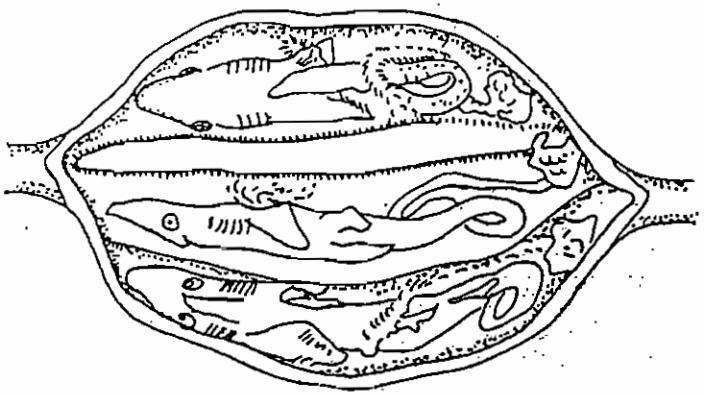

Fig. 15. Diagram showing yolk-sac placenta of *Mustelus*.

retained in the ovary until sexually mature. The yolk sac forms placentae in *Mustelus* and other sharks with interdigitation of foetal and maternal tissues (Fig. 15).

REVISION QUESTION

1. Describe in detail parental care in fishes.

10 BIRD MIGRATION

The migration of birds is the most remarkable and astonishing phenomenon in the animal world. Once in every twelve months various kinds of birds (Fig. 1) in the Northern Hemisphere have been deserting

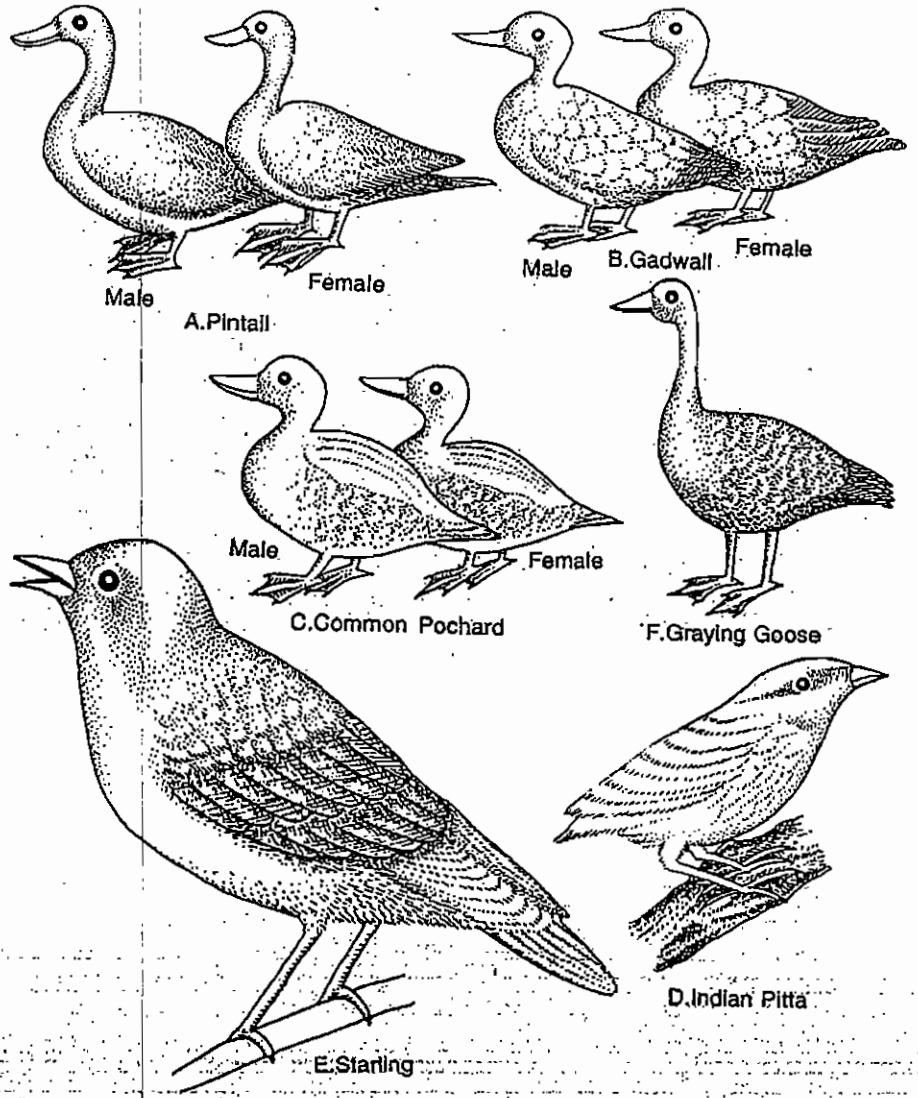

Fig. 1. Some of the migratory birds (A to F).

their houses in autumn and returning in spring to breed again. Siberian birds spend winter in the Indian subcontinent viz. the Bharatpur Bird Sanctuary (Rajasthan) (Fig. 2) and summer in Siberia. Similarly more

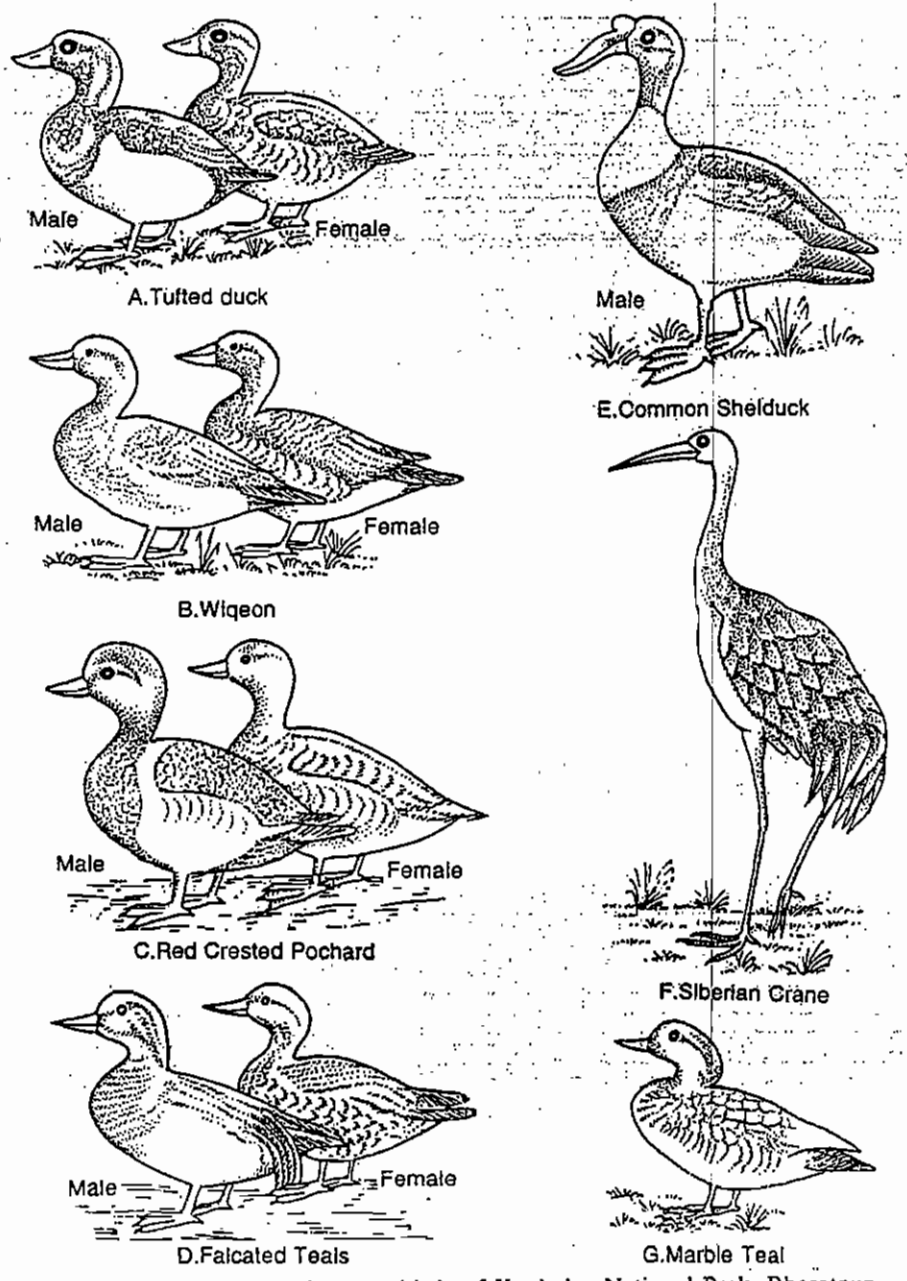

Fig. 2. Some of the migratory birds of Keoladeo National Park, Bharatpur.

than two third of the species breeding in the northern United States move south in winter, making trips upto 6000 Kms. each way (Fig. 3). Most birds do not cover more than about 40 Kms. to 100 Kms., but some may

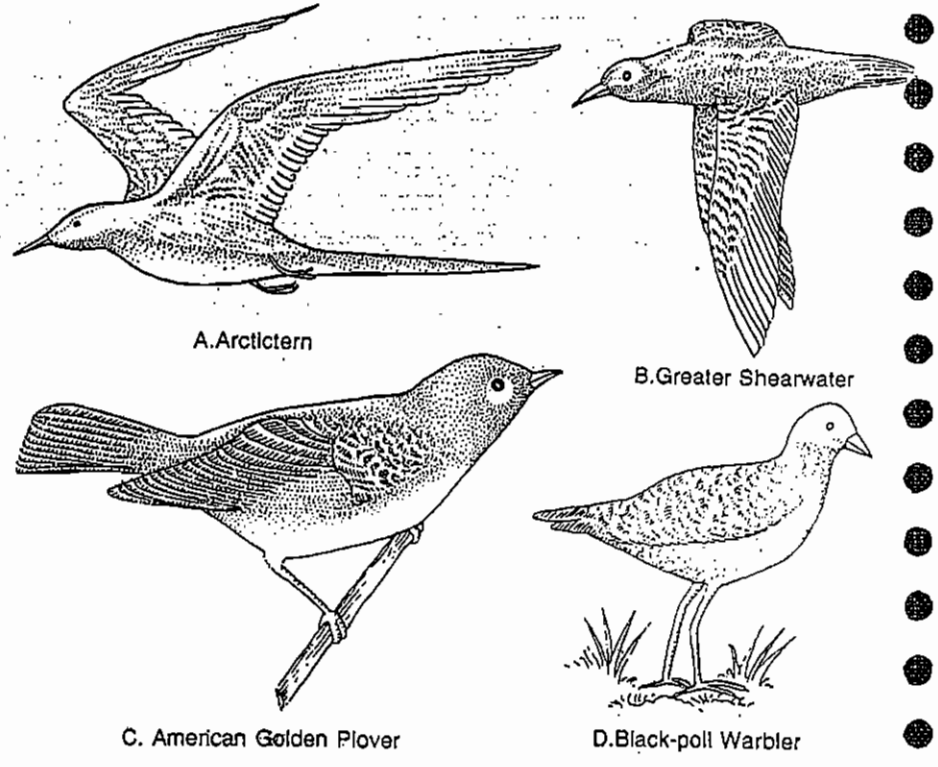

Fig. 3. Long distance migratory birds (*A* to *D*).

make long distance flight of 3218 Kms. or more. Some shore birds migrate for more than 10,000 Kms. in each direction between breeding grounds in the Arctic and Wintering area in the Southern Hemisphere. It is calculated that 5000 million land birds migrate from Europe to Africa each autumn and half of them succeed in returning next spring.

Migration has been defined by Cohn as "A periodic passing of animals from one place to another". The word migration has been derived from the Latin word "Migare" which means to travel. It is different from unidirectional movements and those in which animals are helplessly carried by some other agency. Bird migration is a two way journey in which some birds move from breeding and nesting place to a feeding and resting place and vice-versa. It is correlated with environmental periodicity or with some other stage in the life history of the migrating individual. Migration gives them a maximum daylight at all times and helps them

period for feeding because birds feed only in light and go to a place of resting during darkness.

EXAMPLES OF MIGRATORY BIRDS

There are large number of birds which show this spectacular behaviour. In India alone there are about 2500 species of migratory birds (Fig. 1(*d*)). Most of them remain in India but some of them cross the Indian borders and migrate to other countries.

The cuckoo (*Eudynamis scolopaccus*) is a well known example of a migratory bird. It arrives in Uttar Pradesh in the beginning of March and breeds there. During the month of August it leaves this place and migrates to South India and Ceylon to spend winter there.

The Wagtails (*Motacilla sp.*) appear in India in the beginning of the winter season and at its end they leave this place, migrate to Siberia and Manchuria to spend summer and to lay eggs.

Vertical migration occurs in mountainous regions. The *Chaimmarornius leucocephala* "Girchaundia" of eastern Himalayas breeds at the height of about 7,000 to 8,000 ft.

The Rufous turtle dove (*S. orientalis*) "Kala Phakta" breeds in Central Siberia, Japan, North and Central China, Tibet and Nepal. In winter it migrates southward all over Eastern India and as far south as Deccan. The Central Starling (*Strunus vulgaris porphyronotus*) "Godhuni" is found in thousands in the North-western part of India and becomes a serious pest of wheat fields. In summer, it migrates to Turkistan and Tianshian mountains to breed.

The White Wagtail breeds in Eastern Siberia from the lake Baikal to Machukuo. It spends winter in Eastern Assam, Kashmir and Afghanistan.

The Brown Shrike (*Lanius cristatus*) "Lahtora" breeds in Eastern Siberia in summer. In winter it migrates to India and Ceylon two to three thousand miles away.

Many kinds of geese, ringed and released in Dhar state (Madhya Pradesh) were recorded in Siberia (2,000 miles). The recorded speed of migration was 1,325 miles in 64 days. The Glossy Ibis (*Plegadis falcinellus*) ringed and released on July 7th 1931, at Astrakhan in the Volga Delta at the head of Caspian sea was recorded at Devlali (Nasik) on 14th March, 1934.

Parties of swallows returning to Britain from South Africa may cover 9,650 Kms. in six weeks, often flying back to their old nests.

Some birds fly alone and achieve astonishing speed. A tiny Wheatear weighing less than 30 gms, was ringed in Walesand covered 965 Kms. away on the French Mediterranean coast, only 43 hours later.

Marine birds also make extensive migration. The great Shear Water (*Puffinus*) breeds on Tristan da Cunha but comes to Greenland in May, returning again after months of wandering at sea, apparently without a

landfall. One of the fastest journeys recorded, has been made by this bird during migration. One of the birds was taken from its nest on Island of Stocholm off the Welsh coast, sent by airlines to the U.S.A. and set free in Boston. It flew 495 Kms. from a country never seen before, in twelve days arriving ten hours before the letter of confirming its release.

There are some birds which enjoy two summers in a year. They breed during summer in the Northern Hemisphere and cross the Equator at the approach of winter to live in the summer of Southern Hemisphere. The American Golden Plover (*Pluvialis domesticus*) "Chota battan" (Fig. 3(*c*)), breed in extreme north of America in Arctic Circle. In autumn it moves south until it arrives in the Pampas of South America, a distance nearly 6,000 miles where it spends winter. It returns to the Arctic region in April, thus covering 12,000 miles in a year.

The Arctic Tern (*Sterna paradocoe*) (Fig. 3A) "Dhurikinai" presents the important example of long distance migration. It breeds in the North Temperate zone (Canada, Northern Ireland and West Coast of Greenland) and in winter migrates to Antarctic Continents along both sides of Atlantic islands (Fig. 4). Thus its summer and winter homes are 11,000 miles apart and it makes a yearly round of the world trip of 32,000 miles or more. Several species migrate within the tropics and such migration is not related to the summer and winter seasons but to the occurrence of dry and wet

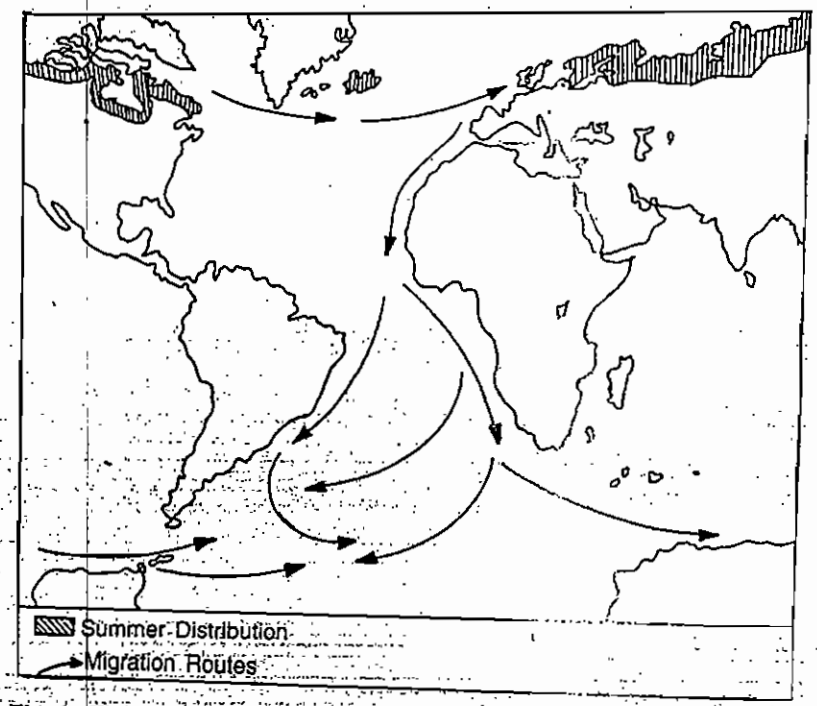

Fig. 4. Figure showing migratory routes of Arctic Terns that breed in Northern Canada.

seasons. The broad - billed Rover, breeds in Madagascar from December to May and migrates northwards to the Congo Basin between June and November. The Widgens breeding in Iceland, migrate to Europe and cross over the Atlantic to reach North America.

Bird migration does not always take place by means of flight. Penguins (*Spheniscus*) breeds on the land of Antarctic continent. In the winter they move hundreds of miles on floating packs of ice and return south in summer. They cover a greater path of the distance by swimming in the sea and march to their nesting sites. Migratory Guillemots (*Uria*) mostly swim and American Coot (*Fulica*) walks for miles across the country.

TYPES OF BIRD MIGRATION

The birds can fly with a speed of 80 to 100 km. per hour from one place to another place. Some of the aquatic birds like ducks and geese swim very fast in water and they are also active fliers. The birds show six different types of migration, which are as follows:

1. **Altitudinal or vertical migration:** This type of migration is seen in the species, which live in the mountain areas. During winter they migrate to warmer, lower altitudes in search of food and shelter. Such migration is seen in the mountain quails, which live at 9500 feet height in central California mountains and migrate downwards below 5000 feet during summer and they move back to the hills of U.K. and Siberia. In Argentina Coots bird migrate from high Andes Mountains to downward regions. Other examples are Redstart of Eastern Himalayas, Rufons Turtle Doves of China, Nepal and Sikkim, Sterling of Turkey, Violet Green Shallows of Great Britain and Willow Ptarmigen of Siberia.
2. **Cyclic migration:** Some birds like snowy owl which live in United States show cyclical migration within 3-5 years of time.
3. **Daily/local migration:** Many birds show daily migration from their place of living to search food, proper light intensities or darkness, temperature, humidity etc. e.g. House sparrow makes short daily migration in search of food and drinking water. Local migration is seen in golden oriole, paradise flies catcher etc. at regular intervals of time.
4. **Latitudinal migration:** Birds show north to south and south to north migration in search of suitable place for nesting, feeding and reproduction purposes. Every year about 5000 to 6000 million birds fly 3200 kms. South to the forest grasslands, lakes, rivers of Central and Southern Africa. During migration they cover several thousands of miles like that seen in species arctic term. Greater Shear water, black-pole warbler (Fig. 3D) etc. The arctic tern covers about 17600 kms.

(Fig 3C) migrates during winter to Argentina likewise many birds leave Siberia and go to Himalayas. Maximum European birds, during winter, migrate to Africa. A bird Wilson's petrel moves from Antarctica nesting grounds to New Found Land in Canada. The birds like shovellers, pintails, greylag geese etc. are found to migrate from Palaearctic region to India and neighbouring countries. European Starling (Fig. 1E) migrate from East Europe or Asia towards Atlantic coast.

5. **Longitudinal migration:** During longitudinal migration birds move from east to west or vice-versa e.g. evening gross beaks nesting in northern Michigan passes its winter in New England. Starlings move from Eastern Europe or Asia to the Atlantic coast. The California gulls, which breed in Utah, show migration to pacific coast during winter.
6. **Seasonal migration:** Due to change in the season, migration occurs in tropics and subtropics as seen in many birds and mammals. Ducks (Fig. 2) are the best example of this.

Status of migratory birds: Four major classes of migratory status are seen in birds:

(*i*) **Summer migrants:** These birds migrate to their breeding grounds during March and April months where they rear their young ones during summer months and return to their wintering grounds during November and pass winter months from December to February living there.

(*ii*) **Winter migrants:** These species migrate from their breeding ground to spend their winter in a suitable place where temperature of the environment and availability of food is upto their liking. Such winter migrants are seen visiting Keoladeo National Park at Bharatpur. For example Siberian Crane, marble Teal, falcated teals, common shel duck, pigeon, red crested pochard etc. (Figs. 2*b,c,e*). The winter migrants like common teal, pin tail, shoveller, and geese come under this category which migrate from Palearctic region or Eurasia region.

(*iii*) **Passage migrant:** They are transient visitors which migrate twice during a year i.e. during spring when they go out to their breeding grounds and then again during winter months to their wintering grounds as seen in the case of gargani teals and other teals, which migrate from Mongolia or Siberia to Bharatpur and they further go to South India where they breed and while returning back they temporarily stop at Bharatpur in India (Figs. 2 *d, g*).

(*iv*) **Permanent resident:** These birds are not migratory birds and they live in a particular area throughout the year e.g. permanent residents of Keotadeo N.P. Bharatpur, spot bill duck, mallards, whistling teals (Figs. 5 *A to F*).

Causes of migration: Generally birds migrate from one place to

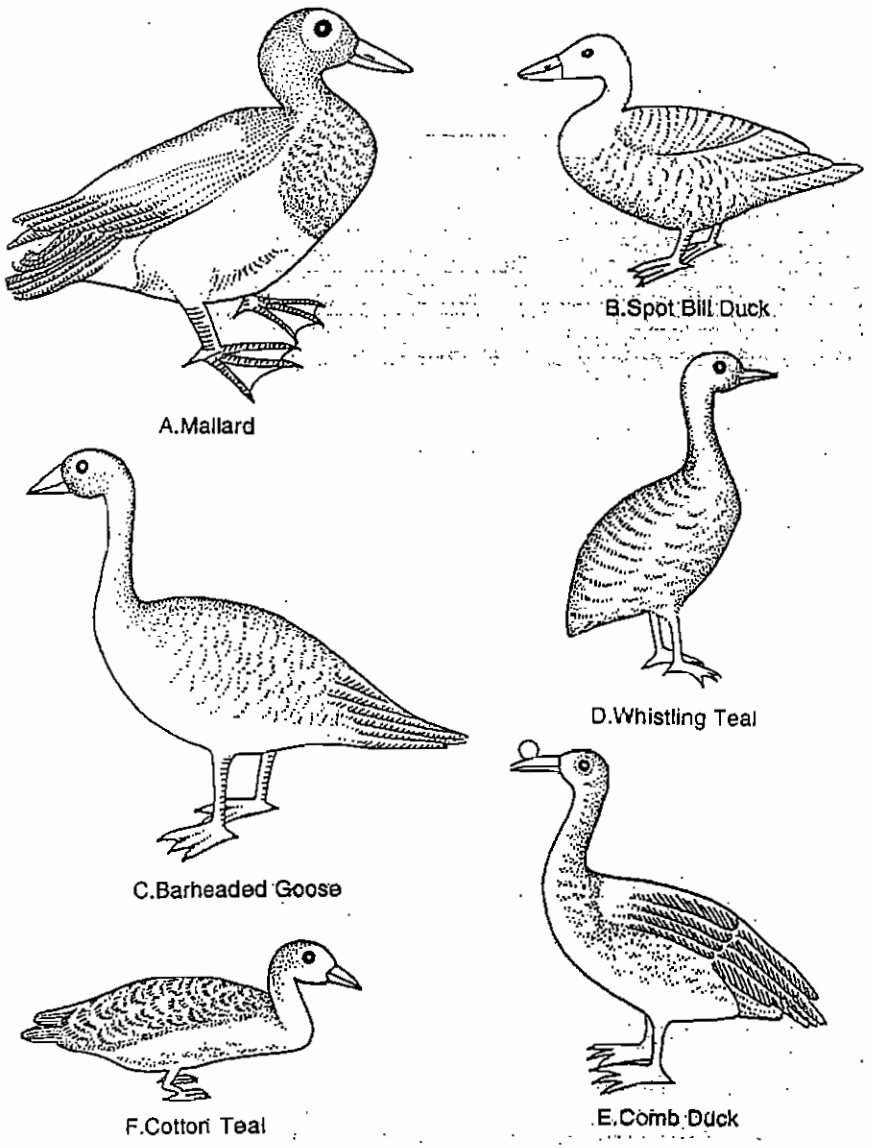

Fig. 5. Permanent residents of Keoladeo National Park, Bharatpur (*A to F*).

and also to get optimum temperature for living. They avoid too much cold in search of a warmer place to live and return to their original home when the optimum temperature is available in that area. Before migrating they store a lot of energy in the form of fat deposits which are considered to be fuel tanks as seen in the case of black pole warbler which becomes almost double its weight before it migrates. This energy is utilised during migratory process. Before migration birds show migratory-restlessness or Zugunruhe. Under these conditions, day length influences pituitary

glands which brings about necessary physiological and behavioral changes in the birds triggering migration. The change in the environmental conditions like temperature, day length, wind velocity on set off winter are responsible for their migratory restlessness.

Advantages of migration

(*i*) Migration helps securing a better climate for living by avoiding rigors of cold and heat.

(*ii*) Different habitats are available for migratory birds for food, nesting, breeding etc.

(*iii*) Migration helps in the geographical dispersal of birds, which isolate population of different species from each other increasing the rate of evolution because genetic variation or mutations occur faster in a small population than the larger one.

(*iv*) During migration migratory birds are exposed to greater variety of foods which may be more nourishing and providing chance for adaptive radiation.

(*v*) Individual survival value becomes more because the predation pressure is divided in the large number of eggs laid in their breeding grounds because of more arrival of the migratory birds.

(*vi*) Migration helps in providing greater ecological diversity and adaptability to the migratory birds than the permanent resident birds, which is of evolutionary significance.

WAY FINDING DURING MIGRATION

Various theories or explanations have been advanced for what determines the direction and course of migration. Birds probably make the use of several possible cues available for migration in different paths of the journey depending on the conditions which are as follows:

a. **Visual landmarks.** It has been established that some migratory birds follow obvious landmarks such as rivers, mountain ranges, islands etc. which give long range guidance in daylight. Landmarks may be learned. Ducks and Geese travelling in family groups transmit the information from generation to generation. Most birds migrate during the night and thus do not make use of landmarks except for the last stage of homing.

b. **Celestial bodies.** If landmarks are of little use, way finding for migration and homing depends largely on flying in a particular compass direction by the sun or stars. Mathew put forward the view that the birds are equipped to use a "Biological Clock" which enables them to make necessary adjustments in their course, according to the changes in the position of the sun and stars. The German Ornithologist, Gustav Kramer claimed that the birds which travel by day use the sun as a compass for orientation. He proved this by altering the direction of flight in Starling

by using mirrors to give a false apparent direction of the sun. Gustav Kramer kept caged Starlings in a circular building with the windows through which only the sky could be seen. He noted that the birds always moved round to face the direction they would normally take in migrating flight. He then closed the windows and installed a powerful light to imitate the sun, but made its rising and setting at wrong times. The bird again oriented itself as it does for migration, but this time according to the position of the electric "Sun". Franz Saner, another young German scientist tested the star guidance theory by releasing night flying old-world Warblers inside a planetarium at Bremer, Germany. He projected an artificial starlit sky matching the night sky on the domed ceiling in autumn and observed that the birds tried to fly south-east on their usual migratory route to Turkey, Cyprus and Africa. He then rotated the planetarium to bring the night sky in different positions. Sauer discovered that in every case the warblers set off on what the star showed to a south-easterly course.

c. **Wind direction and earth's magnetic field.** Inspite of the evidence for way-finding by the sun and stars much remains uncertain. Birds usually avoid flying in clouds. They seem to have some ability to maintain a course when forced to move under clouded skies or even in fog. Probably, they use wind direction and other meteorological information for migration. Van Middendroff and Henry L. Yeaglev gave the idea of way finding by earth's magnetic field. There is some evidence in its favour. According to Wiltschko, Robins (*Erethacus*) oriented their nocturnal activity in the migratory direction even without visual cues but not if they were placed in magnetic field. Particulars of magnetic field have been found in the brain and muscles of the head and trunk of pigeons and sparrow. Presti and Pettigrew reported that magnetic forces may influence the cells and receptors in the muscles.

FACTORS REGULATING MIGRATION IN BIRDS

Various workers have put forward various suggestions which are said to induce migratory birds for migration. Each suggestion is correct in a particular situation but they put difficulties in making a general statement as to what is the cause of migration.

Some workers have suggested that the migratory behaviour of a bird is under hormonal control from the gonads. They have suggested that some birds migrate to north in spring when their gonadial activity increases. Their southward migration after breeding season is associated with regression in gonadial activity. Bullough stated that prenuptial journey is stimulated by sex hormones and movement away from the breeding territory is allowed essentially by their absence. There are arguments both in favour and against this suggestion. For example, northward migration of European Starling is associated with increased

removed. These facts, therefore suggest that it is not the gonadial activity which initiates migration but something else, which not only induces migration but seems to be associated with increased gonadial activity.

Marshall and Coolbs have criticized the role of gonadial activity for migration. According to Lofts and Marshall some migratory birds develop atleast a potentially secretory interstitium before their autumn departure and may exhibit pre migratory sexual behaviour before the approach of the apparently innate, neural drive towards the traditional wintering ground. The thyroid, which exhibits cyclical changes has been suggested by many authors like Hans, Oaklson and Lilley to be involved in migration, but its role remains essentially speculation.

Migrations are obviously correlated with the season and changes in the amount of daylight or photoperiod which certainly play a central part in initiating them. In India, increase in day length (starting from February March onward) induces the Siberian birds to migrate to their breeding habitat, Siberia. On the contrary, decrease in photo period (starting from September - October onward) induces these Siberian birds to migrate to Indian subcontinent because the days are considerably shorter in Siberia during winter and they find considerable difficulty in obtaining food. Some experiments which prove the above view point have been done. A migratory bird was kept in a cage in the north in mid-summer. The cage was covered so as to shut out the light for the part of each day thus giving it an artificially short day similar in length, occurring in September and October. It was observed that when this bird was released from the cage it started its southward migration.

According to Wolfson, the substantial subcutaneous and visceral fat deposits play an important role in migration of the species. This fat deposition is followed by the development of Zugunruhe. The factors stimulating the pre migratory fat deposition (which may provide metabolic water as well as energy en route) have not been determined with certainty. Wolfson has shown that photo-stimulation leading to gonadial activation is followed by fat deposition in migratory birds.

The sexual cycle of seasonal birds is regulated by various external factors that ensure movement to the traditional breeding grounds in time. Light is particularly an important post-regenerated accelerator of sexual cycle of temperature zone birds. Others, under natural conditions are warmth, territory, adequate food, the nest site, nesting materials and behavioural interactions. Inhabitants are cold, inclement weather, hunger, fear and lack of appropriate nesting material and traditional nesting site.

REVISION QUESTIONS

1. Write an essay on bird migration.
2. How do birds find their ways for migration? What are the advantages of migration?

systematic study of interactions between the individuals of a species living in a group is socio biology

11

SOCIO BIOLOGY

Social behaviour can be defined as an interaction taking place between one individual of a species and another (Tinbergen 1953) whereas socio biology deals with "The systematic study of biological basis of all social behaviour. In the study of socio biology information is gathered and analysed regarding evolutionary and reproductive behaviour of the members of the society. Genes and environment play an active role in bringing up the society. The Genetic fitness, natural selection, inclusive fitness, kin selection altruism and reciprocal altruism are the corner stones of the social organisation" (Dewsbury 1978).

The capacity of an organism to reproduce and survive will be based on its genetic fitness. In a population, genetic fitness can be known by the contribution to the next generation of a particular genotype as compared to that of alternative genotypes (Dewsbury 1978). During the course of evolution many different characteristics develop in the organism due to differential gene pool under the influence of natural selection which act on "Individual level" to make it "Fit" or "better adapted" individual. Inclusive fitness includes two components of fitness: Personal and kinship fitness and kin selection. One can increase fitness by increasing the fitness of other relative members of the society (Hamilton 1964). In altruistic behaviour, one's own fitness is sacrificed to increase the personal fitness of other individuals. Such behaviour increases inclusive fitness. Trivers (1971) observed reciprocal altruism, wherein the trading of altruistic acts at different times by two unrelated individuals are found *e.g.* cleaning of hive and warning calls of birds come under this category.

AGGREGATION AND SOCIETY

Many animals come close to form groups for many external reasons. The aggregation may be of temporary or permanent nature. Following advantages are seen in the formation of groups or aggregations:

1. Aggregation is found to increase "Group survival value" by protecting animals against many ecological hazards. For example many insects and vertebrates avoid cold during winter by the formation of groups.
2. It helps in the transfer of learning from one generation to another. For example learning of food capturing techniques, avoiding danger etc. are passed from the parent to the offsprings.

3. It helps in the collection of food. For example it is very difficult for one wolf to kill a deer but is easier in groups, to capture and kill the prey.
4. It provides protection to the members of the group. For example whenever danger approaches the sheep, they form a group where the ram encircles the young sheep and ewes.
5. In a group, opposite sexes come close for breeding purposes by stimulating each other. For example male frogs croak in a pond to attract females there and fertilization occurs in the pond.
6. It helps in predation. For example in a group of Lions or Hyenas few members of a group drive the prey and the other kill the prey.
7. In social aggregation, members of the society co-operate in building the nests as seen in ants, bees and termites etc.
8. In the social aggregation of ants, termites etc. division of labour is seen. Different casts perform different functions in the colony. The fertile kings and queens perform reproductive functions whereas wingless sterile soldiers defend the colony from enemies and wingless sterile workers take care of the colony. In other social organisations like in bees, workers take additional responsibility of work. They fan air to cool the hive and collect water from outside. They perform different duties at different times of their lives (Lindauer 1961). Just after emergence they clean the hive then brood, build combs, guard the hives and finally forage for pollen and nectar. The nurse glands in the head of worker bees produce a nutritive substance and wax glands in the abdomen release comb-building material in the hive. Workers take care of the society members instead of performing reproductive functions which is an altruistic behaviour. This is necessary for the following processes of evolution.

A. INCLUSIVE FITNESS

Is a sum of own fitness plus its influence on the fitness of its relatives who are not directly descendants (Hamilton 1964).

B. KIN SELECTION

Where genes are differentially represented as a result from following the survival and reproduction of relatives, who have some genes from common ancestry.

C. RECIPROCAL ALTRUISM

At different times two or more unrelated individuals trade altruistic acts called reciprocal altruism (Trivers 1971). For example, a man performs an altruistic act of jumping into the water to save a drowning individual with a promise that other individuals will do the same under similar circumstances. Altruistic acts are seen in may other organisms like that seen in the wasp *Polistis*, where a dominant fertile female reproduces in

the colony and the subdominant sterile female workers perform the function of feeding the larvae, building nests and defending their territories. In a pride of lions, females take care and nurse the young ones.

SOCIAL ORGANISATION OR SOCIETY

It is the product of the actions of a group of individuals each adopting a strategy for survival and reproduction that will maximise their individual fitness (Dewsbury 1978). A strong bond of love and communication exists between the members of the society which may not break under stress conditions. Each organisation requires company of other organisms and they live with mutual understanding. In a society, members have adapted well and a great understanding and mutual co-operation is seen which is required to meet the struggle for existence. Sociality has the following advantages and disadvantages (Dewsbury 1978):

Advantages of society

The animals living in different societies have particular advantages, which are as follows:

(*i*) **Mutual vigilance:** The members of the social group respond to alarm calls produced by the members of other species. This is seen in the groups of baboons, gazelles and zebras.

(*ii*) **Guarding behaviour:** Some of the members of the society keep a watch on the entire group like that seen in Hanuman langoor, Presbytis entellus where few adults mainly occupy high canopy areas of the trees and remain vigilant from other intruding members of the other groups. In the male baboons and pata monkeys few members keep a watch while other members of the troop forage in the area.

(*iii*) **Detection of predators:** One or more individuals of the group may be able to detect a predator before the other, by sighting the predator or by listening to the voice of the predator. This warns the other members of the group as in the groups of deer and monkeys, about the presence of approaching predators.

(*iv*) **Mobbing and running away** is a common strategy adopted by animals in the presence of predators. In the large bovine herds adult females form a ring around their calves to protect them from being attacked by wolves. While their adult males form a ring around them and chase wolves collectively to drive them away. Similar defensive formation is also seen in elephants. The ground squirrels and other non-human primates mob snakes. Many Ungulate groups charge predators like lion, hyena etc. In the case of honeybees, soldiers or workers make a defensive screen against a predator to defend their colonies by attacking collectively the, predator. In the case of birds, mobbing

predators as found in the case of hawk attack. The hawk attack on a flock of wood pigeons is decreased when their number increases in the flock. The colonial defense is also seen in the black headed gulls that protect their nest and chicks from predators.

(*v*) **Co-operative foraging:** This is beneficial to the members of the society as it increases the feeding efficiency of the members. It is difficult to catch a prey alone but by making a group and attacking, it is easier to catch the prey. Co-operative hunting is quite common in wild dogs, wolves, lion, hyenas, killer whales etc. In this even small carnivores like wild dogs, wolves are able to hunt larger animals like elk, mountain sheep, zebra, etc. In the bird society usually one member of the society learns by watching the other member what they are doing as seen in the case of house sparrows and the titmice birds.

(*vi*) **Mutual vigilance:** In a group each individual gets more foraging time by mutual vigilance for the predators without being attacked by predators. Other members of the group temporarily look after the young ones of a group member when it goes on foraging. In the case of lions, wolves and wild dogs, few adults of the group look after the young ones while other members go out for hunting. Some times aunt behaviour is seen in a society as reported in the case of Hanuman langoor groups where the related adult female temporarily keep infants away from their mothers to enable her to forage which is called aunt behaviour.

(*vii*) **Reproductive success:** It is easy to find a mate by living in groups. It is very difficult for a solitary animal like Orangutan to find a mate for itself for which they have to cover a large area in the forest and spend more energy to find a suitable mate but this is easy when it lives in groups or society. The sexual urge for mating increases when a member sees others courting and mating.

Disadvantages of the society may be as follows:

1. Food is available in limited quantity in a society but more food is required to sustain a large population.
2. In a society, a slow reproduction rate is seen which in the long run will show lesser number of offsprings.
3. Due to inbreeding, fitness level goes down.
4. Due to sexual selection, more aggressive males are created which have lesser chance of being integrated into societies.
5. Due to the presence of more number of individuals in a society there will be more chance of disease occurrence.

Properties of organised animal society:

Eisenberg (1965) proposed 4 properties of an organised society

(*i*) **Division of labour:** In organised society animals of different age groups and sexes perform different functions to maintain the society e.g. Baboon and Macaque young adult males very often guard the other

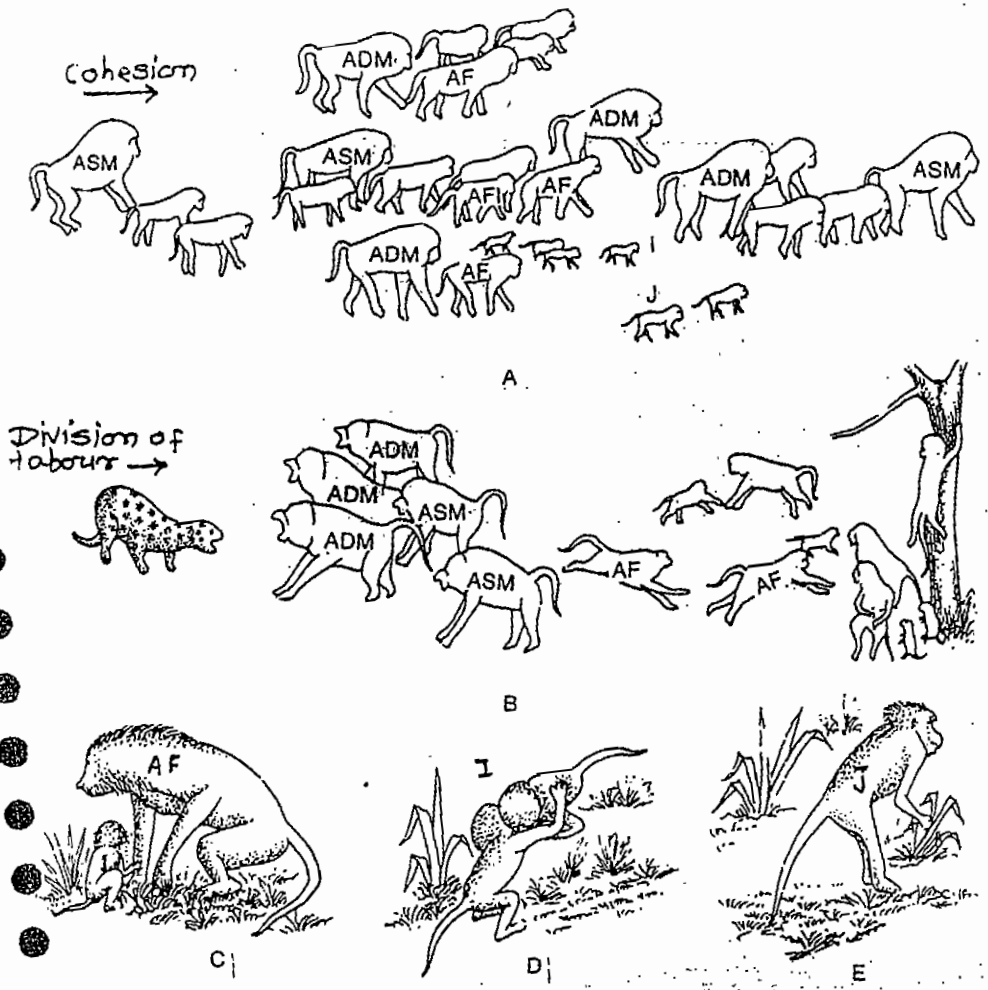

Fig. 1 (*a*) A baboon group showing cohesion and different age-sex individuals. ADM—Adult Dominant male, ASM—Adult sub-dominant male, AF—Adult female, AFI—Infant with adult female, I—Infant, J—Juvenile
(*b*) A group of baboons showing division of labour.
(*c*) Infant with adult female baboon.
(*d*) Infants of baboon playing.
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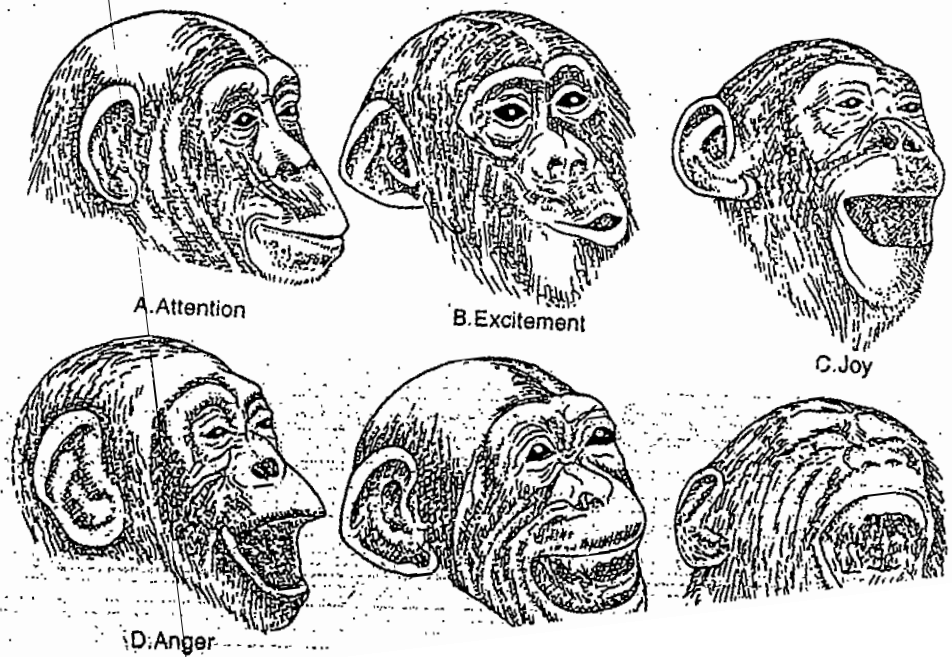
(*Source:* HALL and DeVORE, 1965)

members of the group during movement from the front or rear end to face the predators. The old dominant male occupies a central place to identify the foraging and resting area. The females bear the infants and take care of young ones. It is very interesting to see, a troop of baboons when they are confronted with a predator, the ADM (Adult Dominant male) leaves the center and occupies the front line (Fig. 1*a, b*), followed by ASM (Adult sub-dominant male) while the females and young ones show a retreat process. The females bear and rear infants while juveniles pass their time playing with each other and curiously exploring the area (Fig. 1*b, c, d, e*). In the beehive queen, drones and workers perform different functions. Queen lays the eggs, drones fertilize the queen whereas the workers function as builders, fanners, repairers and foragers etc.

(*ii*) **Communications:** All the social organizations show well developed communicating systems. The different members of the social group communicate either through vocalisation or making different gestures, postures or changing colours of their body or raising hair or making scent marks or passing messages by touching each other or dancing or by producing ultrasonic sound waves etc. The facial expression as seen in Chimpanzees shows complex messages of their emotions. (Fig. 2). In the higher group of animals complex messages are passed between individuals of the society.



(*iii*) **Cohesion:** Society provides close proximity to each other as seen in the bees of a hive, pride of lions, peck of wolves and herd of deer etc. In a troop of baboons, the adult and dominant males (ADM) occupy a center place between females, while the adult sub-dominant males (ASM) take positions at the front and rear (Fig. 1*a*).

(*iv*) **Permanent feature of the society:** The individual members of the society remain in the same group or they may form new groups by little migration as seen in the case of mammals, where core of the group is formed by the females and the males are occasional visitors. The most of the organised societies do not allow outsiders to penetrate in the group.

Social organisations are seen in both Arthropods and Vertebrates which are as follows:

SOCIAL ORGANISATION OF ARTHROPODS

In Arthropod groups, two orders Hymenoptera and Isoptera possess social organisation of insects. Ants, bees and wasp come under Hymenoptra group, whereas termites fall under Isoptera group. Social insects exhibit remarkable organisational capacities, where every individual performs its task well. They know how to recognize their brood, its development, sex and caste and for that, brood has to be correctly fed and cared for. The transfer of food between their members and maintaining cohesion among individuals are two important aspects of the society. In a society protection is provided to its society members by their own individuals who have better structural modifications in them as seen in soldiers of ants and termites etc.

SOCIAL ORGANISATION OF WASP

Wasps are in between non-social and social states. The sphecoid wasps exhibit a transitional grade of organisation between solitary, non-social to sub-social states, whereas Vespoid Wasps are social in nature. The sphecoid wasp at first, sting the prey and then lay eggs by the side of these so that larvae find their food nearby. The parasitic wasps lay eggs inside the body of the prey. The sphecoid wasp makes tunnels in the ground where they hide their prey with their eggs. Normally wasps make their houses either out of mud as seen in the mud-dauber wasp or from paper envelopes made from masticated wood as has been reported for *Polistis* wasp. Wasps hang their houses with downward openings and are arranged in tiers. In a seasonal society of wasp, many functions are seen where workers are more in number. Queens of certain Vespine wasps release a pheromone similar to that seen in honey bees which inhibit laying of eggs in workers and provides stability to the colony and it has been seen that if queen is removed from the colony, workers stop caring the brood.

the secretions produced from the body which indicates that a pheromone of trophallaxis is seen The fertilized females dominate the colony, where wintered queen with sterile female offsprings remain in the form of workers. Besides these, males are also found which fertilize the queen during summer. In a few species of *Polistis* wasp, a dominance hierarchy is seen where a dominant "queen" dominates other mated queens of the colony and gets more food.

SOCIAL ORGANIZATION OF BEES

Bees are found everywhere on flowers. They show a high order of social evolution where division of labour is seen between the members of the society (Fig. 3). About 5% of the total bee population is found

Fig. 3. Diagram showing different castes of honey bees.
A—Drone, B—Worker, C—Queen.

to be social. In bees, honey bees have achieved social evolution of a very high order. It has been seen that a honey bee queen cannot establish colony of its own without the services of her daughters (workers). A queen migrates to a new place with its followers to form a new hive or comb. They build combs in hollow trees or hanging from a tree trunk or in the corners of the walls of a building where they themselves feel safe from enemies. They make combs with wax secreted from the glands, located on the lower side of the abdomen. Each comb whose base consists of wax, hangs vertically with a layer of cells projecting horizontally on both sides where the "brood chambers" having developing larvae are placed near the centre of the combs.

The top of the cells, pollens and honey made from nectar are stored separately. A queen lays eggs after inserting her abdomen into the cells and depositing eggs at its inner end but when it inserts its abdomen in a smaller cell, sperm released from spermatheca fertilizes the egg, which will develop into females. On the other hand, no sperms are released when it inserts its abdomen in a large cell for depositing eggs which remain unfertilized and develop into males. Drones or kings fertilize queens and live in larger hexagonal cells of the hive, whereas workers live in smaller hexagonal cells and help in making the hive, collecting food and nursing

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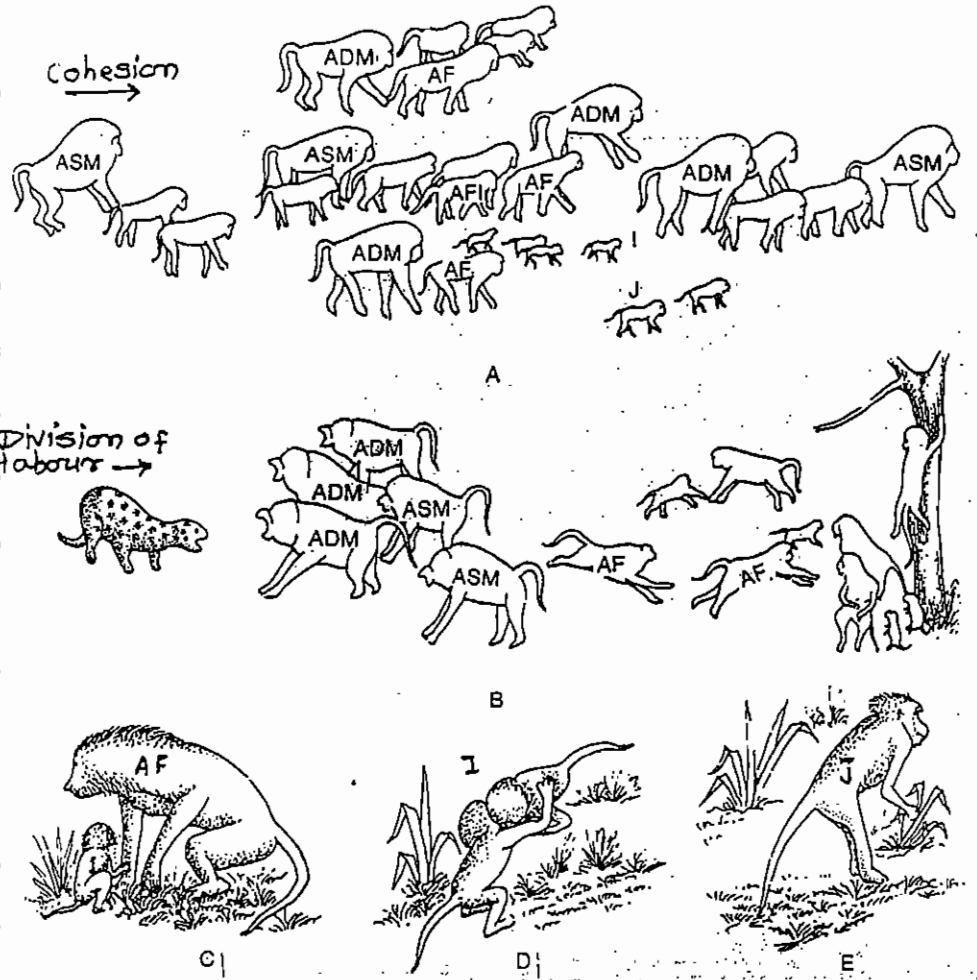

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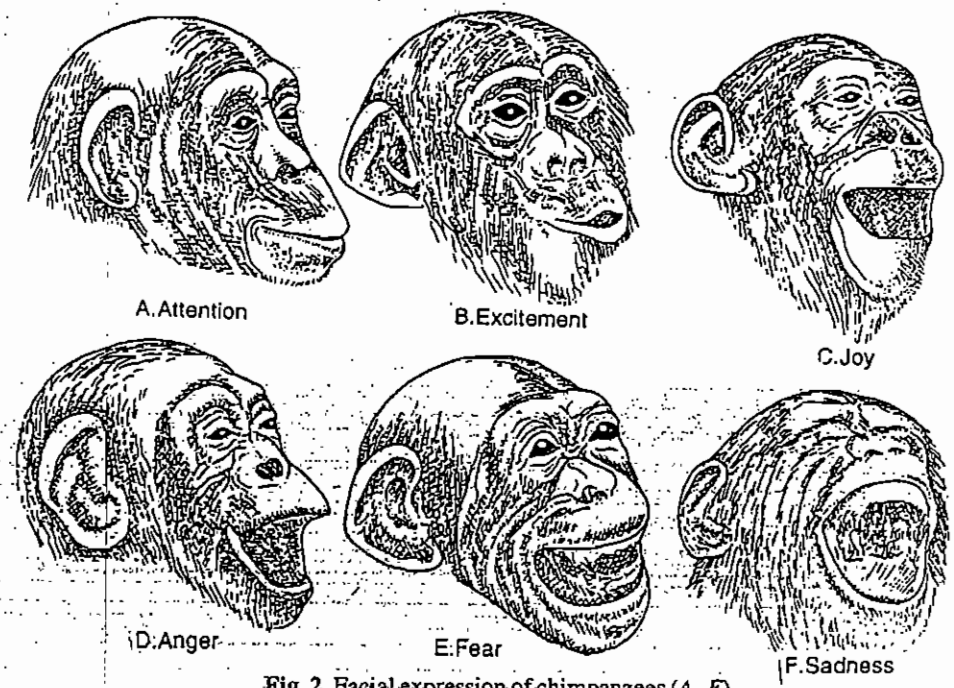


Fig. 2. Facial expression of chimpanzees (*A–F*).

source is horizontally 80 degrees left to the sun's azimut. The number of waggles increase with the increase in the food distance where each waggle is about 250 fts near the hive and it goes on declining if the food source goes on increasing in kilometers. In waggle dance, a circle with a diameter more than three times as that of the bee, a straight run while waggling the abdomen violently about 15 per second from side to side and another tracing circle in direction opposite to that of the first.

In the "Round dance" (Fig. 5B) a nearby food source is indicated by a simple circular dance. The forager repeats clockwise and anti - clockwise circle for a number of times throughout the day. When the food sources are at quite a distance, the round dances are converted into waggle dances, which give information about the distance and direction of food or water source, which is inversely related to the distance covered by the flies in search of food.

Dr. Manning (1972) explained that "The more 8's the dancer completes per unit time, closer is the food source". He further added that "the dancer may also convey distance by the number of waggles she makes on the straight path of her run, by the length of time, she spends on each run or by the duration of the buzzing that accompanies it. We are not sure which of these codes - sound or tempo - the other bees respond to; quite possibly they respond to all of them". The forager bee flights depends on the position of the sun and the waggle dance denotes the same angle vertical as the food is located. A forager takes about 1.25 seconds to complete a figure of eight, if the food is about 100 meters away from the hive. A. Wenner of U.S.A. believed that foraging bees bring back the odours of food source with them while returning to the hive and the other bees are stimulated by dances to search for flowers having similar odours. Gould (1976) conducted an experiment on bees and reported that bee dances communicate both distance and direction of food source and the sister bees use such information to locate the food source.

SOCIAL ORGANIZATION OF ANTS

So far about 3,500 species of ants are known which are adapted to live in colonies with or more caste differentiation. Polymorphism is common in ants. Ant societies are basically like a family where queen mother and her female dominant descendants are seen. Offsprings include wingless worker females, winged males and winged females which become virgin queens. New colonies are established by males and young queens after their short mating flights. During mating flight, queen carries with her about half a dozen workers clinging to her legs. Workers live for a few years where as males die after their mating flights. A wingless female worker is not fertilized by the male but eggs are laid by them which

the worker's presence in the society. The large workers have large heads with enlarged mandibles which are used in fighting. Such workers known as soldiers which protect the colony from enemies. It has been seen that Colobopils soldiers block entrance road of the nest by keep their heads at the entrance functioning like a bottle plug. Ants are terrestrial in habit in contrast to wasps and bees, which are aerial in habit. A make underground tunnels with many branching chambers but a f occupy rotten wooden logs. The worker of the colony takes care of brood, and maintain proper temperature and humidity in the colony. In ants, communicating system is highly developed, where bro recognition is done by releasing contacting pheromone by the workers. This pheromone also helps in identifying broods of different castes a sexes. Ants mark scent trails on the ground and other foragers are attracted towards these trails to locate the food. The queen ant reproduces quick and the larvae live in groups in open chambers and galleries which exhibi trophallaxis phenomenon. Exchange of food occurs between differe members of the society. The ant's food consists of micro-organisms but in few cases it may be nectar or flowers or honey dew released from aphids.

SOCIAL ORGANIZATION OF TERMITES

Caste differentiation in termites is highly developed where both sexes are differentiated- the females into queens, workers and soldiers and the mal into kings, workers and soldiers (Fig. 6A, B, C, D). Termites build their

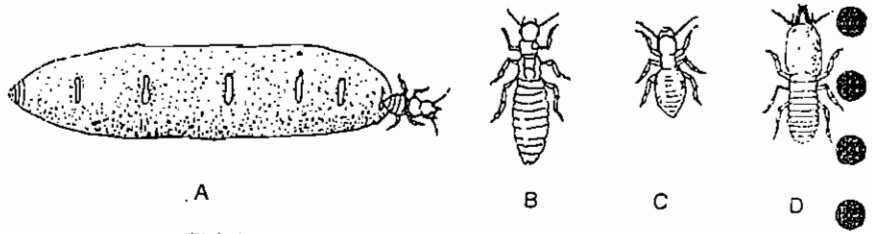


Fig. 6. Diagram showing different castes of termite.
A-Queen, B-King, C-Nymph, D-Large soldier.

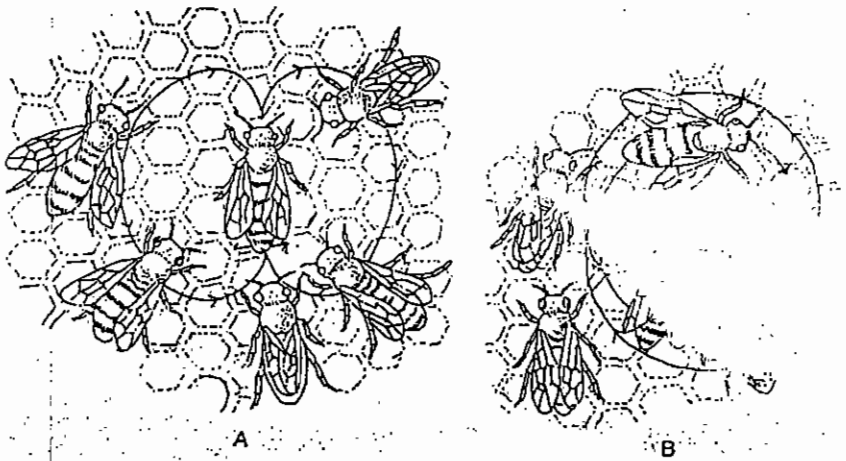
nests by making tunnels in wood or in the ground or sometimes the ne is made out of masticated wood or soil above the ground. Termites are generally seen in tropical countries and are adapted to live in high humidi and dark conditions. They cannot digest their own food which is cellulose of plant bodies, instead, harbour certain protozoans which help in digestin cellulose "food" inside the body of the termite. In a termite colony there are three casts-reproductive (the queen and the king), workers and soldie are found. In one colony, only one pair of queen and king and many soldiers are seen. Males and females of different casts are there in th

the brood. The larvae of smaller cells are fed with normal diet of bee bread which direct them to develop into workers with undeveloped reproductive organs. The reproductive organs of males or drones are well developed. More ovarian growth occurs in queens because the queen's cell larvae are fed with a specialised food called "Royal Jelly". The total life span of a worker is about six weeks, in which, her activities are synchronized with her physiology. In her earlier three days of life, she cleans the cell and starts feeding the older larvae with a mixture of pollen and honey. Between sixth and fourteenth day, Royal jelly is secreted from the pharyngeal gland seen in her abdomen and it starts feeding the younger larvae and the queen larvae in the hive. It has been seen that after tenth day of emergence, wax secreting glands become active on the abdomen with the regression of the pharyngeal gland and it starts constructing comb cells. She starts guarding the entrance of the hive from the eighteenth day onward and makes brief flights outside the comb. From the twenty-first day she becomes a forager collecting pollen, nectar and water etc. The worker bees are seen foraging and sipping sugary nectar of flowers and brushing protein-rich pollen into its "Baskets" on the hind legs and returning to the hive where they were relieved of their load by other workers and flying to the food source again. Such foraging behaviour is repeated a number of times from the morning till the late evening. The foraging of worker bees is affected by many factors like distance of flower, source of water and temperature of environment etc. She performs her duties efficiently in the hive by developing a highly developed communicating system between its fellow members. A worker bee in her hive recognises the presence of queen by the presence of a highly volatile pheromone. It licks her body and agitates the queen's body with their antennae, while doing so their antennae are coated with the pheromone produced by the queen which makes the worker become more active and now this worker bee within a few minutes comes into contact with other worker bees. They generally contact with their palpating antennae which comes into contact with the pheromone. An even distribution of pheromone occurs by mutual palpation of antennae and movement of their bodies in the colony. This pheromone inhibits worker bee's ovarian development, It has been seen that ovarian inhibition occurseven if the queen is removed from the colony because of the presence of brood in the colony. Worker bees possess Nasonov scent gland (NSG) in their abdominal region which are exposed by turning the abdomen (Fig. 4). A pheromone is released from this

Fig. 4. Diagram showing Nasonov scent gland of the worker honey bee (NSG).

gland which attracts other bees. This is also helpful in marking the food and water sources by foraging individual and providing guidance to other bees to return back home. It also helps to mark the nesting site and essential for maintaining cohesion among bees. The distance and direction of the food and water sources are indicated by a "dance language" which is described below:

The language of bees (Dance language). Communication among organisms is an important phenomenon which helps individuals to come close for mating and often for parental care of the offsprings. In social populations, different ways of communications like release of different chemicals, production of sound and touch etc. are seen to help in maintaining cohesion among the society members. The bee's dance is one of them, where forages show a definite dance pattern to locate food and water sources. The language of bees have been studied by Karl Von Frisch (1944) for which he was awarded the Nobel prize in 1973. They show "Waggle dance" (Fig. 5A) and "Round dance" (Fig. 5B) to



A. Waggle's dance B. Round dance

Fig. 5. Diagram showing different types of honey bee dance.

communicate about the location of food and water sources to other individual bees. In a Waggle dance, figure of eight is traced against the vertical surface of the comb. In manoeuvering the central portion, the dancer flies straight and buzzes noisily shaking its abdomen violently. Other members of the society surround this dancer. According to Karl Von Frisch, the straight portion of the dance is "The Waggle Run" which signifies the distance and the direction of the food source. Generally Waggle runs are performed vertical to the honey comb in the hive and points upwards if it is in the direction of the food. He further observed that the dances result 80 degrees to the left of the vertical and the food

colony. All others remain in immature forms. The soldier termite possesses a large mandible with big head portion or frontal projection secreting defensive secretions. After mating, queen abdomen is greatly distended due to the presence of large number of eggs.

In a termite colony, cast differentiation is regulated by a number of individuals of the cast and the colony size. In a colony, the presence of one or two soldiers influence the formation of other soldiers. The worker of both sexes are larger or smaller in size, of white colour, wingless appearance, broad headed and remain sterile. Coloured wingless sterile soldiers of both sexes of large, medium and small sizes are seen in the colony. The presence of a pair of primary reproductives in a colony, produces a pheromone from their anus, which is circulated in the food and enters the other larval bodies, which in turn pass it to the other individuals through their anal discharge.

In warmer climate, the termite's primary king and queen leave the nest and fly in pairs to build a new nest after a short mating flight. In the new nest, large number of secondary and tertiary generations develop. In many termite species, the female lifts her abdomen to release pheromones from its tergal gland placed in the back of the abdomen to attract the male and a pheromone from the gland on the sternum maintains couples to come close for mating.

SOCIAL ORGANIZATION OF VERTEBRATES

Many fishes, amphibians, reptiles, aves and mammals have organized themselves to live in groups or societies. It has been seen that size of social organizations depend on the length of parental care. If the parental care is for a longer duration, the size of the society will be large but if it is of a shorter duration, the size of the society will be of smaller nature. In vertebrates, parental care is highly developed as compared to invertebrates. In a social organization, animals have better chance of mating and raising their offsprings. Sometimes animals pass their whole life in societies but there are other animals also whose opposite sexes come close for a short period of mating and then depart. In a social organization, individual gets more chance of learning many activities of life which will lead to better parental care of the offsprings when the young individuals have their own families. Parents develop a strong bond of love for their offsprings in a society where mother knows when to leave their offsprings after taking care of them so that the offsprings may not feel distressed and uncomfortable. The offsprings are provided independence after certain length of parental care which helps them to learn independent running about in as well as outside the society, catching prey and the art of mating. Such a process is called "Weaning" whereby an infant gets independence from the matter and learns to live

independently. The social organizations help in protecting the members of the group from predators. Mostly edges of the society are affected by the predators. Protection is provided by the dominant members of the society, which move towards the edge in order to defend their territories and the weaker members move towards the center away from the edges in order to protect themselves. It has been seen that it is easier for the members of the society to procure food which may be difficult for them while living alone. Besides advantages of the societies, there are disadvantages too. It is easier for predators to detect animals of a large group. Animal disputes and conflicts may occur in a society for a resource.

SOCIAL ORGANIZATIONS OF DIFFERENT VERTEBRATE GROUPS ARE DISCUSSED BELOW

1. Social organization of fishes. Social attraction is not so well developed in fishes. Fishes live in aquatic conditions where females lay their eggs in large numbers and males discharge their sperms to fertilize the eggs. In *Trouts*, both sexes come together to build the nests. Parental care is also seen in the society. The male *Hippocampus* bears a pouch where the fertilized eggs are stored till hatching. The females of *Tilapia* fish incubate eggs and carry their young ones in their mouth. A saucer-shaped nest is prepared by the male of sunfish when females lay eggs and males discharge its sperms over the eggs.

2. Social organization of amphibians. The social organizations of amphibians are almost similar to that seen in fishes. The members of opposite sexes come close for a short time for mating and then depart. For example the male frogs and toads occupy the female's back for grasping the female's body with forelegs and discharging sperms over the eggs when they are laid. Sometimes a courtship play is seen between the members of opposite sexes before mating as seen in Salamander. The male deposits spermatophores containing sperms in the aquatic condition and the female searches for it and when the female locates the spermatophores, it draws it into its cloaca where internal fertilization occurs with the release of sperms.

The behavioural patterns of amphibians vary considerably from individual to individual. The tree frogs either lay their eggs in the holes of aquatic log or in muddy enclosures. Sometimes eggs are carried on the back of the female or the male. Ovoviviparity is seen in one species of Salamander, whereas other species lay eggs and make a coil around it.

3. Social organization of reptiles. In reptiles, social organization is of a primitive type where mateships are found to be of temporary or permanent nature. In rattle snakes, garter snakes and many lizards etc eggs remain in the oviduct till hatching. Sometimes eggs are laid and buried in the ground as seen in tortoises. Python guards its eggs till their hatching. Crocodiles and alligators keep an eye on their eggs and after

emergence the young individuals are given lessons of swimming and catching the prey. The social organization of reptiles is more advanced than fishes and amphibians because here many individuals come together to form groups for the purpose of liberation. For example many snakes come closer to live in dens to avoid cold. The liberating individual does not eat and remains as it is in resting position. It starts feeding after liberation period.

4. Social organization of birds. In birds, social organization is much more advanced than reptiles. Parental care is more developed where eggs and young individuals are taken care off. Eggs may be laid under the pile of litter and incubated till hatching as seen in the pigeons. Eggs are laid in the nests made over the ground and incubated till hatching, as found in grouse and quail. Young individuals start feeding and they are protected from enemies by their parents. Many birds like Starlings or black birds leave their nestling on their own when the Parakeets move out to collect food but in other birds like ducks, ducklings are provided with food and protection by their mother, while remaining in groups. *Pelicans* easily find their food (fish) by dipping their huge bills in water at the same time. Many birds make calls or sing songs to communicate among their members of society. Sometimes birds lay their eggs in the nests of other species and the foster mother incubates the eggs till hatching as seen in cuckoos. This is called brood parasitism. The other example of the same is Indian koel (*Endynamys scolopacea*) which neither incubates its eggs nor feeds its young but these functions are forced upon the house crow (*Corvus splendens*) and the jungle crow (*Corvus macrorhynchus*) (Davis *et al* 1977). In birds, both interspecific and intraspecific social organizations are seen. The bird society may be open or closed, organized or un-organized type. They may form pairs, families or flocks where cohesion among members is quite apparent in nature for performing different activities of the society. Sometimes prior to mating, a foreplay in the form of courtship behaviour is seen. A bond of love for companionship is observed in the bird society. Here parental care is more developed than the fishes, amphibians and reptiles. Quails form family flocks. Sometimes inter specific breeding is seen as reported for Herons inhabituating around Great Salt lake. Here Blue Herons, Night Herons and glossy Ibises live together. On the islands of Great Salt lake, the Pelicans and Gulls form nests together. Migrating groups are formed where members are not attracted towards their family ties. They come close to each other for either feeding, sleeping and nesting purposes. The members of the flock remains protected from the enemies also.

5. Social organization of mammals. Well developed societies are seen in mammals. Most of the mammals live in pairs or in groups. Sometimes, males live solitary excepting for the mating period when the

members of the opposite sexes come close to mate. This has been observed in case of cats and rhinoceroses etc. There are two factors which affect the social organisation of animals. These are resource distribution and predator pressure. Resource distribution can control the formation of large groups. For *e.g.* a herbivore with grazing habit can form large groups with little danger of depleting resources whereas top carnivores of the food chain cannot live so densely (Dewsbury 1978). Each group is under predator pressure which also determines the size of the group. Large groups are better adapted to deal with predators than their smaller counterparts. More males are seen in a group living in area of predation pressure and they provide protection against predators. Animals of Bovidae group are both solitary as well as gregarious in nature but when solitary bovids are attracted towards open fields, they form groups (Estes 1974). They face more pressure of predation and just to protect themselves they form groups. Whiptale Wallabies become more social and increase in size when they migrate to open habitats for grazing. Vicuna, a variety of camel group shows that harems are protected by males particularly during a short breeding season (Franklin 1974). The territorial male determines the location, limits and size of its territory and nature of the groups (Dewsbury 1978). In primates there are six different grades of grouping patterns from a solitary pattern through monogamous pairs, single male group, aggregate single-male group, multiple-male group and diffused social parties are identified (Southwick and Siddiqui 1974). The social organization of primates is determined by predation pressure and patterns of food distribution in the society. They were adapted for terrestrial foraging, arboreal, diurnal and leaf eating patterns which indicates a male dominated system with small home range and communication by either producing pheromone or vocal calls to maintain their territories (Eisenberg *et al* 1972). One adult male dominates the colony with several females and offsprings thereby living a surplus adult males band which often pose threat to the members of the harem. Such a behaviour is seen in the group of antelopes, deer and sea lion etc. In wild horses two bands are seen where one is dominated by a single male and several females but the other band is represented by unmated males. The unmated females dominate the young groups of the Reindeers.

Many monkeys carry their young ones with their bodies till they have attained certain maturity and learn many of the routine tasks like feeding and drinking etc. Baby monkeys if separated from their mother cry in distress till the mothers find their babies and pick them up quickly. This shows that a strong bond of love exists among the baby monkeys and their mother. In such cases, even death of babies may occur in the absence of the mother. Such a behaviour is also seen in apes. In parental care, mother knows the time upto which care of brood must be taken and

then leaving them on their own fate and starting another reproductive cycle. In monkeys, apes and man etc. the females take care of the babies for a short duration and after which babies attempt to suckle, are aborted by mothers. In chimpanzees, infants and mothers have a psychological bond for years and if they are separated from each other, the infant dies of depression. Group formation is important for the protection of its members from predation. They can also capture the prey easily. In a group, African wild dogs can capture animals of more than their size while hunting.

Sometimes the formation of social organization instead of becoming a boon to the society becomes a curse. Large group of animals are easily detected by their predators. For example lion and tiger easily hunt the deer and zebra. A somewhat look in to hierarchy in reference to dominance is seen in mammalian society, where loyalty and dominance make societies more competitive.

Many mammals know how to make territories. For example dogs make their territories by urinating at certain points. Sometimes mammals mark off different landmarks to make their territories. This is done by the use of certain pheromones released from their scent glands. For *e.g.* the Indian black buck antelope possesses scent glands located anterior to the eyes. It inserts the tip of a plant twig into the dilated ducts of the orbital glands to release the scent. Cows, goats, sheep and many other animals of Artiodactyla group secrete secretions from the inter-digital glands to make enroute marks. The male tree shrews of South and South Eastern Asia mark the territory of its house range with specialised scent marks. The slender loris and the capuchin monkey mark tree branches in the forest with urine-moistured palms whereas the slaw lorris makes the territorial boundary by spraying urine whenever it moves over the tree.

In social organisation of vertebrates, communicating system is highly developed. The Madagascar ring-tailed *Lemur* waves its tail to propagate the scent in air which excites other members of the society. The American skunk fires chemicals by turning its back on its victim which is an offensive yellow oily fluid. The chemical is ethyl mercaptan which affects eyes, throat or even lungs.

Human society (The socialization of man). Human society is the most organised society seen so far in vertebrates where many instinctive behavioural patterns are co-ordinated by the use of intelligence. Here opposite sexes show sexual attraction and the partners care. Parental care is for a much more longer duration *i.e.* 20 to 22 years of age, after which young individuals start their own family life but the parental care goes life long because older parents maintain a bond of love with their children and grand children. This shows that an instinct of love for companionship remains throughout the life of individuals but sometimes anti-social

instincts do develop as a result of population growth. Individual's life is guided by instinct, learning, memory and intelligence. In instinct society, learning and memory are at a primitive stage but in human society they are highly developed. By using their intelligence, they can pass their learned information from one generation to the other. They are strong in vocabulary, learning and reporting information. By developing their speech, an efficient system of communication, they have dominated the vertebrate world. They use intelligence in building houses and multistoreyed buildings for living purposes. They have also developed advance weapon systems to protect themselves, although these systems are often used among themselves whenever conflicts occur for domination.

Various natural resources have been intelligently used and conserved by man. These natural resources may be water, air, soil, wood and domestic live stock etc. For its proper use and conservation, man has made different laws and even laws are made to protect properties of an individual. They have developed efficient systems to control the effect of heat and cold.

DOMINANCE HIERARCHY AND TERRITORIALITY

Dominance hierarchy. Apparently all social animals show hierarchy where the pattern of authority or dominance subordination is found between either parent-child or between stronger and weaker animals. Dominance may be defined as a priority of access to an approached situation or of leaving and avoidance situation that one individual has over the other (Van Kreveld 1970). It is adaptive behavioural pattern where one animal has privileged access to a resource which remains in limited quantity. According to Alcock (1979), in dominance hierarchy the strongest will remain strong while the weaker will not be able to survive long. A dominance hierarchy is seen in almost all animals which live in groups like chicken, pigeons, crickets, monkeys, deer, mice, cows etc. Chickens and pigeons show dominance hierarchies in the form of "Peck Order". In a chicken flock, one which is dominant, has access to food in an area, excludes all other chickens from the area of food by delivering a peck at them. Such a pecking in a flock has been named "Peck Order" by Schjelderup-Ebbe. This first animal is called Alpha animal who has priority over access to food. In the same way, the flock possesses Beta animal who has priority over others excepting Alpha. Here a linear hierarchy is seen in the flock. Similarly G. Bruins and H. Hediger have reported Alpha, Beta and Gamma ranks in the deer of the Basel Zoo where Alpha dominated over others and when its antlers were cut off, it gives its privileges to the Beta animal.

The males of Hamadryas baboon display their fangs for claiming superiority. Higher rank of the male is displayed by the bigger and larger fangs it possesses. In gorillas, the silver-backed males remain at the top

in ranking and females with young ones rank second. Professors V. D. Lebedev and V. D. Spanovskaya observed in the movement of the Malabar Danio that they show different angles in their hierarchy while swimming in the water. The strongest fish swim horizontally at about 2 degrees in relation to the water surface while the second in the hierarchy swim at 20 degrees and the third at 32 degrees etc. The dominance hierarchy may be simple or intricate in animals. Intraspecific and interspecific hierarchies are found as seen in the mixed flock of titmice. All grey titmice rank superior to blue titmice whereas blue titmice remains superior to the black-capped chickadees.

In animals rank orders have developed in order to avoid fighting and death and to provide protection to the weaker section of their group. A weaker animal submits to the stronger animal by exhibiting a submissive pose. For *e.g.* carp closes its fins while submitting to submissive behaviour. A dog shows respect to its superior (master) by licking the face of the master because he thinks his master to be a dominant dog. Sometimes two animals fight in order to decide their ranking as to which one of them is superior. The fight goes on till one submits to the other and accepts its superiority.

Territoriality. Basic need of an organism is to have a space for living. The area covered by several members of a species in search of food and mate is called Home Range. A pair or group of individuals occupy a territory for breeding purposes and different groups may occupy an overlapping home range but not the territory. The territories or the definite areas of land occupied by most of the animal species where the resident enjoys priority of access to limited resources which may not be enjoyed by the same animal in other areas (Kaufmann 1971). This behaviour of organism is called territorial behaviour or territoriality. For example the male stickleback fish during breeding season, protects its territorial border from intruders. Such territorial defense is seen in many groups of insects and vertebrates. A territory may be large or small depending upon the size of animal population. In early breeding season, territorial behaviour is exhibited by male birds. Whenever a female bird comes in the area, it is courted by males and eventually it settles to form a nest. Animals are confident of the faithfulness of their mates in their own territory and even they do not allow them to leave their territorial boundaries and if by chance females move out of the boundary males allure them to come back in their own boundary. A smaller territory is seen in the case of insects, spiders, fishes and lizards *e.g.* Texas frogs make their territory in about 400 sq. meters whereas swan has 1 sq. km. and deer one to two and a half thousand acres. The hunting lions and tigers remain between 20 to 25 sq. km. Territorial behaviour of animals control the population size of animals *e.g.* in an over populated area of birds, birds without territories fail to

raise young ones and also have a low survival chance for themselves. Whenever population is low all birds have a suitable nesting place and breed successfully. The territory may be divided into smaller areas where an animal performs different activities like sleeping, drinking or eating etc. It is not that the animals roam randomly but they follow a definite routine in the daily activities like eating, resting, bathing and mating etc. A daily routine activity has been observed in Indian Rhinoceros by Prof. Wolffan Ulrich which has never changed in their life time. After waking in the morning Rhinoceros eats first, then rests in a muddy pool of water and by noon it goes to its bedroom for resting. In the evening till late midnight, it grazes and then goes to its bedroom for sleeping where it spends its rest of the night. Dogs, tigers and lions mark their territories by urination and it is defended by their dominant members. A stronger animal which is also a dominant one in the group will also try to defend its home territory. Dogs defend their territories as observed by Niko Tinbergen. He observed in the sledge dogs of Greenland that a trespassing strange dog will be removed from their territories. The young dogs of the group follow their elders because they do not yet know of their territories. In insects, territorial defense is seen *e.g.* in dragon flies whenever a male dragonfly meets another male in his territory, it lifts its abdomen by showing threatening postures but if the male encounters a female it lowers the abdomen. The upliftment of the abdomen by the male is a warning signal to the opponent by which it signals to the opponent to leave the territory.

Mating strategies

The reproductive success in all organisms depend upon the chances of mating relationships between the male and female partners but mating success is not the same for both sexes. The mating group is generally classified into monogamy, polygamy, promiscuity and other variations within each category.

(*i*) **Monogamy (Fig. 7):** Here mating relationship between one male and one female at a time is found. This situation is seen in 90% birds, about 4% in mammals and 20% in human societies. Here life long breeding pairs live together, and if by chance single mate dies then only, new mate is accepted as found in the gibbon. Typical monogamy is seen in the case of dik-dik, steenbok, songbirds, eagles, swan, foxes etc. It may be classified into three categories (*a*) Male parental association, whether more or less or equal as compared to female parent. (*b*) Extension of space or territoriality, (*c*) Temporal relationships.

(*a*) The category (a) showing male parental investment is further classified into three categories:

(1) The female parental investment is more than the male parental investment. This is known as facultative monogamy as seen